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Volume IX of XIII

Appendices D4 through D8

Waste Isolation Pilot Plant
Carlsbad, New Mexico

DOE/WIPP 95-2094

Waste Isolation Pilot Plant

Site Environmental Report for Calendar Year 1994

June 1995

U.S. Department of Energy
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WIPP

Annual

Site

Environmental

Report for

Calendar Year 1994

DOE/WIPP 95-2094

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1994 WIPP Site Environmental Report
Table of Contents

Section — Page

Acronyms and Abbreviations ix
List of Figures vii
List of Tables v
Preface xvi

Chapter 1 EXECUTIVE SUMMARY 1-1

1.1 Compliance Summary 1-1

1.1.1 The No-Migration Variance Petition 1-2
1.1.2 NEPA Annual Mitigation Report 1-3
1.1.3 SARA Title III Emergency and Hazardous Chemical Inventory 1-4
1.1.4 New Mexico Air Quality Permit 310-M-2 1-4
1.1.5 Environmental Leadership Program 1-4
1.1.6 Biennial Environmental Compliance Report 1-4
1.1.7 NEPA Training 1-4
1.1.8 Environmental Compliance Assessments 1-5

1.2 Environmental Monitoring Program Information 1-5

1.2.1 Environmental Monitoring Plan 1-5

1.3 Environmental Radiological Program Information 1-5

1.3.1 Airborne Particulate and Effluent Monitoring 1-6
1.3.2 Soil Sampling 1-7
1.3.3 Groundwater 1-7
1.3.4 Surface Water and Sediment Sampling 1-7
1.3.5 Game Animals and Fish Samples 1-7

1.4 Nonradiological Environmental Monitoring Information 1-8

1.4.1 Land Management 1-8
1.4.2 Meteorology 1-9
1.4.3 Air Quality Monitoring 1-9
1.4.4 Wildlife Population Monitoring 1-9
1.4.5 Vegetation Monitoring 1-10
1.4.6 Raptor Research and Management Program 1-11
1.4.7 Reclamation of Disturbed Lands 1-11

1.5 Quality Assurance 1-11

Table of Contents

Section		Page
Chapter 2	**INTRODUCTION**	2-1
2.1	Description of the WIPP Project	2-1
2.2	Description of the Environment and Lands	2-3
Chapter 3	**COMPLIANCE SUMMARY**	3-1
3.1	Compliance Assessment for Calendar Year 1994	3-1
3.2	Compliance Status	3-1
3.2.1	Atomic Energy Act of 1954 (AEA)	3-2
3.2.2	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	3-5
3.2.3	Resource Conservation and Recovery Act (RCRA)	3-7
3.2.4	National Environmental Policy Act (NEPA)	3-8
3.2.5	Clean Air Act (CAA)	3-10
3.2.6	Clean Water Act (CWA)	3-11
3.2.7	Safe Drinking Water Act (SDWA)	3-13
3.2.8	Toxic Substances Control Act (TSCA)	3-14
3.2.9	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	3-14
3.2.10	Endangered Species Act (ESA)	3-14
3.2.11	National Historic Preservation Act (NHPA)	3-15
3.2.12	Floodplain Management	3-17
3.2.13	Protection of Wetlands	3-17
3.2.14	Environmental Radiation Standards	3-17
3.2.15	Hazardous Material Transportation Act (HMTA)	3-18
3.2.16	Packaging and Transportation of Radioactive Materials	3-18
3.2.17	Department of Energy National Security and Military Application of Nuclear Energy Authorization Act of 1980	3-19
3.2.18	Waste Isolation Pilot Plant Land Withdrawal Act of 1991	3-20
3.2.19	Taylor Grazing Act	3-22
3.2.20	Federal Land Policy and Management Act (FLPMA)	3-22
3.2.21	Public Rangelands Improvement Act	3-23
3.2.22	Executive Order 12548-Grazing Fees	3-23
3.2.23	Materials Act of 1947	3-23
3.2.24	Federal Mine Safety and Health Act of 1977 (MSHA)	3-24
3.2.25	Occupational Safety and Health Administration (OSHA) Regulations	3-24
3.2.26	Noise Control Act of 1972	3-25
3.2.27	Bald and Golden Eagle Protection Act	3-25
3.2.28	Migratory Bird Treaty Act	3-25
3.2.29	National Defense Authorization Act - Fiscal Year 1989	3-26
3.2.30	Protection and Enhancement of Environmental Quality	3-26
3.2.31	Federal Compliance with Pollution Control Standards	3-27

Table of Contents

Section		Page
3.3	Other Significant Environmental Issues	3-27
3.3.1	Environmental Leadership Program	3-27
3.3.2	Environmental Compliance Assessment Program	3-28
Chapter 4	**ENVIRONMENTAL PROGRAM INFORMATION**	4-1
4.1	Environmental Monitoring Plan	4-1
4.2	Baseline Data	4-1
4.3	Environmental Monitoring and Planning Activities	4-2
4.3.1	Waste Minimization Committee	4-3
4.3.2	Environmental Training	4-4
4.3.3	WIPP Land Management Plan	4-4
Chapter 5	**ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION**	5-1
5.1	Radioactive Effluent Monitoring	5-1
5.2	Environmental Radioactivity Monitoring	5-1
5.2.1	Atmospheric Radiation Baseline	5-2
5.2.2	Ambient Radiation Baseline	5-2
5.2.3	Radiological Soil Monitoring	5-3
5.2.4	Hydrologic Radioactivity	5-3
5.2.5	Biotic Radioactivity	5-4
5.3	Assessment of Potential Dose to the Public	5-5
Chapter 6	**ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION**	6-1
6.1	Principal Functions of Nonradiological Sampling	6-1
6.2	Meteorology	6-1
6.2.1	Climatic Data Summary	6-2
6.2.2	Wind Direction and Wind Speed	6-2
6.3	Environmental Photography	6-2
6.4	Air Quality Monitoring	6-3
6.5	Wildlife Population Monitoring	6-4
6.5.1	Cooperative Raptor Research and Management Program	6-4
6.5.2	Breeding Bird Densities	6-7
6.5.3	Small Nocturnal Mammal Population Densities	6-8

Table of Contents

Section		Page
6.6	Surface and Subsurface Soil Monitoring	6-9
6.7	Vegetation Monitoring	6-9
6.8	Volatile Organic Compounds (VOC) Monitoring	6-10
6.9	Reclamation of Disturbed Lands	6-10
6.10	Seismic Activity	6-11
6.11	Liquid Effluent Monitoring	6-12
Chapter 7	**GROUNDWATER SURVEILLANCE**	7-1
7.1	Groundwater Quality	7-3
7.2	Groundwater Level Surveillance	7-3
7.3	Program Changes	7-5
Chapter 8	**QUALITY ASSURANCE**	8-1
8.1	Sample Collection Methodologies	8-2
8.2	Revision of Procedures	8-3
8.3	Interlaboratory Comparisons	8-3
8.4	Analytical Laboratory Quality Assurance and Quality Control	8-5
8.5	Data Handling	8-6
8.5	Records Management	8-6
Chapter 9	**REFERENCES**	9-1
Appendix A		
1994 RADIOLOGICAL ENVIRONMENTAL SAMPLE ANALYSIS		
A1	Air	A1-1
A2	Soils	A2-1
A3	Surface Water	A3-1
A4	Bottom Sediments	A4-1
A5	Groundwater	A5-1
A6	Biotics	A6-1
Appendix B		
1994 NONRADIOLOGICAL SOIL ANALYSIS		B-1

LIST OF TABLES

TABLE	TITLE	PAGE
3-1	Compliance Status with Environmental Regulations Applicable to the WIPP Project	3-29
3-2	DOE Orders and Agreements Affecting the WIPP Environmental Program	3-31
3-3	Summary of Agreements Between DOE and the State of New Mexico that Affect the Environmental Program	3-33
3-4	Active/Pending Permits for the Waste Isolation Pilot Plant During 1994	3-35
4-1	EMP Sampling Schedule	4-6
4-2	EMP Analytical Array	4-7
5-1	Activity Concentrations in Quarterly Averages of the Low Volume Aerosol Filters	5-6
7-1	Parameters Analyzed During CY 1994	7-6
7-1.1	H-02c, Culebra Round 6, Comparison To Background Characterization	7-8
7-1.2	H-03b3, Culebra Round 9, Comparison To Background Characterization	7-9
7-1.3	H-04b, Culebra Round 9, Comparison To Background Characterization	7-10
7-1.4	H-05b, Culebra Round 9, Comparison To Background Characterization	7-11

LIST OF TABLES
(continued)

TABLE	TITLE	PAGE
7-1.5	H-06b, Culebra Round 9, Comparison To Background Characterization	7-12
7-1.6	H-09b, Culebra Round 5, Comparison To Background Characterization	7-13
7-1.7	H-11b3, Culebra Round 8, Comparison To Background Characterization	7-14
7-1.8	H-14, Culebra Round 7, Comparison To Background Characterization	7-15
7-1.9	WIPP-19, Culebra Round 9, Comparison To Background Characterization	7-16

LIST OF FIGURES

FIGURE	TITLE	PAGE
2-1	Location of the WIPP Site	2-5
2-2	WIPP Sectors	2-6
5-1	Primary Pathways to Man for Radioactive Releases from the WIPP Site	5-8
5-2	1994 Gross Alpha/Beta - Carlsbad	5-9
5-3	1994 Gross Alpha/Beta - Smith Ranch	5-10
5-4	1994 Gross Alpha/Beta - WIPP Far Field	5-11
5-5	1994 Gross Alpha/Beta - WIPP East	5-12
5-6	1994 Gross Alpha/Beta - WIPP South	5-13
5-7	1994 Gross Alpha/Beta - Mills Ranch	5-14
5-8	1994 Gross Alpha/Beta - Southeast Control	5-15
5-9	1994 Gross Alpha/Beta - Eunice	5-16
5-10	WIPP Air Sampling Locations	5-17
6-1	1994 Precipitation	6-13
6-2	1994 Annual Windrose	6-14
6-3	Average Monthly Temperatures	6-15
6-4	WIPP Seismograph Station Locations	6-16
6-5	DP-831 Compliance Sampling Analysis - Kjeldahl Nitrogen and Nitrates	6-17
6-6	DP-831 Compliance Sampling Analysis - Radium 226	6-18
6-7	DP-831 Compliance Sampling Analysis - TDS, Ponds 3 and 4	6-19

LIST OF FIGURES
(continued)

FIGURE	TITLE	PAGE
6-8	DP-831 Compliance Sampling Analysis - TDS, Pond 5	6-20
7-1	Water Quality Sampling Program Sample Wells 1994	7-7
7-2	Groundwater Level Surveillance Wells	7-17
7-3	Potentiometric Surface of the WIPP Site (Culebra)	7-18
7-4	Potentiometric Surface of the WIPP Site (Magenta)	7-19
7-5	New Monitoring Well Locations	7-20

ACRONYMS AND ABBREVIATIONS

AA	Atomic Absorption
AEC	United States Atomic Energy Commission
AHPA	Archaeological and Historic Preservation Act
AMS	Ambient Air Monitoring Station
AQCR	Air Quality Control Regulation
ARA	Archaeological Recovery Act
ASER	Annual Site Environmental Report
ASME	American Society of Mechanical Engineers
BECR	Biennial Environmental Compliance Report
BMP	Best Management Practices
BLM	Bureau of Land Management
C and C	Consultation and Cooperation
CAA	Clean Air Act
CDC	Centers for Disease Control
CED	Committed Effective Dose
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act

ACRONYMS AND ABBREVIATIONS

(continued)

CMS	Central Monitoring System
CRRMP	Cooperative Raptor Research and Management Program
CRA	Carlsbad Resource Area
CRF	Central Records Facility
CWA	Clean Water Act
CY	Calendar Year
DMR	Discharge Monitoring Report
DOE	United States Department of Energy
DOL	Department of Labor
DOI	United States Department of the Interior
DOT	Department of Transportation
DP	Discharge Plan
ECAP	Environmental Compliance Assessment Program
EEG	Environmental Evaluation Group
ELP	Environmental Leadership Program
EML	Environmental Measurements Lab
EMP	Environmental Monitoring Plan

ACRONYMS AND ABBREVIATIONS

(continued)

EO	Executive Order
EPA	United States Environmental Protection Agency
EPCRA	Emergency Planning Community Right-to-Know Act
ESA	Endangered Species Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ESH&RC	Environment, Safety, Health and Regulatory Compliance
FEIS	Final Environmental Impact Statement
FLPMA	Federal Land Policy and Management Act of 1976
FSAR	Final Safety Analysis Report
GSP	Groundwater Surveillance Program
HAP	Hazardous Air Pollutant
HEPA	High Efficiency Particulate Air
HMP	Habitat Management Plan
HPIC	High Pressure Ionization Chamber
HSWA	Hazardous and Solid Waste Amendments of 1984 (to RCRA)
ICAP	Inductively Coupled Argon Plasma
LDR	Land Disposal Restrictions

ACRONYMS AND ABBREVIATIONS

(continued)

LEPC	Local Emergency Planning Committee
LLCL	Low-Level Counting Laboratory
LMIP	Land Management Implementation Plan
LMP	Land Management Plan
LS	Liquid Scintillation
LWA	Land Withdrawal Act
MAP	Mitigation Action Plan
MBTA	Migratory Bird Treaty Act
MET	Meteorological Station
MOC	Management and Operating Contractor
MOU	Memorandum of Understanding
MSHA	Federal Mine Safety and Health Act
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NES	Nonradiological Environmental Surveillance
NESHAPS	National Emissions Standards for Hazardous Air Pollutants

ACRONYMS AND ABBREVIATIONS

(continued)

NHPA	National Historic Preservation Act
NMD	No-Migration Determination
NMED	New Mexico Environment Department
NMIMT	New Mexico Institute of Mining Technology
NMVP	No-Migration Variance Petition
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission/National Response Center
NWPA	Nuclear Waste Policy Act
OSHA	Occupational Safety and Health Administration
PCB	Poly-chlorinated Biphenyl
PESP	Performance Evaluation Study Program
PI	Principal Investigator
PPOA	Pollution Prevention Opportunity Assessment
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAP	Quality Assurance Program

ACRONYMS AND ABBREVIATIONS

(continued)

QC	Quality Control
QSL	Qualified Suppliers List
RBP	Radiological Baseline Program
RCRA	Resource Conservation and Recovery Act
REMP	Radioactive Effluent Monitoring Program
RES	Radiological Environmental Surveillance
RIDS	Records Inventory and Disposition Schedule
RL	Radiochemistry Laboratory
RMP	Resource Management Plan
ROD	Record of Decision
RRMP	Raptor Research and Management Program
SAA	Satellite Accumulation Area
SARA	Superfund Amendments and Reauthorization Act
SERC	State Emergency Response Commission
SDWA	Safe Drinking Water Act
SEIS	Supplemental Environmental Impact Statement
SHPO	State Historic Preservation Officer

ACRONYMS AND ABBREVIATIONS

(continued)

SNL	Sandia National Laboratories
SPDV	Site Preliminary Design and Validation
TDS	Total Dissolved Solids
TPY	Ton Per Year
TRU	Transuranic Waste
TRUPACT-II	Transuranic Package Transporter Model II
TSCA	Toxic Substances Control Act
TSDF	Treatment Storage Disposal Facility
TSP	Total Suspended Particulates
USF&WS	United States Department of the Interior, Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound
VPP	Voluntary Protection Program
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plan
WQSP	WIPP Groundwater Quality Surveillance Program

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1994 WIPP Site Environmental Report
Preface

This is the eleventh Annual Site Environmental Report (ASER), documenting the progress of environmental programs at the U.S. Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP).

Although the cancellation of the Test Phase, during 1993, was a significant change in work scope for the WIPP, there are still numerous environmental monitoring and reporting activities that must be performed as a routine part of daily operations. These activities, and the WIPP's ability to demonstrate compliance with both state and federal environmental compliance requirements, are documented in this report.

This report is a compilation and summarization of environmental data collected at the WIPP site during the calendar year 1994. Should a reader of this report desire to obtain copies of the raw data used to generate this document, please write the U.S. Department of Energy, Manager of the Environment, Safety and Health Department, at P.O. Box 3090, Carlsbad, NM 88221.

PREFACE

CHAPTER 1

EXECUTIVE SUMMARY

Chapter 1
Executive Summary

The U.S. Department of Energy (DOE) Order 5400.1 *General Environmental Protection Program,* requires each DOE facility that conducts significant environmental protection programs to prepare an Annual Site Environmental Report (ASER). The purpose of the ASER is to summarize environmental data in order to characterize site environmental management performance, to confirm compliance with environmental standards and requirements, and to highlight significant programs and efforts. This ASER not only documents the required data, it also documents new and continued monitoring and compliance activities during the 1994 calendar year.

Data contained in this report are derived from those monitoring programs directed by the Waste Isolation Pilot Plant (WIPP) *Environmental Monitoring Plan* (EMP) (DOE/WIPP 94-024). The EMP defines a comprehensive set of parameters that must be monitored to detect potential impacts to the environment and to establish baseline measurements for future environmental evaluations. Surface water, groundwater, air, soil, and biotics are monitored for radiological and nonradiological activity levels. The baseline radiological surveillance program covers the broader geographic area that encompasses nearby ranches, villages, and cities. Nonradiological studies focus on the area immediately surrounding the WIPP site.

To date, the WIPP is still in a preoperational phase. As a result, certain operational requirements specified in DOE Order 5400.1 and in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T) are not yet applicable. This report does not address programs and activities that will be developed to meet future (operational) requirements such as radionuclide emissions and effluents and respective impacts upon the public and the environment.

1.1 Compliance Summary

A summary of significant compliance-related activities at the WIPP during Calendar Year (CY) 1994 is presented in this chapter. Chapter 3 will address environmental statutes and executive orders. These important statutes and orders will be comprehensively discussed in terms of compliance status, significant issues, actions, and accomplishments specific to WIPP.

On January 13, 1994, the DOE recommended that the New Mexico Environmental Department (NMED) allow the DOE to modify the Resource Conservation and Recovery Act (RCRA) permit

1.1 Compliance Summary (continued)

application to reflect disposal rather than test-phase operations. On September 2, 1994, the NMED rescinded the draft permit issued in August 1993 and ordered the submittal of a revised permit application due May 31, 1995. As of January 1995, the DOE has submitted nine chapters to NMED for review.

The *No-Migration Determination Annual Report for the Period of September 1993 through August 1994* (DOE/WIPP 94-2029) was submitted to the Environmental Protection Agency (EPA) Region VI, and to EPA Headquarters on November 14, 1994. This report was prepared to satisfy the annual reporting requirements contained in the *Conditional No-Migration Determination for the U.S. Department of Energy Waste Isolation Pilot Plant* (NMD), published in the *Federal Register* on November 14, 1990. Although the NMD was written specifically for the WIPP test phase, compliance conditions mandated by the first WIPP NMD will continue until issuance of a Disposal Phase NMD. A Disposal Phase No-Migration Variance Petition is being developed, based on waste characterization data and applicable modeling results. It is expected to be submitted to the EPA in CY 96.

The Land Withdrawal Act (LWA), Section 8, requires the DOE to submit to EPA an application for certification of compliance with EPA's final disposal regulations. The EPA finalized disposal regulations (40 CFR 191) in December of 1993. Currently, the EPA is developing criteria for certifying compliance with these regulations. After EPA has finalized the compliance criteria, a compliance certification application, in accordance with the mandates of the WIPP LWA, will be developed.

1.1.1 The No-Migration Variance Petition

In 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to the RCRA which established, in Sections 3004(d) through (n), a stringent regulatory program to prohibit the land disposal of hazardous waste unless: (1) the waste is treated to meet treatment standards or other requirements established by the EPA under Section 3004 (n), or (2) the EPA determines that the Land Disposal Restrictions (LDR) are not applicable in order to protect human health and the environment. With respect to the second condition, if it can be demonstrated, ". . . to a reasonable degree of certainty that there will be no migration of hazardous constituents from the disposal unit . . . for as long as the wastes remain hazardous," a No-Migration Variance Petition (NMVP) is

1.1.1 The No-Migration Variance Petition (continued)

submitted to the EPA, and upon approval by the EPA, a no-migration variance may be granted according to the requirements of 40 CFR Section 268.6.

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

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

Pursuant to the provisions of 40 CFR Section 268.6, the DOE submitted an NMVP for the WIPP facility in March 1989 and a revision in 1990. A final No-Migration Determination (NMD) was granted by the EPA in November 1990. The NMD allows the DOE to emplace a limited quantity of untreated transuranic (TRU)-mixed waste in the WIPP facility for the purpose of testing. In order to proceed with the disposal phase, the DOE must seek another variance from the EPA for permanent disposal of TRU-mixed waste.

The disposal-phase NMVP is currently being developed and will be submitted to the EPA in phases. The Draft NMVP will address a no-migration demonstration for disposal operations and is scheduled for submittal to the EPA in May 1995. The Final NMVP is the long-term (post closure) portion and is scheduled for submittal to EPA in June 1996.

1.1.2 NEPA Annual Mitigation Report

The 1994 Annual Mitigation Report for the Waste Isolation Pilot Plant (NEPA ID# WIP:94:0001) was issued July 1994 in accordance with the requirement of DOE Order 5440.1E *National Environmental Policy Act Compliance Program*. This Order further requires DOE facilities to "track and report annually to EH-1 the progress made in implementing and the effectiveness of any mitigation action plan ... until mitigation is completed."

1.1.3 SARA Title III Emergency and Hazardous Chemical Inventory

On February 9, 1994, the WIPP submitted the *Emergency and Hazardous Chemical Inventory Report* for CY 1993 to the New Mexico State Emergency Response Commission, the Eddy County Local Emergency Planning Committee, and the local fire department with jurisdiction over the WIPP site, as required by Section 312 of the *Superfund Amendments and Reauthorization Act* (SARA) Title III. In March 1994, the WIPP submitted the Emergency and Hazardous Chemical Inventory Report for CY 1993 to appropriate organizations.

1.1.4 New Mexico Air Quality Permit 310-M-2

On February 26, 1994, the WIPP completed the emission monitoring requirements established in the New Mexico Air Quality Permit 310-M-2. With the submittal of the *Final Compliance Sampling Report* on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit.

1.1.5 Environmental Leadership Program

On September 21, 1994, the WIPP submitted a proposal application to the EPA's Environmental Leadership Program. The purpose of the program is to recognize and reward facilities that have developed innovative environmental management systems. From the pool of proposal applications, three to five pilot projects are selected.

1.1.6 Biennial Environmental Compliance Report

In October 1994, the DOE submitted the *Biennial Environmental Compliance Report* (BECR) to the EPA Region VI Office, and to the NMED. The submittal of this report was mandated in section 9(a)(2) of the WIPP LWA. The BECR documents WIPP's compliance with applicable federal and state laws, regulations, and permit conditions pertaining to public health and safety or the environment.

1.1.7 NEPA Training

A new computer-based National Environmental Policy Act (NEPA) training module was released in December 1994. This program provides to trainees, current NEPA guidelines in the planning, coordination, and performance of work.

1.1.8 Environmental Compliance Assessments

During 1994, 21 environmental compliance assessments were conducted. Many improvements were identified and implemented as a result of these assessments. Some of the assessed areas included: RCRA Training; Satellite Accumulation Areas; Equipment Inspections, New Mexico Special Waste; Occupational, Safety, and Health Administration (OSHA) Bloodborne Pathogens; Diesel Generator Permit; HAZMAT Inventories; Waste Characterization; Construction and Demolition Landfill; Hazardous Waste Generator Requirements; and New Mexico Discharge Plan and Water Supply Regulations.

1.2 Environmental Monitoring Program Information

In 1975, efforts to establish site characterization and environmental baseline measurements at the WIPP were initiated. These baseline measurements continue to be maintained on radiological and nonradiological databases. When the WIPP becomes operational, these baseline measurements will be transitioned to the "operational phase" and will be constantly monitored throughout the life of the project.

1.2.1 Environmental Monitoring Plan

The WIPP's EMP provides schedules and guidelines for monitoring a comprehensive set of parameters to detect and quantify present or potential environmental impacts, both nonradiologically and radiologically, Nonradiological surveillance covers the immediate area surrounding the WIPP site. Radiological surveillance covers a broader geographic area that includes nearby ranches, villages, and cities. Both nonradiological and radiological parameters involve sampling activities. Sampling activities conducted during CY 1994 were performed at the monitoring locations established by the EMP. Monitoring parameters may need to be modified from time-to-time to ensure a technically sound program. Environmental Monitoring will continue at the WIPP site during project operations and throughout decommissioning activities.

1.3 Environmental Radiological Program Information

The following presents monitoring topics for the subprograms of the EMP. These subprograms are consistent with policies established in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, (DOE/EH-0173T).

1.3 Environmental Radiological Program Information (continued)

DOE Order 5400.1 requires that a radiological baseline be established during the preoperational phase. Once a radiological baseline has been established, applicable radiological sampling programs can be maintained or can be modified to improve sampling efficiency. As radiological sampling protocol evolves to reflect program requirements (e.g., DOE Orders, EPA directives), the continuation of baseline sampling is necessary to provide adequate and timely measurements prior to waste receipt. As specifically outlined in the EMP, five subprograms are being conducted to document the background levels of potential radionuclide pathways leading from the WIPP to the environment and the public. These five subprograms are presented in the *Statistical Summary of the Radiological Baseline Program (RBP) for the Waste Isolation Pilot Plant* (DOE/WIPP 92-037).

1.3.1 Airborne Particulate and Effluent Monitoring

The WIPP began sampling airborne aerosol particulates in 1985 and this sampling activity continues to be an important subprogram of the EMP. The *Final Safety Analysis Report* (FSAR) (DOE, 1990) identifies the atmosphere pathway as the most credible exposure pathway for the public to radiation. To monitor this pathway, particulate aerosol samplers continuously operated at eight locations during 1994; three, within 1000 meters of the facility boundary; four, at local ranches and communities; and one, at a sample control site. On November 2, 1994, the sample location situated in Eunice, New Mexico, was evaluated and determined to be of no added value because its location on the roof of the Eunice City Hall exceeded the height recommendations for sampler configuration, and additionally, presented a personnel safety hazard. Accordingly, it was decommissioned.

The continuous aerosol samplers presently being used to collect particulates maintain a regulated flow rate of .057 cubic meters per minute (approximately two cubic feet per minute) of air through a 47-millimeter (1.9 inch) fiber filter. Particulate filters are collected weekly at all locations and counted at the WIPP Site Low-Level Counting Laboratory (LLCL). Samples are further analyzed at an off site contract analytical laboratory (see Table 5-1 for contract lab preliminary results). The weekly filters are counted for gross alpha and beta activity. The data are then grouped into 13-week segments or calendar quarters and are presented as a calculated quarterly average. Table 5-1 lists the quarterly alpha and beta concentrations for each sampling location.

1.3.2 Soil Sampling

Soil Samples were collected and analyzed in accordance with applicable guidance (e.g. DOE EH/0173T) and sampling procedures. Results from the radiological analysis of subject samples are provided in Chapter 5, *Environmental Radioactivity Monitoring*. Chapter 6, *Environmental Nonradiological Program Information,* contains results from nonradiological analysis.

1.3.3 Groundwater

Groundwater surveillance activities during CY94 consisted of two separate programs: Groundwater Quality Sampling and Groundwater Level Surveillance Measurements. Groundwater quality samples were gathered from nine well locations completed in the Culebra dolomite. Groundwater level surveillance measurements were recorded at 58 well bores. During CY 1994, seven new monitoring wells were drilled; six, in the Culebra dolomite; and one, into the Dewey Lake. Results pertaining to groundwater sampling activities are provided in Chapter 7, *Groundwater Surveillance.*

1.3.4 Surface Water and Sediment Sampling

Surface water was collected at 12 locations with concurrent sediment samples taken at 10. Analysis revealed no unusual levels of background radioactivity. Discussions pertaining to surface water and sediment sampling are provided in Chapter 5, *Environmental Radiological Program Information.*

1.3.5 Game Animals and Fish Samples

Because of profound drought conditions during CY 1994, quail and rabbit populations were drastically low. Quail sampling was postponed until the population increases to the capacity that sampling will not adversely affect population status. Sampling of rabbits was restricted to only two individual road kills. Mule Deer, killed by automobile strikes, were also sampled.

Discussions pertaining to the radiological analysis of game animals and fish are presented in Chapter 5, *Environmental Radiological Program Information*. Results from the laboratory analysis of tissue is contained in Appendix A *Radiological Sample Analysis for Calendar Year 1994.*

1.4 Nonradiological Environmental Monitoring Information

Nonradiological environmental surveillance was also conducted in accordance with the EMP. This program was preceded by the WIPP Biology Program (1975-1982). An extensive baseline of information describing the major components of the Los Medaños ecosystem, prior to the initiation of the WIPP site construction activities, was developed. Six universities participated in the initiation of the characterization and baseline surveillance programs.

A significant portion of the nonradiological surveillance documented the effect fugitive salt dust generated by the surface stockpiling activities has on the surrounding ecosystem see (Reith, et al., 1985). This study is described in the *Summary of the Salt Impact Studies at the Waste Isolation Pilot Plant 1984 to 1990* (DOE/WIPP 92-038).

1.4.1 Land Management

On July 19, 1994, in response to the LWA, a new Memorandum of Understanding (MOU) between the U.S. Department of the Interior Bureau of Land Management (BLM) and the DOE was finalized. This MOU outlines the responsibilities of each agency with regard to land use management for the withdrawal area. The MOU also provides an additional mechanism to protect the withdrawal area from unallowable or inadvertent uses.

In August 1994, the DOE issued the *Waste Isolation Pilot Plant Land Management Implementation Plan* (LMIP) (DOE/WIPP 94-026). The need for a comprehensive, "living" land management document for the WIPP was identified in the 1993 *Waste Isolation Pilot Plant Land Management Plan*. The *Land Management Plan* (LMP) was submitted to Congress in accordance with requirements contained in the LWA, on October 30, 1993. The LMIP encourages direct communication among stakeholders, including federal and state agencies involved in managing the resources within, or activities impacting the areas adjacent to, the WIPP land withdrawal area. The LMIP focuses on management protocol related to the following issues: execution of the plan; environmental compliance; emergency management; industrial safety; maintenance and work control; minerals/oil and gas; reclamation; cultural resources; access/rights-of-way; recreation; security; wildlife; and grazing.

1.4.2 Meteorology

The WIPP Nonradiological Environmental Surveillance (NES) includes a primary meteorological (MET) station that provides support for various programs at the WIPP. The primary function of the MET is to generate data to model atmospheric conditions for Radiological Environmental Surveillance (RES). The station records standard meteorological measurements for wind speed, wind direction, and temperatures at a radius of 3, 10, and 40 meters (10, 30, and 130-feet respectively) with dew point and precipitation monitored at ground level. These parameters are measured continuously, and the data are logged, at fifteen minute intervals, in the Central Monitoring System (CMS).

In 1994, the annual rate of precipitation at the WIPP site was 16.58 cm (6.53 inches), which is 7.29 cm (2.87 inches) below last year's rate. The annual precipitation for 1994 was 31 percent less moisture than that recorded for 1993 and 74 percent less moisture than recorded for 1992, indicating drought conditions.

The wind direction at the WIPP site is predominately from the southeast. In CY 1994, the data collected on wind direction in the WIPP area were consistent with data previously collected on wind direction in the same area. Discussions pertaining to meteorological monitoring are contained in Chapter 6, *Environmental Nonradiological Program Information,* pages 6-2 and 6-3.

1.4.3 Air Quality Monitoring

Seven pollutant gases were monitored at the WIPP site on a continuous basis. These gases are sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), hydrogen sulfide (H_2S), nitrous oxide (NO), nitrogen dioxide (NO_2), and oxides of nitrogen (NO_x). In addition, weekly measurements of Total Suspended Particulates (TSP) were collected by the low-volume continuous air sampler at the far-field air sampling location.

On October 30, 1994, per DOE notification and subsequent approval, the monitoring of ambient levels of noxious gas emissions at the WIPP Ambient Air Monitoring Station (AMS) was discontinued because no compliance related driver exists.

1.4.4 Wildlife Population Monitoring

Population density measurements of various species of wildlife are performed annually to assess the effects of the WIPP's activities on transient and resident wildlife populations.

1.4.4.1 Bird Densities

Prior to 1994, distribution patterns of species living between the WIPP transects and the control transects remained constant, with the most significant changes occurring near the facility. It was speculated that more abundant food (i.e., insects drawn to the lights of the facility) and greater habitat diversity accounted for the increase in the number of species near the WIPP transects, compared to those of the control transects. Insect-dependant species such as barn swallows, ash-throated flycatchers, and king birds were the prominent species on the increase in the immediate vicinity of the facility. Rock doves, the common city pigeon, have been observed around the WIPP site. During 1994, investigations into population densities of transient species were postponed pending reassessment of the value added to baseline appraisals. Resident species (i.e. quail) are currently being considered for more specialized evaluations as they are considered non-migratory and are sampled annually as radiological sentinels.

1.4.4.2 Small Nocturnal Mammal Population Densities

Reports of the presence of the Hantavirus in West Texas and other neighboring states prompted the suspension of small nocturnal mammal population studies, pending the collection of evidence to ascertain the status (presence or absence) of the Hantavirus in local populations of small mammals. Midway through the census period of CY 1993, reported outbreaks of the virus in New Mexico and every state bordering New Mexico occurred. The primary pathogen for the disease is a virus endemic in particular populations of mice common to the genus *Peromyscus* (e.g. Brush Mice, Cactus Mice, Deer Mice). To assess the small mammals near the WIPP for the presence of the pathogen, staff from the Environmental Monitoring section of the WIPP attended training seminars conducted by the Centers for Disease Control (CDC). The training provided instruction regarding the appropriate protocol for Hantavirus sampling. Subsequently, an appraisal was conducted. Trapping and blood collection was performed in accordance with CDC recommended protocol. Results from the CDC indicate the Hantavirus was not detected in the WIPP samples.

1.4.5 Vegetation Monitoring

The CY 1994 ecological vegetation monitoring was postponed because the data indicated negligible effects of salt tailings on the peripheral environment. A pattern was observed from the 1989-1992 data which was repeated in the 1993 data. The pattern confirms an increased progression in shrub cover near salt tailings. This increase is a result of the colonization of more saline-tolerant species

1.4.5 Vegetation Monitoring (continued)

(e.g. 4-winged saltbush) in close proximity to the salt piles. Cursory observations of peripheral effects resulting from salt-induced physiological stress near the salt tailings was not observed during 1993 or 1994. Responses of these plots to seasonal precipitation rates should reveal whether this pattern is reflecting the beginning of significant changes in the structure of the plant community or whether it is only a short-term effect caused by seasonal conditions. Abnormally dry conditions during CY 1994 (Figure 6-1) prohibited any validation of assumptions regarding repercussions of salt migration from the tailings piles into the adjacent environment.

1.4.6 Raptor Research and Management Program

The 1994 field season culminated a three year program reorganization regarding investigations into the life history, ecology and impact of human-related activities on transient and resident raptor populations occupying the Los Medaños. Nest locations of the hawks were identified and approximated with Loran navigators. Nestlings, if present, were banded with U.S. Fish and Wildlife Service (USFWS) bands. Additionally, Harris' Hawks were banded with anodized aluminum bands inscribed with unique alphanumeric codes. These bands afforded biologists the ability to identify entities within groups, while conducting inquiries into the territorial demeanor of the species. In accordance with commitments in existing MOUs and Interagency Agreements, research results have been transmitted to the local BLM for consideration in land use decisions.

1.4.7 Reclamation of Disturbed Lands

Reclamation activities during CY 1994 consisted of the decommissioning of numerous fenced areas that had been constructed for site characterization studies in the late 1970s. In addition to the exclosures, re-bar that had been emplaced within these study areas to delineate sampling points was removed to alleviate safety hazards to personnel and livestock. Problem areas (e.g. drainages, eroded slopes, etc.) in existing reclamation sites received additional stabilization that included seeding and straw mulching.

1.5 Quality Assurance

Programs described in this document adhere to policies set forth by federal Quality Assurance (QA) regulations including: American Society of Mechanical Engineers (ASME) NQA-1, Quality Assurance Program (QAP) Requirements for Nuclear Facilities (ASME, 1989) and EPA,

1.5 Quality Assurance (continued)

QAMS-005/80, Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans (EPA, 1980), and fulfills the requirements of the QA plans specified in DOE Orders 5400.1 (DOE, 1988d), 5400.3 (DOE, 1988e), 5700.6C (DOE, 1991) and the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T).

CHAPTER 2

INTRODUCTION

Chapter 2
Introduction

This 1994 Annual Site Environmental Report (ASER) is prepared in accordance with the guidance contained in the 1990 DOE Order 5400.1, *General Environmental Protection Program*; DOE/WIPP 91-054, *Environmental Protection Implementation Plan*, and DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. The above orders and guidance documents require that DOE facilities submit an ASER to DOE Headquarters, Office of the Assistant Secretary for Environment, Safety and Health.

The ASER provides a comprehensive description of operational environmental monitoring activities at the WIPP during CY 1994. This report also discusses the Quality Assurance (QA) and Quality Control (QC) programs, which ensure that samples collected and the analytical data obtained are representative of actual conditions at the WIPP site. The requirements and goals driving these activities are more fully described in the *Environmental Monitoring Plan for the Waste Isolation Pilot Plant* (DOE/WIPP 94-024).

The Environmental Monitoring Plan (EMP) was drafted in accordance with the guidelines contained in the *General Environmental Protection Program* (DOE Order 5400.1). The EMP defines the scope and extent of the WIPP Environmental Monitoring Programs and ensures that all appropriate sampling efforts are in place to generate the following: (1) The amount and type of naturally occurring radioactivity in the WIPP area prior to operational status. This quantitative data will support comparisons between preoperational and operational environmental conditions, once the WIPP site is operating as a waste repository for TRU waste. (2) A comparison between preoperational and operational radiological emissions, once the WIPP site is operating as a waste repository for TRU waste. Since waste has not yet been received, certain elements of DOE Order 5400.1 are not relevant to the WIPP Environmental Monitoring Program (i.e., no discussion is included in this report of radionuclide emissions with subsequent calculation of doses to the public). The EMP is reviewed annually and updated every three years, as required by DOE Order 5400.1. The revisions/updates address general changes, improvements, and enhancements to be implemented based upon the data generated from the monitoring programs.

2.1 Description of the WIPP Project

The WIPP project is authorized by the DOE, National Security, and Military Applications of Nuclear Energy Authorization Act of 1980 (i.e., Public Law 96-164). The legislative mandate is to demonstrate the safe disposal of transuranic wastes resulting from national defense activities and programs. To fulfill this mandate, the WIPP has been designed to scientifically investigate:

2.1 Description of the WIPP Project (continued)

(1) the behavior of bedded salt and the interactions between the salt and radioactive wastes and (2) to demonstrate safe and efficient handling, transport, and emplacement of transuranic (TRU) waste in a fully operational disposal site.

The first radioactive wastes will be emplaced once permitting activities are completed. Subsequent to successful permit completion, the WIPP site will be designated as an operational facility. TRU wastes will then be transported from generator/storage sites throughout the United States to the WIPP site.

The TRU waste received from the generator sites will be transported to the WIPP site via tractor-trailer trucks. Each truck can carry up to three TRU Package Transporters (TRUPACT IIs), and each transporter may contain fourteen 55-gallon drums or two standard waste boxes. The TRUPACT II is a durable, reusable container that has been certified by the Nuclear Regulatory Commission (NRC) to transport contact-handled (waste containers that can be handled without shielding) transuranic waste to the WIPP.

Once TRU wastes have arrived at the WIPP, they are transported into the Waste Handling Building. The waste containers will be removed from the TRUPACT IIs, placed on the waste hoist, and lowered to the repository level of 655 m (2150 feet) below the surface. During the disposal phase, waste drums will be removed from the hoist and emplaced in excavated storage rooms in the Salado formation, a thick sequence of salt beds deposited approximately 250 million years ago in the Permian Age. After the disposal areas have been filled, specially designed closures will be placed in the excavated disposal rooms and seals will be placed in the shafts. The self-healing nature of the salt formation will aid in gradual closure causing encapsulation and isolation of the waste within the Salado formation.

During site operations, the underground area will be ventilated with ambient air that enters the Air Intake Shaft, the Salt Handling Shaft, the Waste Handling Shaft, and exits through the Exhaust Shaft. In the event of an underground accident involving radioactivity, exhaust air can be circulated at a reduced flow rate through the Exhaust Filter Building. This building contains banks of High Efficiency Particulate Air (HEPA) filters that remove contaminated particulates.

2.2 Description of the Environment and Lands

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 2-1, page 2-5). The WIPP site is 40 kilometers (26 miles) east of Carlsbad, New Mexico, in an area known as the Los Medaños (the dunes). The unique diversity of plant and animal communities is representative of the convergence between the northern region of the Chihuahuan Desert and the Llano Estacado (staked plains). The majority of the lands outside the WIPP site boundary, are managed under the jurisdiction of the U.S. Department of the Interior's (DOI) Bureau of Land Management (BLM) Carlsbad Resource Area (CRA) local office. Land uses in the surrounding areas include livestock grazing, potash mining, oil and natural gas production, and recreational uses. Recreational uses include hunting, trapping, birdwatching and other uses as permitted by the BLM.

The WIPP site boundary extends at least 1.6 kilometers or one mile beyond any of the WIPP underground developments and is defined on the surface by the 16-section (4,146 ha) Land Withdrawal Area. On October 30, 1992, the WIPP Land Withdrawal Act, Public Law 102-579, was signed by President Bush transferring the land from the Department of Interior (DOI) to the DOE. A WIPP Land Management Plan, DOE/WIPP 93-004, was then prepared and submitted to Congress in October 1993.

Consisting of 16 sections (4,146 ha) of federal land, the WIPP site is located in Eddy County, New Mexico in Township 22 South, Range 31 East. With the exception of properties located within the boundaries of the posted 1454 acre (589 ha) area, the surface land uses remain largely unchanged and are managed in accordance with accepted practices for multiple land use. Mining and drilling for purposes other than those which support the WIPP project are prohibited within the 16-section (4,146 ha) area.

The WIPP site is divided into sectors as represented in Figure 2-2. The sector identified as the "Property Protection Area" is surrounded by a chain-link fence that encompasses all major surface facilities. The sector identified as the "Off Limits Area" is the area surrounded by a four-strand barbed wire fence. This fence encircles the Property Protection Area in addition to outlying properties and structures used in the operation of the WIPP (e.g. salt tailings piles, meteorological station) that are necessary to secure from public access. The Exclusive Use Area represents an expanded secure area, posted against trespass, but unfenced. Although livestock grazing will continue inside the 1454 acre sector, other activities associated with the concept of multiple land use (e.g., hunting, camping, etc.) are prohibited. The aforementioned sectors are posted against trespass

2.2 Description of the Environment and Lands (continued)

under the authority of Section 229 of the Atomic Energy Act, 42 U.S.C. 2278a, and pursuant to the regulations set forth in 10 CFR 860 and DOE Order 5632.6, *Physical Protection of DOE Property and Unclassified Facilities*. These sectors are patrolled by the WIPP security and regulations are enforced commensurate with laws pertaining to property protection. The sector identified as "Zone II" is not a surface sector. This designation illustrates the surface image of the original conception of the maximum extent of the proposed underground repository. The WIPP site boundary (4 miles x 4 miles) provides a functional barrier of intact salt between the underground region defined by the Exclusive Use Area and the accessible environment.

There are 26 permanent residents within ten miles of the WIPP site. Most of the population within 50 miles of the site is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal, and Artesia, New Mexico. The two nearby ranch residences (Smith Ranch and Mills Ranch) are continuously monitored as part of the Environmental Monitoring Program. Detailed demographic summaries and projections are listed in the *WIPP Final Environmental Impact Statement* (FEIS) (DOE, 1980), the *Final Supplement Environmental Impact Statement* (SEIS) (DOE, 1990), the WIPP Land Management Plan (LMP) (DOE/WIPP 93-004) and the *WIPP Final Safety Analysis Report* (DOE, 1990).

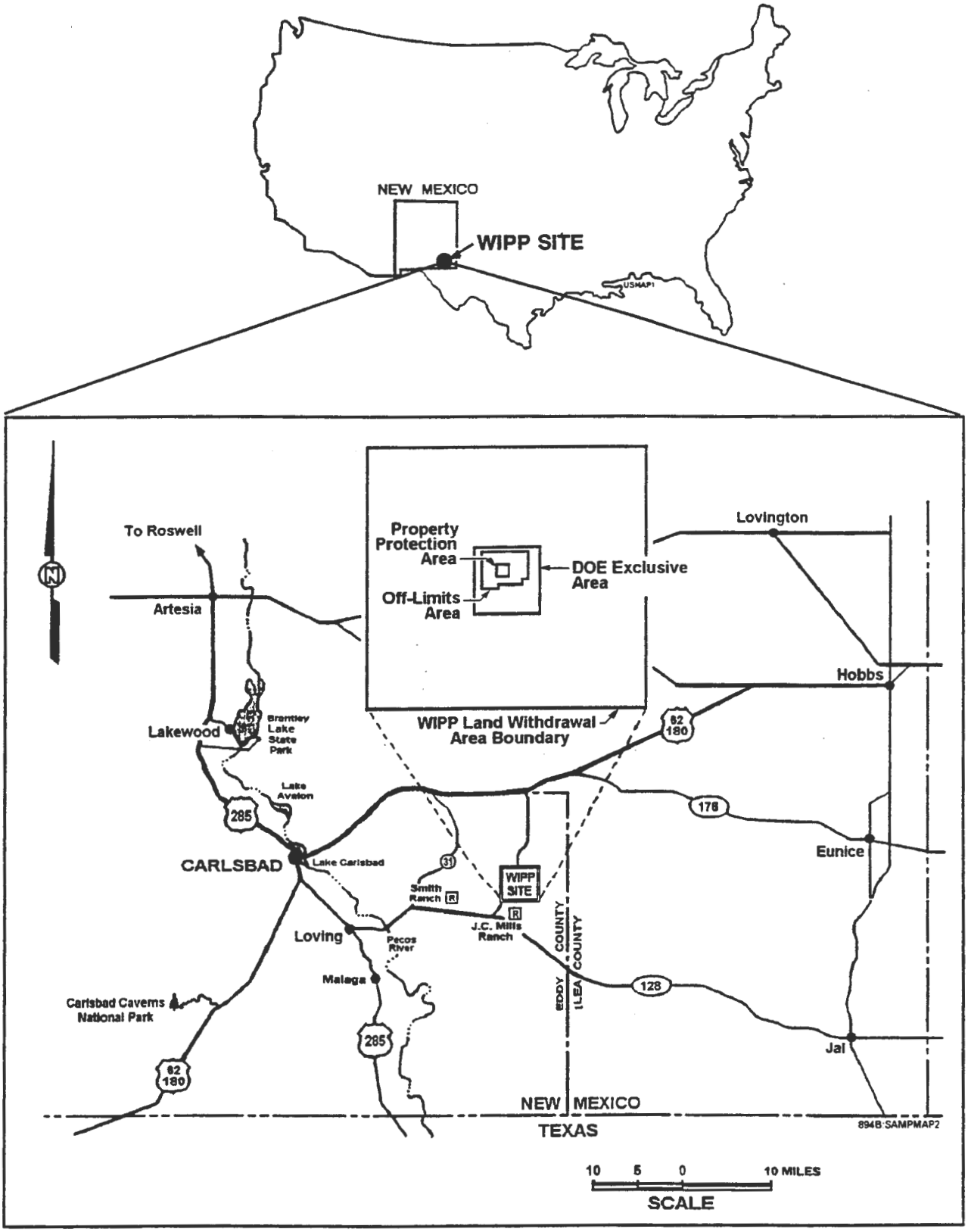

Figure 2-1
Location of the WIPP Site

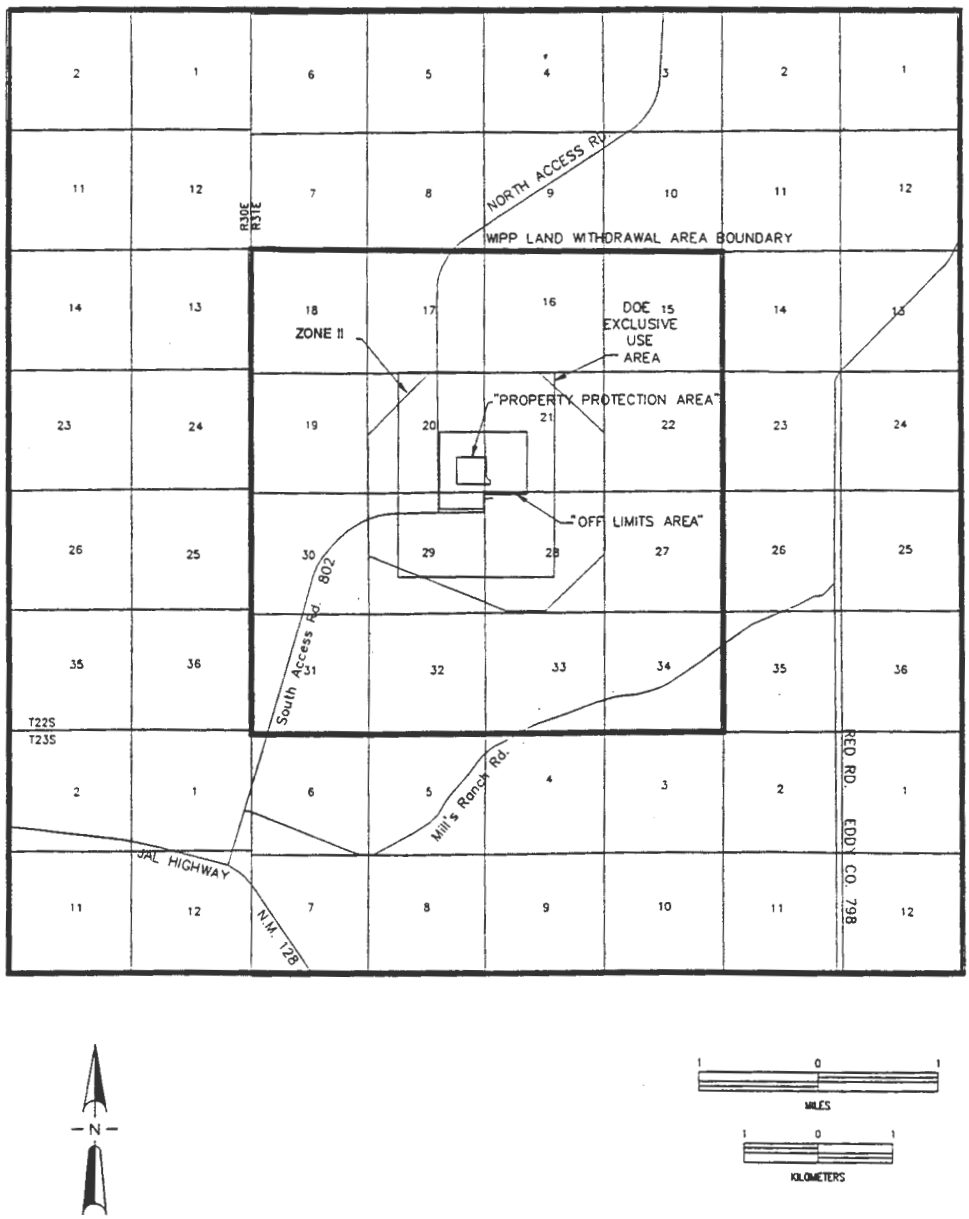

Figure 2-2
WIPP Sectors

CHAPTER 3

COMPLIANCE SUMMARY

Chapter 3
Compliance Summary

The WIPP is required to comply with all applicable DOE Orders and federal and state laws and regulations. Documentation of required federal and state permits, notifications, and approvals is maintained by the Environment, Safety, Health and Regulatory Compliance (ESH&RC) Department of the Management and Operating Contractor (MOC). Regulatory requirements are incorporated in facility plans and implementing procedures.

Table 3-1, pages 3-29 through 3-30, provides a summary of the major federal and state statutes applicable to the WIPP Project. Table 3-2, pages 3-33 through 3-37, presents DOE Orders and agreements affecting the WIPP environmental program. Table 3-3, pages 3-33 through 3-34, is a summary of agreements between the DOE and the State of New Mexico that affect the environmental programs of the WIPP. Table 3-4, pages 3-35 through 3-37, details active/pending environmental permits for the WIPP in CY 1994.

3.1 Compliance Assessment for Calendar Year 1994

In 1994 the WIPP maintained compliance with applicable federal and state environmental regulations. Section 3.2 lists the compliance status of each major environmental statute and executive order applicable to the WIPP, including significant issues generated by, and actions and accomplishments driven by these statutes and orders. Section 3.3 describes other significant compliance accomplishments at the WIPP facility in CY 1994.

3.2 Compliance Status

This section documents compliance with the following regulatory requirements at the WIPP:

- Atomic Energy Act of 1954 (AEA)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (includes the Superfund Amendments and Reauthorization Act of 1986)
- Resource Conservation and Recovery Act (RCRA)
- National Environmental Policy Act (NEPA)
- Clean Air Act (CAA)
- Clean Water Act (CWA)
- Safe Drinking Water Act (SDWA)
- Toxic Substances Control Act (TSCA)

3.2 Compliance Status (continued)

- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Endangered Species Act (ESA)
- National Historic Preservation Act (NHPA)
- Floodplain Management Executive Order
- Protection of Wetlands Executive Order
- Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
- Hazardous Materials Transportation Act (HMTA)
- Packaging and Transportation of Radioactive Materials
- Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
- Waste Isolation Pilot Plant Land Withdrawal Act (LWA)
- Taylor Grazing Act
- Federal Land Policy and Management Act (FLPMA)
- Public Rangelands Improvement Act
- Grazing Fees Executive Order
- Materials Act of 1947
- Federal Mine Safety and Health Act of 1977 (MSHA)
- Occupational Safety and Health Administration Regulations (OSHA)
- Noise Control Act of 1972
- Bald and Golden Eagle Protection Act
- Migratory Bird Treaty Act (MBTA)
- National Defense Authorization Act - Fiscal Year 1989
- Protection and Enhancement of Environmental Quality Executive Orders
- Federal Compliance with Pollution Control Standards Executive Order

3.2.1 Atomic Energy Act of 1954 (AEA)

(42 U.S.C. § 2011 et seq.)

The AEA established a national program for research, development, and atomic energy for both national defense and domestic civilian purposes. Section 161 (i) (3) of the AEA provides that the Atomic Energy Commission (succeeded by the DOE for national defense purposes) is authorized to prescribe regulations and orders to:

3.2.1 Atomic Energy Act of 1954 (AEA) (continued)

> . . . govern any activity authorized pursuant to this Act [the AEA], including standards and restrictions governing the design, location, and operation of facilities used in the conduct of such activity, in order to protect health and to minimize danger to life or property . . .

The authority of the DOE to develop policies, issue orders, and promulgate regulations addressing environment, safety and health protection standards regarding radioactive waste and nuclear materials is derived directly from the AEA. The EPA has also derived its authority to establish standards for the protection of the public and the environment from ionizing radiation from the AEA. The DOE, under the authority of the AEA and in accordance with various Executive Orders (EOs), uses a system of Orders, Notices, and Directives to carry out the mandate to implement effective and consistent programs to protect the public, the environment, and employees from adverse consequences resulting from the DOE operations. Implementation of those Orders, Notices, and Directives dealing with environmental monitoring and surveillance is addressed in the *Waste Isolation Pilot Plant Environmental Monitoring Plan* (DOE/WIPP 94-024).

Much of the waste to be emplaced at the WIPP is mixed (i.e., radioactive waste with hazardous constituents). This waste is subject to dual regulation: the radioactive constituents of the waste are regulated under the AEA, whereas the hazardous constituents are regulated under RCRA. Standards contained in 40 CFR 191, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Waste*, will become applicable when waste receipt begins.

The EPA's authority to establish standards for the protection of the public and the environment from radiation is derived from the AEA, as amended; Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act (NWPA) (PL 97-425). The protection standards found at 40 CFR 191 apply to spent nuclear fuel and high-level radioactive waste, as defined by the NWPA, and to TRU waste that contains more than 100 nanocuries per gram of waste of alpha-emitting TRU isotopes with half-lives greater than 20 years. These standards consist of three subparts A, B, and C. Each subpart will be discussed in the following paragraphs.

Subpart A, *Standards for Management and Storage*, sets the operational term requirements limiting annual doses to members of the public. These annual dose requirements are established from the management and storage operations at disposal facilities that are operated by the DOE, not regulated

3.2.1 Atomic Energy Act of 1954 (AEA) (continued)

by either the National Regulatory Commission (NRC) or by agreement states. The annual dose equivalent to any member of the public in the general environment may not exceed 25 millirem (mrem) to the whole body and 75 mrem to any critical organ.

Subpart B, *Environmental Protection Standards For Management And Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, sets the long term repository performance standards applicable to the WIPP. As the result of a legal challenge, Subpart B had been remanded by "the court" in 1987. The Land Withdrawal Act (LWA) reinstated the standard with the exception of 40 CFR 191.15, *Individual Protection Requirements* and 191.16, The *Ground-Water Protection Requirements*, which were subject to the remand order. The LWA also directed the EPA to expedite issuance of final disposal standards. On December 20, 1993 (FR Vol. 58, No 242, 66398) the EPA issued the final disposal standards in the form of amendments to Subparts B (including 40 CFR 191.15 and 191.16) and the addition of Subpart C. The primary changes to Subpart B are as follows: The individual protection requirements in 191.15 were replaced with a new set of requirements. Part 191.15 now requires that the disposal system be designed to provide reasonable expectation that for 10,000 years (not 1,000 years) after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose (CED) to any member of the public to exceed 15 millirems. The changes are in the time frame for individual protection requirements (1,000 years to 10,000 years) and in the dose calculation methodology (previously "whole body/specific organ," now CED). Although Subpart B had been remanded, the WIPP previously committed to comply with Subpart B until the EPA issues the final standards. The WIPP's compliance issues and long-term disposal standards are addressed through the use of performance assessments. Sandia National Laboratory (SNL) periodically issues the performance assessment report, which models results. The report analyzes the performance of the WIPP repository using available operational parameters.

Subpart C, *Environmental Standards for Ground-Water Protection*, was added and 40 CFR 191.16 was deleted. This standard essentially requires that the disposal system be designed to provide reasonable expectation that for 10,000 years of undisturbed performance disposal will not cause the levels of radioactivity in any underground source of drinking water, in the accessible environment, to exceed the limits specified in 40 CFR 141, *National Primary Drinking Water Regulations*, as they existed on January 19, 1994.

The Land Withdrawal Act directed the EPA to issue final criteria for certifying the DOE's compliance with the final repository disposal standards (40 CFR 191) and to issue

3.2.1 Atomic Energy Act (AEA) (continued)

the criteria in a rulemaking procedure conducted under 5 U.S.C. 553. The LWA directed the EPA to issue draft criteria within one year of enactment (i.e., by November 1993) and final criteria, within two years of enactment (i.e., by November 1994). In response to these directives, the EPA issued draft criteria for comments on March 8, 1995, *Criteria for the Certification and Determination of the Waste Isolation Pilot Plant's Compliance with Environmental Standards for the Management and Disposal of Spent Nuclear Fuel,* 40 CFR 194. The DOE provided comments on the draft criteria to the EPA on March 8, 1995. The EPA then hosted public hearings to consider public comments on the draft criteria. After finalization of the criteria, the WIPP will submit an application for certification of compliance with the final disposal standards per the LWA.

3.2.2 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 U.S.C. § 9601 et seq.), (including the Superfund Amendments and Reauthorization Act of 1986)

The CERCLA, or "Superfund," and the Superfund Amendments and Reauthorization Act (SARA) establish a comprehensive federal strategy for responding to, and establishing liability for, releases of hazardous substances from a facility to the environment. Hazardous substance cleanup procedures are specified in the National Contingency Plan (NCP), 40 CFR 300. No release sites have been identified at the WIPP that would require cleanup under the provisions of the CERCLA. Any spill of hazardous substances that exceeds a reportable quantity, must be reported to the National Response Center (NRC) under the provisions of Section 103 of CERCLA and 40 CFR 302.

3.2.2.1 Accidental Releases of Reportable Quantities of Hazardous Substances

During 1994, there were two spills of ethylene glycol that exceeded reportable quantity limits. The reportable quantity for ethylene glycol is one pound. Both spills were less than one gallon and were reported to the NRC, the State Emergency Response Commission (SERC), and the Local Emergency Planning Committee (LEPC). A follow-up report was sent to the SERC and the LEPC. All spills were immediately contained and remediated in accordance with the WIPP Spill Response Procedures. All contaminated soils and spill containment pads were drummed, manifested, and transported to an offsite disposal facility.

3.2.2.1 Accidental Releases of Reportable Quantities of Hazardous Substances (continued)

The WIPP facility is required to report such events under Sections 311 and 312 of SARA Title III, also known as the *Emergency Planning and Community Right-to-Know Act* (EPCRA). Reports required by these two sections are submitted to the SERC, the LEPC, and the local fire department. The WIPP also submits Section 311 data and Section 312 annual reports to the Carlsbad Fire Department, the Hobbs Fire Department, and the Otis Fire Department. For emergency response purposes, the DOE maintains Memoranda of Understanding (MOU) with each of these agencies.

The WIPP facility is currently exempt from the reporting requirements in Section 313 of the EPCRA. Section 313 lists the following toxic chemicals, currently in use at WIPP, that exceed the 10,000 pound threshold level: ethylene glycol, sulfuric acid, toluene, and xylene. Ethylene glycol and sulfuric acid meet the 10,000 pound reporting threshold, however, these chemicals are used as a structural component of the facility and are subject to the use exemption. Toluene and xylene are contained in unleaded gasoline and are subject to the vehicle maintenance exemption. Documentation of this exempt status is reviewed annually.

3.2.2.2 Waste Minimization and Pollution Prevention Programs

In May 1994, the first revision to the *WIPP Waste Minimization and Pollution Prevention Awareness Program Plan* was issued. This plan is reviewed annually and updated at least once every three years.

On December 1, 1993, the WIPP began recycling white bond paper, corrugated cardboard, and aluminum cans. All project participants, including the DOE, Westinghouse, Sandia National Laboratories, and minor subcontractors are involved in this recycling effort. In 1994, the WIPP site recycled 44.2 tons of paper and cardboard and approximately 800 pounds of aluminum cans.

In March 1994, the WIPP initiated a printer toner cartridge recharging program. The WIPP now recharges toner cartridges for a cost of $40 per recharge, instead of discarding them and purchasing new cartridges for $70-$130. After the cartridges have been recharged three times, they are sent for recycling. In 1994, the WIPP recharged 246 cartridges for a savings of over $13,000.

3.2.2.3 Waste Minimization and Pollution Prevention Programs (continued)

In December 1994, the aerosol can puncturing program began with surface operations. This program allows cans to be punctured and emptied thereby reducing the amount of hazardous waste and saving on disposal costs.

3.2.3 Resource Conservation and Recovery Act (RCRA)
(42 U.S.C. § 3251 et seq.)

The RCRA was enacted in 1976 and implementing regulations were promulgated in May 1980. This body of regulations ensures that hazardous wastes are managed and disposed in an environmentally safe manner. Facilities that store, treat, or dispose of hazardous waste also must protect human health and the environment. The Hazardous and Solid Waste Amendments (HSWA) of 1984 prohibit land disposal of hazardous wastes unless certain treatment standards are satisfied or unless the EPA approves a petition to receive a variance from Land Disposal Restriction (LDR) standards. The HSWA also places increased emphasis on waste minimization activities and serves as a mechanism to enforce the RCRA cleanup requirements.

The WIPP facility is subject to the permitting requirements under the RCRA and the New Mexico Hazardous Waste Act. Title 40 CFR 264 outlines the technical standards for Treatment, Storage, and Disposal facilities that must be addressed in a permit application (as applicable). Title 40 CFR 270 outlines the requirements of the RCRA permitting program with respect to general format and content for applications, and the administrative aspects of the permitting and modification processes. The WIPP RCRA permit application will address TRU mixed waste management activities for surface facilities and in the repository as required for disposal operations. This application is being prepared for submittal to the NMED in May 1995. In general, programmatic changes reflected in this application center on the DOE decision to forego test phase activities at the WIPP. The RCRA permit is expected to be issued by the NMED in December 1997.

In order to permanently dispose of TRU mixed waste, the DOE has petitioned the EPA for a variance from the LDR of the RCRA, codified in 40 CFR 268. As defined in the provisions of 40 CFR 268.6, the DOE must demonstrate "to a reasonable degree of certainty" that hazardous constituents will not migrate from the disposal unit in concentrations exceeding health-based levels. The WIPP is currently developing a new No Migration Variance Petition (NMVP). The NMVP will be submitted to the EPA in two phases. The first phase will address a no-migration demonstration within the WIPP operational time frame (waste emplacement). This phase of the

3.2.3 Resource Conservation and Recovery Act (continued)

petition is near completion and will be submitted to the EPA in fiscal year 1995. The second phase consists of a complete NMVP, all-inclusive of the first submittal, and will demonstrate no migration after closure of the facility.

3.2.3.1 Mixed-Waste Management

In August 1993, the New Mexico Environment Department (NMED) issued, for public comment, a draft permit for the WIPP facility. In October 1993, the DOE made the decision not to conduct tests with radioactive wastes at the WIPP. At that time the DOE also requested an extension to the public comment period. On January 13, 1994, the DOE submitted a request to modify the RCRA permit application to reflect disposal, rather than test-phase operations. The NMED granted an extension to the public comment period until January 15, 1994. On September 2, 1994, NMED requested that a revised permit application be submitted by May 31, 1995, to accurately reflect future WIPP activities. As of January 19, 1995, the DOE has submitted nine chapters to the NMED for their review.

3.2.3.2 Hazardous Waste Generator Compliance

Nonradioactive hazardous waste is currently generated through normal facility operations. These wastes are managed in Satellite Accumulation Areas (SAA) and "less than 90-day" storage areas. In addition, hazardous waste generated at the WIPP is characterized, packaged, labeled, and manifested prior to shipment to an offsite Treatment Storage Disposal Facility (TSDF) in accordance with those requirements as codified in 40 CFR 262. Various waste minimization activities have been implemented at the site. One such activity is the Aerosol Can Puncturing Program. Once a can is punctured and drained of the contents, it is then classified as RCRA "empty" and managed as nonhazardous. The remaining residual liquids are the only portion of the waste managed as hazardous, which substantially reduces the volume of this particular waste stream.

3.2.4 National Environmental Policy Act (NEPA)
(42 U.S.C. § 4321 et seq.)

The National Environmental Policy Act (NEPA) requires the federal government to use all practicable means to consider potential environmental impacts of proposed projects as part of the decision-making process. The NEPA dictates that the public shall be allowed to review and comment on proposed projects that have the potential to significantly affect the environment. The

3.2.4 National Environmental Policy Act (continued)

NEPA also directs the federal government to use all practicable means to improve and coordinate federal plans, functions, programs, and resources relating to human health and the environment. NEPA procedural objectives and public involvement requirements are detailed in the Council on Environmental Quality (CEQ) regulations implementing the NEPA in 40 CFR 1500-1508. DOE codified its requirements for implementing CEQ's regulations in 10 CFR 1021. Further procedural NEPA compliance guidance is provided in DOE Order 5440.1E, *National Environmental Policy Act Compliance Program.*

Title 10 CFR 1021.331 requires that ". . . following the completion of each environmental impact statement and its associated Record of Decision (ROD), the DOE shall prepare a Mitigation Action Plan (MAP) that addresses mitigation commitments expressed in the ROD." DOE Order 5440.1E further requires DOE facilities to "track and report annually to EH-1 the progress made in implementing and the effectiveness of any mitigation action plan until mitigation is completed." *The 1994 Annual Mitigation Report for the Waste Isolation Pilot Plant* (NEPA ID# WIP:94:0001) was issued July 1994.

In December 1994, a new computer-based NEPA training module was released for use at the WIPP. The training module provides specific instructions to workers for completing environmental checklists, which assess the impacts of their proposed actions.

Two WIPP NEPA procedures are currently being revised. These procedures provide directions to personnel responsible for the planning, coordination, and performance of work. At the WIPP site purchase requisitions and engineering work packages, which initiate modifications to the facility, are reviewed in accordance with these procedures to assess their potential environmental impacts and their compliance with the DOE's NEPA regulation and Order. The procedure revisions will simplify day-to-day WIPP NEPA compliance and facilitate a more thorough, expedient review/approval process.

Planning for the preparation of the second Supplemental Environmental Impact Statement (SEIS-II) is underway. The SEIS-II document originated from a commitment made in the Final Supplemental Environmental Impact Statement (FSEIS) to prepare another environmental impact statement prior to the decision to proceed with waste disposal activities at the WIPP site.

3.2.5 Clean Air Act (CAA)
(42 U.S.C. § 7401 et seq.)

The CAA provides for the preservation, protection, and enhancement of air quality, particularly at locations of special interest such as areas of natural, recreational, scenic, or historic value. Under Section 109 of the Clean Air Act, the EPA established the National Ambient Air Quality Standards (NAAQS) for six "criteria" pollutants: sulfur dioxide, total suspended particulates, carbon monoxide, ozone, nitrogen oxide, and lead. These standards establish primary and secondary standards for ambient air quality that the EPA considers necessary to protect public health and welfare.

In 1993, Westinghouse Electric Corporation, Waste Isolation Division (WID), completed the *WIPP Hazardous Air Pollutant (HAP) Emission Inventory* (WP 02-15). The HAP's inventory was developed as a baseline document to calculate maximum potential hourly and annual emissions of both hazardous and criteria air pollutants. Emission estimates were used to determine if the WIPP is required to obtain an air permit as specified in the following regulations:

- Clean Air Act § 112 National Emission Standards for Hazardous Air Pollutants
- Clean Air Act Part C (Prevention of Significant Deterioration - Criteria Pollutants)
- New Mexico Air Quality Control Regulation 752
- New Mexico Air Quality Control Regulation 702.

The CAA, Section 112 establishes emission standards for Hazardous Air Pollutants. The 1990 Clean Air Act Amendments (CAAA) increased to 189 the number of hazardous air pollutants regulated under the CAA. Hazardous air pollutant emissions are regulated under 40 CFR 61, the *National Emission Standards for Hazardous Air Pollutants* (NESHAP). The NESHAP establishes permitting and reporting requirements for facilities that have the potential to emit hazardous air pollutants. At the WIPP, the majority of hazardous air pollutants are regulated in Subpart A of the NESHAP. Radionuclide emissions other than radon are regulated in Subpart H of the NESHAP.

Based on an MOU with the EPA, the DOE committed to compliance with the requirements of 40 CFR 61, Subpart H, through the disposal phase of operations at the WIPP. A revised standard for radionuclide emissions was promulgated by the EPA in a final ruling published in the *Federal Register*, effective December 15, 1989 (54 FR 51654). In the *1990 Final Safety Analysis Report* (FSAR) for the WIPP facility, the anticipated dose from future WIPP facility emissions was calculated to be less than one percent of the allowable effective dose equivalent of 10 millirem per

3.2.5 Clean Air Act (CAA) (continued)

year to any one member of the public. The DOE documented the expected emission levels in 1990 data submitted to the EPA.

A revised data package will be submitted to the EPA prior to waste receipt. An emissions monitoring system was installed to comply with the periodic confirmatory monitoring compliance requirements established in NESHAP. On November 21, 1994, the EPA approved the use of a single-point source shrouded probe for compliance sampling. The shrouded probe will be used to conduct periodic confirmatory monitoring at the WIPP.

Based on the HAP's inventory, WIPP operations do not exceed the 10 ton per year (TPY) emission limit for any individual HAP or the 25-tpy limit for any combination of HAPs emissions established in Subpart A. The WIPP does not have any NESHAP Subpart A permitting or reporting requirement at this time. However, 40 CFR 61, Subpart A, Section 61.09(a)(1), requires that the WIPP facility notify the EPA of its anticipated date of initial startup (i.e., receipt of wastes) not more than 60 days and not less than 30 days before actual startup date. In addition, the EPA required that notification of the actual date of initial startup must be made within 15 days after startup.

Based on emission estimates generated in the HAPs inventory, the WIPP site is not required to obtain any federal CAA permits. The WIPP, in consultation with the NMED Air Quality Bureau, working in concert with data provided in the HAP's inventory, was required to obtain a New Mexico Air Quality Control Regulation (AQCR) 702 Operating Permit for two primary backup, diesel generators at the site. The only emission points where the WIPP site exceeds state threshold criteria is with the WIPP backup diesel generators. On June 18, 1993, the DOE submitted an AQCR 702 permit application for the WIPP backup diesel generators. On December 7, 1993, the New Mexico Air Quality Bureau issued Air Quality Permit 310-M-2. On February 26, 1994, the WIPP completed the emission monitoring requirements established in the permit. With the submittal of the *Final Compliance Sampling Report* on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit.

3.2.6 Clean Water Act (CWA)

Section 402 of the CWA, establishes provisions for the issuance of permits for discharges into waters of the United States. Regulations promulgated to define this permitting process are contained in 40 CFR 122. Subpart A, Section (b)(1), and state that ". . . National Pollutant Discharge

3.2.6 Clean Water Act (CWA) (continued)

Elimination System (NPDES) program requires permits for the discharge of "pollutants" from any "point source" into "waters of the United States." The WIPP has no pollutant discharges from point sources and is currently exempted from obtaining a standard NPDES permit.

On September 9, 1992, the EPA issued the final requirements for NPDES *General Permits for Storm Water Discharges Associated with Industrial Activity*. The storm water regulations establish requirements for managing industrial storm water runoff that has the potential to discharge into waters of the United States. The WIPP submitted a Notice of Intent (NOI) to the EPA to obtain a NPDES Storm Water General Permit on December 31, 1992. The NOI describes how the WIPP site mitigates the discharge of contaminated storm water through the use of Best Management Practices (BMPs). These BMPs include engineering controls such as storm water retention basins, the covering of materials storage areas, and the reclamation of disturbed areas. The EPA issued a New Mexico NPDES Storm Water General Permit (NMR00A021) on January 31, 1992. As part of the Nationwide General Permit Program, the WIPP is included in the New Mexico General Permit.

No sampling is required to demonstrate compliance with the WIPP Storm Water Permit unless a release occurs from one of the BMPs. Operational permit compliance activities are limited to quarterly inspections of retention basins, spill containment devices, reclamation sites, and site housekeeping practices.

The NPDES sewage sludge regulations promulgated in 40 CFR 122.21 require all facilities that generate or dispose of sewage sludges to submit an information package describing sewage sludge management and disposal practices. This information is reviewed by the EPA to determine if a NPDES permit will be required for the disposal of sewage sludges at a facility.

On February 14, 1994, the DOE submitted an information package to the EPA Water Management Division and requested a written determination whether a NPDES permit would be required for sewage sludges generated at the WIPP. On March 31, 1994, the EPA Region VI Permits Issuance Section notified the DOE that they had received the information package. The agency determined that the information package was complete and stated they would notify the DOE if a full and complete sewage sludge permit application would be required at a future date.

On January 16, 1992, the NMED issued the Discharge Plan (DP-831) for the WIPP sewage facility. The approved Discharge Plan superseded an Emergency Discharge Permit issued on September 18, 1991. In addition to sewage effluent, the Discharge Plan allows for the disposal of a maximum of

3.2.6 Clean Water Act (CWA) (continued)

1500 gallons a day of nonhazardous brines generated by seepage into shaft sumps and from pumping of observation wells at the site. Brine waters are collected in portable tanks and transported to the north sewage system evaporation basin. Characterization samples were collected throughout 1994 to demonstrate that site-generated brines are nonhazardous and can be disposed in the sewage evaporation pond. The DOE submits quarterly Discharge Monitoring Reports (DMR) to the NMED to demonstrate compliance with the inspection, monitoring, and reporting requirements identified in the plan.

3.2.7 Safe Drinking Water Act (SDWA)
(42 U.S.C. § 300f et seq.)

The SDWA of 1974 provides the regulatory strategy for protecting public water supply systems and underground sources of drinking water. The NMED notified the WIPP in a September 9, 1992, letter that the WIPP Public Water Supply was categorized as a nontransient, noncommunity system for reporting and testing requirements. At that time, the NMED determined that the WIPP was required to sample drinking water for total coliform bacteria, lead, copper, nitrate and nitrite. In a March 11, 1994, letter the NMED again modified compliance sampling requirements, stating that only lead, copper, and bacteriological samples are required. The modification was based upon New Mexico Water Supply Regulations which mandate that when a public water supply system supplements other systems, that water system is treated as a single system for compliance sampling purposes.

On June 2, 1994, lead and copper samples were collected from 20 locations to demonstrate compliance with the newly identified SDWA sampling requirements. Five of the 20 samples exceeded the SDWA lead action levels. At the direction of the NMED, these five locations were resampled on June 30, 1994. Based on the results of these five samples, three locations (site drinking fountains) were permanently taken out of service and the faucets at the two remaining locations were replaced. Follow-up sampling was conducted at each of these locations and all were below the SDWA action levels. Bacterial samples were collected monthly throughout 1994. All bacteriological/analytical results were below the SWDA regulatory limits.

The Carlsbad Municipal Public Water Supply System is contracted to provide drinking water to the WIPP from city-owned wells located 31 miles north of the site. Because of this contractual agreement, the city of Carlsbad completes the source or point-of-entry samples for the various chemical constituents at each wellfield source.

3.2.8 Toxic Substances Control Act (TSCA)
(15 U.S.C. § 2601 et seq.)

The TSCA applies primarily to manufacturers, importers, and processors of toxic chemicals for commercial purposes. The WIPP is not considered a manufacturer or processor of chemical products, therefore, most of the provisions of TSCA do not apply. The TSCA regulates the use of Poly-chlorinated Biphenyls (PCBs), asbestos, and materials containing PCBs and asbestos. Current DOE policy prohibits the use of PCB-containing materials in DOE-installed equipment at facilities like the WIPP; therefore, the TSCA does not apply to DOE-installed equipment at the WIPP. In the future, relative to received waste, the TSCA will not apply to future WIPP repository activities because disposal of PCB-contaminated wastes is excluded by the WIPP Waste Acceptance Criteria (WAC). The WIPP site will comply with the TSCA regulations contained in 40 CFR 761.60 and 761.65 with respect to any possible future storage or disposal of PCB-contaminated materials. Future procurement of asbestos containing materials is also prohibited at the WIPP site.

3.2.9 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
(7 U.S.C. § 136 et seq).

The FIFRA authorizes the EPA to regulate the registration, certification, use, storage, disposal, transportation, and recall of pesticides. Recommended procedures for storage and disposal of pesticides and pesticide containers are contained in 40 CFR 165. The EPA at its discretion may exempt federal agencies from any FIFRA provisions if emergency conditions exist (40 CFR 166). FIFRA standards are considered mandatory for regular conditions at DOE facilities. The DOE will continue to comply with the standards of the FIFRA at the WIPP site.

3.2.10 Endangered Species Act (ESA)
(16 U.S.C. § 1531 et seq.)

The Endangered Species Act (ESA) provides protection for threatened or endangered species of flora and fauna. Under Section 7 of the Act and its implementing regulations in 50 CFR 402, the EPA is prohibited from authorizing activities ". . . likely to jeopardize the continued existence of any endangered species or threatened species or result in destruction or adverse modification of habitat of such species. . . ." The Section 7 process may involve a biological assessment and "formal consultation" followed by the issuance of a "nonbiological opinion" by the U.S. Fish and Wildlife Service ". . . for any species that is determined to be in potential jeopardy."

3.2.10 Endangered Species Act (ESA) (continued)

In compliance with Section 7, Consultation Requirement, the DOE requested a list of endangered species from the U.S. Department of the Interior, Fish and Wildlife Service (USF&WS) to determine if such species are known to have a critical habitat on or in the vicinity of the WIPP site. As required by Section 7(c) of the Endangered Species Act Amendments of 1978, Mr. J. L. Stegman, USF&WS Region 2, acting regional director, provided correspondence on November 15, 1979, that:

1. Identified those species, both proposed and listed, that could occur in the WIPP's proposed project area.

2. Determined that no critical habitat for endangered species had been identified at the WIPP site.

3. Requested a biological assessment that included the listed species.

This correspondence also established that if the biological assessment revealed the proposed project had no affect on the listed species, there was no need for further consultation. As requested by this correspondence, the DOE prepared a *Biological Assessment* for the purpose of identifying listed species that were likely to be affected by the Site Preliminary Design and Validation (SPDV) program and other potential site usage. The *Biological Assessment*, conducted during CY 1978, documented that the listed species would not be affected by the project. The assessment was forwarded to the USF&WS for their review, completing the requirement for the consultation process mandated by the Endangered Species Act.

3.2.11 National Historic Preservation Act (NHPA)
(16 U.S.C. § 470 et seq.)

The NHPA was enacted to protect the nation's cultural resources and to establish the National Register of Historic Places. Other related legislation affecting the WIPP facility lands include the Archeological Recovery Act (ARA), which was amended by the Archeological and Historic Preservation Act (AHPA) (16 U.S.C. § 469a et seq.).

Throughout June and July 1994, a comprehensive WIPP site archaeological database was created. Research revealed that 60 archaeological sites and 91 isolated occurrences had been discovered

3.2.11 National Historic Preservation Act (NHPA) (continued)

within the WIPP land withdrawal area. During the creation of the database some inconsistencies were discovered with regard to the number of archaeological sites (eligible and ineligible for inclusion in the National Register) reported to exist within the WIPP land withdrawal area. Some sites previously included as "WIPP archaeological sites" are located within the outer perimeters of the WIPP's Control Zone IV. The boundary of Control Zone IV was later annulled, consequently, when the WIPP site was configured to the present sixteen section square, much of Control Zone IV reverted to the management of the Department of Interior. Therefore, the archaeological sites located in those areas are no longer the responsibility of the DOE.

Of the 60 WIPP archeological sites, 33 sites recorded within the central 4-square mile area of the WIPP land withdrawal area were subjectively determined, by the archaeologists conducting the surveys, to be potentially eligible for inclusion in the National Register.

Prior to the issuance of the WIPP Land Withdrawal Act, the Bureau of Land Management (BLM) was responsible for archaeological resource management on the WIPP site. The BLM served as the DOE's liaison with the State Historic Preservation Officer (SHPO). Following the issuance of the WIPP Land Withdrawal Act, the BLM continued to serve in this capacity until July 19, 1994, when the *Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Department of Interior* was finalized. At that time, the WIPP began communicating directly with the SHPO regarding archaeological concerns.

On July 15, 1994, the BLM, using provisions contained in their *Memorandum of Agreement with the State Historic Preservation Officer*, processed and approved WIPP surface disturbing activities associated with the construction of six new well-pads. On September 7, 1994, the State Historic Preservation Officer granted the DOE approval to construct a short access road, and on September 27, 1994, the SHPO granted the DOE approval to construct another well pad. During 1994 WIPP archaeological surveys, no new archaeological sites were discovered, and stipulations for avoidance of previously known sites were observed during construction activities.

3.2.12 Floodplain Management
(Executive Order 11988)

Floodplain Management, Executive Order (EO) 11988 directs federal agencies to avoid making modifications that adversely impact floodplains, to consider alternatives to a proposed action, to provide early public review of proposed actions, and to propose mitigation measures for proposed actions within floodplains. Because the WIPP site is not located within a floodplain zone, EO 11988 does not apply to the WIPP facility.

3.2.13 Protection of Wetlands
(Executive Order 11990)

Protection of Wetlands, Executive Order (EO) 11990 requires that federal agencies consider the effects of proposed actions in wetlands, determine whether wetlands are present, assess the impacts, consider alternatives to a proposed action, provide for early public review, and propose mitigation measures for proposed actions that could affect wetlands. The WIPP facility is neither located within nor will it impact a wetlands area; therefore, EO 11990 does not apply to the WIPP facility.

3.2.14 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes
(40 CFR 191)

The authority of the EPA to establish radiation protection standards for nuclear wastes is derived from the Atomic Energy Act, as amended; the Reorganization Plan No. 3 of 1970; and the Nuclear Waste Policy Act (NWPA) (PL 97-425).

Since the mid-1970s, the EPA has been developing guidance and standards for the management and disposal of radioactive wastes. The EPA's final rule, 40 CFR 191, was published on September 19, 1985 (50 FR 38066). In a challenge by a coalition of environmental organizations and states, the U.S. Court of Appeals for the First Circuit vacated and remanded Subpart B of the 1985 standard for further consideration by the EPA. The Court found, among other things, that the EPA did not protect groundwater as stringently as provided under the SDWA underground injection provisions [NRDC v EPA 824 F.2d 1258 (1st cir. 1987)].

The Second Modification to the Agreement for Consultation and Cooperation between the DOE and the State of New Mexico dated August 4, 1987, specified that, although the standards were on

3.2.14 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes (continued)

remand status, the DOE would continue to guide its performance assessment planning efforts as though the vacated regulations were still in effect. In the WIPP Land Withdrawal Act of 1992 (PL 102-579), Congress reinstated all of the 40 CFR 191, Subpart B regulations with the exception of those that were specifically questioned by the court (i.e., Sections 191.15, *Individual Protection Requirements* and 191.16, *Ground Water Protection Requirements*). Congress also required the EPA to issue final disposal regulations by April 30, 1993. On February 10, 1993, the EPA proposed revised disposal regulations under 40 CFR 191, Subpart B (58 FR 7924). On December 20, 1993, the EPA promulgated amendments to the final standard pertaining to individual and groundwater protection requirements (58 FR 66398). The three subparts have been thoroughly discussed under **3.2.1 Atomic Energy Act of 1954**, pages 3-3 through 3-5.

3.2.15 Hazardous Materials Transportation Act (HMTA)
(49 App. U.S.C. § 1801 et seq.; 49 CFR 106-179)

The HMTA provides for safe intra and inter-state transportation of hazardous/nuclear materials. The HMTA allows states to regulate the transport of hazardous/nuclear materials if regulations are consistent with the HMTA or U.S. Department of Transportation (DOT) regulations. The DOT regulations for hazardous/radioactive materials are contained in 49 CFR 171-177. Specifications for the kinds and designs of packages to be used for the transport of various types of radionuclides are contained in 49 CFR 173, Subpart I (and parallel NRC regulations in 10 CFR 71). The DOT regulations in 49 CFR 177 provide a routing and quantity rule for highway shipments of radioactive material; 49 CFR 174 contains segregation rules for shipment by rail. In the Second Modification to the
C and C Agreement dated August 4, 1987, the DOE agreed to comply with all applicable DOT regulations and the corresponding NRC regulations by way of the Trupact Safety Analysis Report (SAR), the Trupact Consultation and Cooperation (C and C), and Waste Acceptance Criteria (WAC) requirements.

3.2.16 Packaging and Transportation of Radioactive Materials
(10 CFR 71)

Regulations for shipping containers and safe packaging and transportation of radioactive materials are under the authority of the NRC and the DOT. Packaging requirements for radioactive materials, including the Type B packages to be used to transport waste to the WIPP facility, are detailed in

3.2.16 Packaging and Transportation of Radioactive Material (continued)

the DOT regulations (49 CFR 173, Subpart I). This references the NRC regulations. The NRC regulations in 10 CFR 71 reference the DOT regulations in 49 CFR 173.

The NRC requirements for shipping containers apply to the certification of the TRUPACT-II shipping container, the container that will be used to transport radioactive waste to the WIPP facility. The NRC certified the TRUPACT-II container August 30, 1989, after compliance with the 10 CFR 71 requirement for Type B packaging was demonstrated.

A container supplier inspection audit was conducted by the NRC from January 12-14, 1993. The scope of the inspection audit was to determine whether procedures have been established, documented, and executed at the DOE's WIPP facility to meet the quality assurance requirements of 10 CFR 71. The audit also determined whether containers were fabricated and maintained in accordance with the design approved by the Commission. The NRC had no findings and stated that all quality assurance requirements of 10 CFR 71 were being followed.

3.2.17 Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
(PL 96-164)

This Act, which authorized the WIPP Project, follows:

> Not withstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy . . . for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States . . .

The statute provides for the DOE consultation and cooperation with appropriate officials of the State of New Mexico with respect to public health and safety concerns. It also provides for a written agreement between the DOE and the appropriate officials of the State of New Mexico, setting forth consultation and cooperation. In compliance, the DOE has entered into two agreements with the State of New Mexico: the C and C Agreement and the Working Agreement for the C and C. Both agreements have been modified several times (see Table 3-3). The most recent modification of the C and C Agreement is the Second Modification to the Consultation and Cooperation Agreement dated August 4, 1987. The Working Agreement for the C and C Agreement was last modified in

3.2.17 Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980
(PL 96-164) (continued)

March 1988. These agreements are implemented through the DOE and the New Mexico Radioactive Waste Consultation Task Force. In addition, the DOE interfaces regularly with the NMED and the New Mexico Legislature's Radioactive and Hazardous Waste Committee.

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act (LWA)
(PL 102-579)

On October 30, 1992, the Waste Isolation Pilot Plant Land Withdrawal Act withdrew land from the public domain for use by the Department of Energy (DOE) for the construction, experimentation, operation, maintenance, disposal, shutdown, monitoring, and decommissioning activities at the WIPP.

As a result of the LWA, the Secretary of Energy is required to develop a management plan to provide for grazing, hunting and trapping; wildlife habitat; the disposal of salt tailings; and mining. The *WIPP Land Management Plan* (LMP) was submitted to Congress in October 1993 establishing management guidelines to be used throughout the life of the facility, including decommissioning activities. In accordance with the LMP, the DOE identified the need for the development of a concurrent *Land Management Implementation Plan* (LMIP). The design of this plan was developed with consultation from the U.S. Department of the Interior's Bureau of Land Management (BLM) and the State of New Mexico. Guidelines prescribed in the LMIP provide for the management and oversight of the WIPP lands under the jurisdiction of the DOE. In addition, these guidelines provide for the management and oversight of lands outside the WIPP boundary that are used in the operation of the WIPP (e.g., groundwater surveillance well pads outside the withdrawn area). The LMIP provides for multiagency involvement in the administration of the DOE land management actions.

On July 19, 1994, the Memorandum of Understanding (MOU) between the U.S. Department of Energy and the (U.S. Department of Interior) BLM was finalized. This new MOU outlines the responsibilities of each agency with regard to land use management for the withdrawal area and provides an additional mechanism to protect the area from unallowable or inadvertent uses. The LMIP and the MOU serve to provide equitable and consistent administration of archaeological resources within the WIPP withdrawal area.

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act (LWA) (continued)

Compliance with the following statutes or regulations is also required under the Land Withdrawal Act:

- Taylor Grazing Act
- Subchapter IV of the Federal Land Policy and Management Act
- Public Rangelands Improvement Act
- Materials Act of 1947
- Federal Mine Safety and Health Act of 1977
- Solid Waste Disposal Act
- 40 CFR 191
- 29 CFR 1910.120
- Clean Air Act
- Safe Drinking Water Act
- Toxic Substance Control Act
- Comprehensive Environmental Response, Compensation, and Liability Act
- All other applicable federal laws pertaining to public health and safety of the environment.

A summary of the provisions of the LWA are as follows:

- The EPA must publish final radioactive waste disposal standards (40 CFR 191).

- The EPA must certify the WIPP's compliance with 40 CFR 191, Subparts B and C.

- The EPA must determine that the DOE has complied with the terms and conditions of the NMD issued on November 14, 1990 (55 FR 47700).

- The federal Occupational Safety and Health Administration (OSHA) must certify that it has reviewed the DOE emergency response training programs and has concurred that such programs are in compliance with 29 CFR 1910.120.

In October 1994, the DOE submitted the *Biennial Environmental Compliance Report* (BECR) to the Environmental Protection Agency Region VI Office and to the New Mexico Environment Department. The submittal of this report was mandated in Section 9(a)(2) of the WIPP Land

3.2.18 Waste Isolation Pilot Plant Land Withdrawal Act (LWA) (continued)

Withdrawal Act of 1992. The BECR documents the WIPP's compliance with applicable federal and state laws, regulations, and permit conditions pertaining to public health and safety and/or the environment.

3.2.19 Taylor Grazing Act
(43 U.S.C. § 315 et seq.)

The Taylor Grazing Act is intended to prohibit injury to public grazing lands by preventing overgrazing and soil deterioration. The Act promotes the orderly use and/or improvement to public grazing lands by establishing grazing districts and a grazing permit system. As defined in the LWA, the DOE may allow grazing to continue on the WIPP facility land where grazing districts had been established prior to the date of enactment of the Land Withdrawal Act. The Department of Interior, in consultation with the DOE, will issue any future grazing permits on WIPP lands.

3.2.20 Federal Land Policy and Management Act (FLPMA)
(43 U.S.C. §1701-1782)

The Federal Land Policy and Management Act was enacted to ensure, among other things, that

> . . . public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use . . .

The Secretary of Energy is required to comply with Subchapter IV of the Federal Land Policy and Management Act. Subchapter IV establishes the authority for grazing fees, range betterment funds, grazing permits, and grazing advisory boards. Under the LWA, the Secretary of Energy is empowered to administer these programs.

3.2.21 Public Rangelands Improvement Act
(43 U.S.C. § 1901 et seq.)

The Public Rangelands Improvement Act establishes a national policy and commitment to

- Inventory and identify current public rangeland conditions and trends.
- Manage, maintain, and improve the condition of public rangelands in a manner that the land becomes as productive as is feasible.
- Continue the policy of protecting wild free-roaming horses and burros and of removing and disposing of those excess animals that pose a threat to themselves, their habitat, and other rangeland values.

The DOE administers the WIPP facility lands as public rangelands in accordance with the guidelines prescribed in the LMP.

3.2.22 Executive Order (EO) 12548 -- Grazing Fees

Executive Order (EO) 12548 orders the establishment of fees for grazing of domestic livestock on public rangelands. The Department of Interior, in consultation with the DOE, will establish grazing fees for the WIPP facility lands.

3.2.23 Materials Act of 1947
(30 U.S.C. § 601 et seq.)

The Materials Act of 1947 addresses the disposal of mineral materials (e.g., sand, stone, gravel, pumice, cinders, and clay etc.) on public lands. The disposal of vegetative materials (e.g., yucca, manzanita, mesquite, cactus, and timber or forest products) is also addressed. Under the LWA, the WIPP facility must dispose of those salt tailings not used for backfill, in accordance with the bidding, advertising, contract negotiation, and disposition of monies provisions (Sections 602-603) of the Materials Act.

3.2.24 Federal Mine Safety and Health Act of 1977 (MSHA)
(30 U.S.C. § 801 et seq.)

Under the Federal Mine Safety and Health Act of 1977, the U.S. Department of Labor (DOL) is responsible for developing and enforcing regulations and standards to protect mine workers. In an MOU between the DOE and the DOL, effective July 9, 1987, the Mine Safety and Health Administration (MSHA) conducts periodic health and safety compliance inspections of WIPP facility underground operations. When the WIPP Land Withdrawal Act was signed into law on July 10, 1993, MSHA became the agency responsible for conducting at least four surface and underground safety inspections per year at the WIPP.

MSHA conducted four quarterly inspections in 1994. During three of these quarterly inspections, no Compliance Assistance Visit Notices were issued. During one inspection, two Compliance Assistance Visit Notices were issued. Neither of these two notices were marked as "Significant and Substantial" indicating that the violations would not significantly or substantially contribute to an accident. The conditions responsible for the notices were abated before the inspection was completed

3.2.25 Occupational Safety and Health Administration (OSHA) Regulations
(29 CFR 1900-1999)

The 1970 Williams-Steiger Occupational Safety and Health Act Section 6 (a) provides that the Department of Labor (DOL) establish employee safety and health standards compatible with those that are commonly practiced in industry and that have been found to meet national consensus standards or established federal standards. The DOE complies with OSHA standards and the OSHA safety and health management guidelines for all WIPP facility activities. In addition, the WIPP facility has established safety procedures in accordance with DOE policy.

Secretary of Energy Hazel R. O'Leary inducted the WID as the first Star Site in the Department of Energy's Voluntary Protection Program (DOE-VPP). Modeled after the OSHA VPP, the DOE-VPP was initiated in January 1994 to recognize exemplary contractor safety and health programs. An eleven member onsite review team representing a cross-section of environment, safety and health disciplines unanimously voted to recommend the WID as operating a Star Site after an August 29 - September 2, 1994, evaluation of the WID's safety and health program. The team's evaluation included review of records and over 160 interviews with managers and staff.

3.2.26 Noise Control Act of 1972
(42 U.S.C. § 4901 et seq.)

According to the policy clause in Section 2(a)(3) of the Noise Control Act of 1972, the primary responsibility for noise control is vested in state and local governments. Federal regulation is deemed essential only for commercial noise sources requiring national uniformity of treatment (e.g., aircraft noise). However, federal agencies are required to comply with federal, state, interstate, and local requirements respecting control and abatement of environmental noise ". . . to the fullest extent consistent with their authority . . . " (Section 4[a] and [b][1], [2]).

DOE facilities are required to comply with OSHA standards in 29 CFR 1910, which include the Occupational Noise Exposure standards in 29 CFR 1910.95. Any WIPP facility noise sources that exceed these standards have been mitigated (e.g., noise dampers have been installed in the WIPP facility underground air exhaust fans). There are no noise sources at the WIPP facility that could affect the general public.

3.2.27 Bald and Golden Eagle Protection Act
(16 U.S.C. § 668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to capture, kill, molest, or disturb these eagles, their nests, or their eggs anywhere in the United States. A permit must be obtained from the U.S. Department of the Interior to relocate a nest that interferes with resource development or recovery operations. The Act potentially applies to the WIPP facility because there is a possibility that these birds could be present on facility lands.

Surveys to identify raptor nests on the WIPP facility lands since 1985 have thus far failed to locate any bald or golden eagle nests near operational activities. Through the Cooperative Raptor Research and Management Program (CRRMP) at the WIPP facility the DOE will continue to monitor for raptor nests on WIPP lands and near operational buildings.

3.2.28 Migratory Bird Treaty Act (MBTA)
(16 U.S.C. § 703 et seq.)

The Migratory Bird Treaty Act is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. The Act stipulates that it is unlawful to indiscriminately ". . . kill . . . any migratory bird." It regulates the harvest of

3.2.28 Migratory Bird Treaty Act (MBTA) (continued)

migratory birds by specifying the mode of harvest, hunting seasons, and bag limits. Although the WIPP facility is not located within a major migration corridor, there are migratory birds present on WIPP facility lands. As required by the MBTA, the DOE will consult annually with the U.S. Fish and Wildlife Service with respect to impacts on migratory birds from the hunting activities permitted on WIPP facility lands.

3.2.29 National Defense Authorization Act - Fiscal Year 1989

The DOE has contracted the New Mexico Institute of Mining and Technology (NMIMT) to conduct independent reviews of the health and safety aspects of the design, construction, and operations of the WIPP facility, as required by the National Defense Authorization Act of 1989. The Environmental Evaluation Group (EEG) at the Institute performs the reviews. The DOE will cooperate, as appropriate, with the EEG reviews of health and safety practices at the WIPP facility.

3.2.30 Protection and Enhancement of Environmental Quality
(Executive Order 11514, as amended by Executive Order 11991)

Executive Order 11514 directs federal agencies to perform the following:

- Monitor, evaluate, and control activities so as to protect and enhance the quality of the environment.

- Review statutory authority, regulations, policies, and procedures in order to identify any deficiencies or inconsistencies that limit compliance with the NEPA.

- Develop procedures to ensure the public is informed of federal programs with environmental impact.

- Ensure that information regarding existing or potential environmental problems brought to light by research, development, demonstration, test, or evaluation activities are made available to federal agencies, states, counties, municipalities, institutions, and other appropriate entities.

- Comply with statutory authority, regulations, policies, and procedures in order to identify any deficiencies or inconsistencies that limit compliance with the NEPA.

3.2.30 Protection and Enhancement of Environmental Quality (continued)

The DOE complies with the CEQ regulations and public disclosure requirements by preparing NEPA documentation on WIPP Project activities as necessary. The DOE also conducts continuing, comprehensive environmental monitoring programs at the WIPP site.

3.2.31 Federal Compliance with Pollution Control Standards (Executive Order 12088)

Executive Order (EO) 12088 advises the director of each federal agency to ensure that all necessary actions are taken for the prevention, control, and abatement of environmental pollution. Each agency is responsible for compliance with applicable pollution control standards established by such statutes as the CWA, the CAA, the AEA of 1954, and others. Each agency must submit an annual plan for the control of environmental pollution at its facilities. This EO mandates that the DOE control pollution at the WIPP facility.

The *Waste Minimization and Pollution Prevention Awareness Plan* was updated on May 31, 1994. This plan is reviewed annually and updated at least every three years. Pollution prevention awareness guidance is contained in the *Resource Conservation and Recovery Act Compliance Manual* (WP 02-6, 02-7) and its implementing procedures, as well as in the *Environmental Compliance Manual* (WP 02-5). These environmental compliance manuals are currently being revised to incorporate elements of the Waste Minimization and Pollution Prevention Awareness Program.

The WIPP has developed a central inventory database to track the type and quantity of hazardous materials on site. The software for the inventory database was installed in December 1993. In 1994, WIPP inventory data were entered in the database. Currently, inventory is performed on a quarterly basis.

3.3 Other Significant Accomplishments and Ongoing Compliance Activities for Calendar Year 1994

3.3.1 Environmental Leadership Program

A proposal for the WIPP's inclusion in the EPA's Environmental Leadership Program (ELP) was submitted to EPA on September 21, 1994. The ELP is designed to recognize and reward facilities that develop innovative environmental management systems and thereby commit to achieving notable compliance and pollution-prevention results. The ELP pilot project phase will help EPA design a

3.3.1 Environmental Leadership Program (continued)

full-scale leadership program. The ELP will also serve as a vehicle for analyzing the EPA's audit policies and voluntary disclosure approaches. The program has the potential to not only build and strengthen liaisons among the EPA, the states, and the regulated community, but to implement new environmental performance measures that foster employee and community involvement.

3.3.2 Environmental Compliance Assessment Program (ECAP)

The ECAP plays a major role in the overall program for environmental protection activities at the WIPP. The ECAP was developed to determine if impactive or potentially impactive facility activities protect human health and the environment and if these activities are in compliance with applicable federal, state, and local requirements; with permit condition/requirements; and with best management practices. This program provides a comprehensive system, not only to assess compliance with applicable environmental statutes and requirements at the WIPP, but also to identify operationally feasible and environmentally sound corrective action measures for nonconformances or observations identified. The ECAP is designed to address five compliance assessment processes: (1) environmental compliance appraisals; (2) environmental audits; (3) independent review group evaluations; (4) environmental event evaluations; and (5) environmental compliance status tracking and reporting process.

During 1994, 21 assessments were conducted. Some of the assessed areas included: RCRA Training, Satellite Accumulation Areas, Equipment Inspections, New Mexico Special Waste, OSHA Bloodborne Pathogens, Diesel Generator Permit, HAZMAT Inventories, Waste Characterization, Construction Landfill, Hazardous Waste Generator Requirements, and New Mexico Discharge Plan and Water Supply Regulations.

Table 3-1
Compliance Status with Major Environmental Regulations
Applicable to the WIPP Project

Statute/Regulation	Status
Atomic Energy Act	No radioactive waste was received during CY 1994.
Clean Air Act	NESHAP data package and letter of notification submitted. No monitoring/reporting required until after receipt of waste.
Clean Water Act	Quarterly inspections of best management practices to comply with (stormwater retention basins) NPDB storm water general permit (NMR00A021).
Comprehensive Environmental Response, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act	No Land Disposal Units (LDUs) exist at the site. No CERCLA site cleanup required. Reports filed as required under SARA for hazardous substances are maintained onsite.
Endangered Species Act	Permits to collect biological samples and to band nonendangered species of raptors are maintained.
Federal Land Policy and Management Act	An MOU between the DOE and the BLM was issued in July 1994. This MOU outlines the responsibilities the BLM and the DOE have with regard to land use management for the withdrawal area. The WIPP Land Management Implementation Plan was issued August 1994.
Federal Insecticide, Fungicide, and Rodenticide Act	All use of pesticides is approved by Industrial Safety and is performed by subcontractors.
Hazardous Materials Transportation Act	Hazardous wastes to be sent offsite are reviewed to ensure compliance with HMTA.
National Environmental Policy Act (as supplemented by DOE Order 5440.1E, and 10 CFR 1021)	The 1994 *Annual Mitigation Report for the Waste Isolation Pilot Plant* (NEPA ID# WIP:94:0001) was issued July 1994. This provides a status of the commitments made in the WIPP's Records of Decision. A new computer-based NEPA training module was released for use in December 1994. Purchase requisitions and engineering work packages which initiate changes and modifications to the WIPP facility continue to be reviewed for potential environmental impacts.
National Historic Preservation Act	Activities requiring excavation in previously undisturbed areas are surveyed by licensed, permitted archaeologists. Required reports are submitted to the New Mexico State Historic Preservation Officer.

Table 3-1
Compliance Status with Major Environmental Regulations
Applicable to the WIPP Project

Statute/Regulation	Status
New Mexico Air Quality Control Act	The New Mexico Air Quality Bureau issued Air Quality Permit 310-M-2 on December 7, 1993. On February 26, 1994, the WIPP completed the emission monitoring requirements established in the permit. With the submittal of the *Final Compliance Sampling Report* on March 28, 1994, the DOE has fulfilled all monitoring and reporting requirements identified in the permit. New Mexico does not yet have primacy for NESHAP for radionuclide emissions from DOE facilities. New Mexico Hazardous Waste Management Regulations See "Resource Conservation and Recovery Act." NMED does not yet have primacy for all areas by the RCRA.
New Mexico Radioactive Materials Act	No radioactive wastes had been received at the WIPP in CY 1994.
New Mexico Water Quality Act	The DOE submits quarterly discharge monitoring reports to the NMED Groundwater Quality Bureau to comply with the requirements of the WIPP Discharge Plan, DP-831.
New Mexico Wildlife Conservation Act	See "Endangered Species Act."
Resource Conservation and Recovery Act	*Hazardous-waste generator compliance:* All site-generated hazardous wastes were transported off-site within the 90-day accumulation period. *No-Migration Determination compliance:* The fourth annual report was submitted to EPA on November 14, 1994. *Mixed-waste management:* On January 13, 1994, the DOE formally requested that the NMED allow the DOE to modify the RCRA permit application to reflect disposal operations. In September 1994, the NMED ordered the submittal of a complete revised permit application by May 31, 1995. DOE has submitted Chapters B, D, E, F, G, H, I, J & K to the NMED for their review. *Underground Storage Tanks:* Annual registration fee paid. Maintenance of inventory control records continues.
Toxic Substances Control Act	Procurement of asbestos-/PCB-containing materials not allowed. Other portions of TSCA not applicable.

Table 3-2

DOE Orders Affecting the WIPP Environmental Program

ORDER NO.	DATE	TITLE	ANNOTATION
DOE 5400.1	11/09/88 Change 1-06/29/90	General Environmental Protection Program	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for ensuring compliance with federal and state environmental protection laws and regulations, federal executive orders, and internal department policies.
DOE 5400.2A	01/31/89	Environmental Compliance Issue Coordination	Establishes DOE requirements for coordination of significant environmental compliance issues.
DOE 5400.4	10/06/89	Comprehensive Environmental Response, Compensation, and Liability Act Requirements	Establishes basic requirements for implementation of the Superfund at DOE facilities.
DOE 5400.5	02/08/90 Change 2-01/07/93	Radiation Protection of the Public and the Environment	Establishes standards and requirements for operations of the DOE and DOE contractors with respect to protection of the public and the environment against undue risk from radiation.
DOE 5440.1E	11/10/92	National Environmental Policy Act	Establishes DOE policy for implementation of the National Environmental Policy Act of 1969 (PL 91-190).
DOE 5480.1B	03/27/90 Change 5-05/10/93	Environment, Safety, and Health Program for DOE Operations	Establishes overall framework of program requirements for safety, environmental, and health protection.
DOE 5480.3	07/09/85	Safety Requirements for the Packaging of Fissile and Other Radioactive Materials	Establishes requirements for packaging and transportation of radioactive materials for DOE facilities.
DOE 5484.1	02/24/84 Change 7-10/17/90	Environmental Protection, Safety, Health Protection Information Reporting Requirements	Establishes requirements and procedures for reporting information having environmental protection, safety, or health significance to DOE operations.
AL 5484.1	08/23/82 Change 1-10/24/86	Environmental Protection, Safety and Health Protection Information Reporting Requirements	Albuquerque Operations Office implementation of 5484.1.

Table 3-2

DOE Orders Affecting the WIPP Environmental Program
(continued)

ORDER NO.	DATE	TITLE	ANNOTATION
DOE 5480.23	04/30/92 Change-1 3/10/94	Nuclear Safety Analysis Reports	To establish uniform requirements for the preparation and review of safety analyses of DOE operations which include the following: identification of hazards, their elimination or control, assessment of the risk, and documented management authorization of their operation.
DOE 5482.1B	9/23/86 Change-5 05/10/93	Environmental, Safety and Health Appraisal Program	To establish the Environmental Protection, Safety, and Health (ES&H) appraisal program for the DOE.
DOE 5500.3A	04/30/91 Change 1- 02/27/92	Planning, and Preparedness, for Operational Emergencies	To establish requirements for the development of DOE site-specific emergency plans and procedures for radiological emergencies occurring in existing or planned DOE reactors and non-reactor nuclear facilities. It also requires that comprehensive emergency actions are planned, coordinated, and implemented to respond effectively to the onsite and offsite consequences of a radiological emergency at these facilities, and it provides for appropriate coordination between DOE and offsite officials to ensure the protection of onsite personnel, public health and safety, and the environment.
DOE 5700.6C	08/21/91	Quality Assurance	To provide DOE policy, set forth principles, and assign responsibilities for establishing, implementing, and maintaining programs of plans and actions to ensure quality achievement in DOE programs.
DOE 5820.2A	09/26/88	Radioactive Waste Management	Establishes policies and guidelines by which DOE manages radioactive waste, waste byproducts, and radioactively contaminated surplus facilities.
DOE 6430.1A	04/06/89	General Design Criteria	To provide general design criteria for use in the acquisition of DOE facilities and to establish responsibilities and authorities for the development and maintenance of these criteria.

Table 3-3

Summary of Agreements Between the DOE and the State of New Mexico That Affect the WIPP Environmental Program

Stipulated Agreement on Civil Action No. 81-0363 JB - This agreement, approved by the U.S. District Court proceedings, held in abeyance in the lawsuit against the DOE by the State of New Mexico, was executed on July 1, 1981. The eight-page agreement assures that a binding, enforceable "consultation and cooperation" agreement will be entered into by the DOE and the state, and that the DOE will make a "good faith effort" to resolve certain state offsite concerns (which are covered in the Supplemental Stipulated Agreement). The Stipulated Agreement also addresses a number of additional studies and experiments to be conducted by the DOE for the Site Preliminary and Design Validation Phase of the WIPP facility. This agreement was signed by Jeff Bingaman (Attorney General, State of New Mexico) and Myles Flint (Attorney, U.S. Department of Justice), and was issued July 1, 1981, by Juan G. Burciaga (U.S. District Judge, District of New Mexico).

Agreement for Consultation and Cooperation -- Usually referred to as the "C&C Agreement," this agreement is contained in Appendix A to the Stipulated Agreement. It affirms the intent of the Secretary of Energy to consult and cooperate with New Mexico with respect to state public health and safety concerns. It was signed in July 1981 by Bruce King (Governor, State of New Mexico) and James B. Edwards (Secretary, U.S. Department of Energy).

Working Agreement for Consultation and Cooperation, Appendix B, Article IV, Revision I -- This agreement, Appendix B to the Stipulated Agreement, identifies in Article IV over 60 "key events" and "milestones" in the construction and operation of the WIPP facility that must be reviewed by the state before they are commenced. Many environmental items are included. It was signed in March 1983 by Robert McNeill (Chairman, Radioactive Waste Task Force), and R. G. Romotowski, (Manager, Albuquerque Operations Office, U.S. Department of Energy). (Article IV of the Working Agreement was revised on April 8, 1983).

Supplemental Stipulated Agreement Resolving Certain State Off-Site Concerns Over WIPP -- This agreement dated December 27, 1982, addresses five state concerns including the need for state "verification" of the WIPP Environmental Monitoring Program. The concerns addressed are: state liability for a nuclear incident, emergency response preparedness, transportation monitoring of the WIPP facility waste, the WIPP facility environmental monitoring by the state, and upgrading of state highways. It was signed in December 1982 by Bruce King (Governor, State of New Mexico) et al., and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

First Modification to the July 1, 1981, Agreement for Consultation and Cooperation on WIPP by the State of New Mexico and the U.S. Department of Energy -- This modification was signed November 30, 1984, wherein the DOE and the state agree to address certain concerns of the state regarding: (1) the specific mission of the WIPP Project, (2) a demonstration of retrievability prior to waste emplacement, (3) post-closure control and responsibility, (4) completion of certain additional scientific testing and reports, (5) compliance with applicable federal regulatory standards for waste repositories, and (6) a program for encouraging and reporting on the hiring of New Mexico residents at the WIPP Project. It was signed in November 1984 by Joseph Goldberg (Secretary, Health and Environment Department, State of New Mexico), and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Second Modification to the July 1, 1981, Agreement for Consultation and Cooperation on the WIPP by the State of New Mexico and the U.S. Department of Energy -- Signed August 4, 1987, wherein the DOE and the state agree to address certain concerns of the state regarding: (1) surface and subsurface mining and drilling after closure of the WIPP site, (2) the disposal of salt tailings at the WIPP site, and (3) compliance with U.S. Environmental Protection Agency, U.S. Department of Transportation, and U.S. Nuclear Regulatory Commission regulations. It was signed in August 1987 by Garrey Carruthers (Governor, State of New Mexico) et al., and R. G. Romotowski, (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Table 3-3
Summary of Agreements Between the DOE and the State of New Mexico That Affect the WIPP Environmental Program
(continued)

1988 Modification to the Working Agreement of the Consultation and Cooperation Agreement Between the U.S. Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant – This modification deleted the sorbing tracer test from the list of required reports and substituted additional tests. In addition, the state is allowed to operate a fixed-air sampler in the mine ventilation effluent air stream. It was signed in March 1988 by Kirkland Jones (Deputy Director, New Mexico Environmental Improvement Division, State of New Mexico) et al., and R. G. Romotowski (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Environmental Oversight and Monitoring Agreement – This agreement states that the DOE will provide additional technical and financial support for state activities in environmental oversight, monitoring, access, and emergency response to ensure compliance with applicable federal, state, and local laws at several DOE facilities including the WIPP facility. It was signed in October 1990 by Garrey Carruthers (Governor, State of New Mexico; Dennis Boyd (Secretary, Health and Environment Department), and Bruce G. Twining (Manager, Albuquerque Operations Office, U.S. Department of Energy).

Site-Specific Protocol for Implementation of the Environmental Oversight and Monitoring Agreement – Signed October 23, 1992, this protocol describes the site-specific protocol for day-to-day activities involving the NMED and the DOE contract personnel stationed at the WIPP. This protocol is a result of the "Environmental Oversight and Monitoring Agreement of 1990" between the State of New Mexico and the DOE. It is designed within the context of the unique nature and purpose of the WIPP.

Table 3-4
Active/Pending Permits for the Waste Isolation Pilot Plant During 1994

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	1994 Permit Status
Department of the Interior, Bureau of Land Management	Right-of-Way for Water Pipeline	NM53809	8/17/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for the North Access Road	NM55676	8/24/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Railroad	NM55699	9/27/83	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Dosimetry and Aerosol Sampling Sites	NM63136	7/31/86	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Seven Subsidence Monuments	NM65801	11/7/86	None	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Aerosol Sampling Site	NM77921	8/18/89	8/18/2019	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Ten Raptor Nesting Platforms	NM82212	9/12/89	12/13/2019	Active
Department of the Interior, Bureau of Land Management	Right-of-Way for Survey Monument Installation	NM82245	12/13/89	12/13/2019	Active
Department of the Interior, Bureau of Land Management	Approval to Drill 2 new test wells on existing pads at P-1 and P-2	None	9/18/86	None	Active
Department of the Interior, Bureau of Land Management	Free Use Permit for Caliche	NM-FU3-91183	7/27/94	7/27/95	Active
New Mexico Environment Department	Open Burning Permit to train fire control Crews	None	3/1/94	3/1/95	Active
New Mexico Environment Department	Operating Permit for two backup generators	310-M-2	12/7/93	None	Active

Table 3-4

Active/Pending Permits for the Waste Isolation Pilot Plant During 1994
(continued)

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	1994 Permit Status
New Mexico Environment Department	Submittal of Part B RCRA Permit Application		Submitted to the NMED and EPA Region VI on 2/26/92 and on 2/27/92. Revisions were delivered to the NMED on 3/4/92 and 1/27/93.		NMED declared permit administrat-ively complete 7/22/92. Draft permit issued 8/24/93. Public comment period was held open to 7/14/94.
New Mexico Environment Department	Acknowledgement of Notification of Hazardous Waste Activity	NM4890139 088	1/88 Latest report delivered on 2/28/92	None - Contingent upon delivery of biennial report	Active
New Mexico Department of Game and Fish	Individual Banding	1,961.00	4/1/94	3/31/95	Active
New Mexico Department of Game and Fish	Master Collecting	1,894.00	4/5/94	3/31/95	Active
New Mexico Department of Game and Fish	Concurrence that WIPP construction activities will have no significant impact on State-listed threatened or endangered species	None	5/26/89	None	Active
U.S. Department of the Interior, Fish and Wildlife Service	Master Personal Banding	22,478.00	5/19/93	6/30/95	Active
U.S. Department of the Interior, Fish and Wildlife Service	Concurrence that WIPP construction activities will have no significant impact on Federally-listed threatened or endangered species	None	5/29/80	None	Active

Table 3-4

Active/Pending Permits for the Waste Isolation Pilot Plant During 1994
(continued)

Granting Agency	Type of Permit	Permit Number	Granted/ Submitted	Expiration	1994 Permit Status
New Mexico Department of Finance and Administrative Planning Division, Historic Preservation Bureau	Concurrence that the DOE Archaeological Resources Protection Plan is adequate to mitigate any adverse impacts upon cultural resources resulting from construction of the WIPP facility	None	7/25/83	None	Active
U.S. Environmental Protection Agency	Notification of the presence of 2 Underground Storage Tanks	None	4/15/86	None	Active
U.S. Environmental Protection Agency	New Mexico NPDES Storm Water General Permit	NMR00 A021	12/31/92	12/31/97	Active
New Mexico Commissioner of Public Lands	Right-of-Way for High Volume Air Sampler	RW-22789	10/3/85	10/3/2020	Active

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CHAPTER 4

ENVIRONMENTAL PROGRAM INFORMATION

Chapter 4
Environmental Program Information

The WIPP's policy is to conduct its operations in a manner that complies with all applicable environmental laws and regulations.

4.1 Environmental Monitoring Plan (EMP)

The WIPP's Environmental Monitoring Plan outlines a program that monitors a comprehensive set of parameters to detect and quantify present and future environmental impacts. Nonradiological portions of the plan focus on the immediate area surrounding the site.

The goal of the EMP is to identify what impacts may exist from the WIPP on the local ecosystem. Evaluation of the severity, geographic extent, and environmental significance of these impacts is important to the mission of the facility and future research. Although the WIPP has performed a detailed study of these impacts, additional samples will be collected and analyzed to investigate and explain trends or anomalies that may have a bearing on environmental impacts. The EMP sampling schedule is provided in Table 4-1, page 4-6.

As recommended in DOE/EP-0023 (i.e., Corley et al. 1981) and DOE/EH-0173T, the EMP monitors levels of naturally occurring radionuclides. This surveillance includes the monitoring of world-wide fallout and fallout expected from the WIPP waste. The geographic scope of radiological sampling is based on projections of potential release pathways (see Figure 5-1, Primary Pathway Exposure model, page 5-8) and those in WIPP waste. The surrounding population centers are also monitored as sampling devices. Table 4-2, pages 4-7 through 4-8, represents the EMP analytical array.

As required by DOE Order 5400.1, the EMP is to be reviewed annually and updated every three years. The most recent EMP was updated in March 1994 (DOE/WIPP 94-024).

4.2 Baseline Data

Within the WIPP Environmental Monitoring section there are five programs currently in place: the Nonradiological Environmental Surveillance (NES), the Radiological Environmental Surveillance (RES), the Cooperative Raptor Research and Management Program, Land Management, and the WIPP Groundwater Surveillance Programs (WQSP). The purpose of these programs is to collect

4.2 Baseline Data (continued)

the data needed to detect and quantify possible impacts that construction and operational activities at the WIPP may have on the surrounding ecosystem and, when necessary, provide technical support for issues that require expertise in the disciplines of environmental science or land management. The data are used to assess impacts of WIPP operations on the environment and to demonstrate compliance with applicable standards for radiological and nonradiological programs.

Preliminary studies must be considered when evaluating environmental monitoring efforts. These preliminary studies have contributed to baseline data gathered during the construction phase, as well as the long-term monitoring programs. These studies include the following:

- WIPP Site Characterization Program - instituted in 1976 by Sandia National Laboratories (SNL) to monitor air quality, background radiation levels, and groundwater quality (Pocalujka et al., 1979; 1980a, b, c; 1981a, b; Powers et al., 1978; Lappin, 1989).

- WIPP Biology Program - began in 1975 with site characterization studies of climate, soils, vegetation, arthropods, and vertebrates (Best, 1980).

- Investigations of the Site Geohydrology - conducted by the U.S. Geological Survey (USGS) at the request of the DOE. In addition, the NRC issued a contract to Columbia University to perform a study of radionuclide mobility in the highly saline groundwaters of the Delaware Basin (USGS, 1983).

- Radiological Monitoring of Air, Water, and Biological media - conducted by the Atomic Energy Commission (ACE) before and after the Project Gnome nuclear detonation (U.S. AEC, 1962a, b, c, d).

4.3 Environmental Monitoring and Planning Activities

This section addresses significant environmental activities that occurred during CY94.

4.3.1 Waste Minimization Committee

The Waste Minimization Committee was formed in 1993 with representatives from groups generating or working with hazardous and/or large volumes of waste. The Committee prepared a Waste Minimization Charter, which outlines the Committee's responsibilities.

The Waste Minimization Committee is split into separate subcommittees to concentrate on different areas of pollution prevention. These subcommittees are the Employee Awareness, Community Outreach, Waste Assessments, and Hazardous Solvent Substitution.

In 1994, the Employee Awareness Subcommittee participated in the Six Weeks of Safety and National Quality Month. Articles were printed in the *TRU-News* periodically to educate employees on the importance of waste minimization. Another project conducted in 1994 was in conjunction with the Quality Improvement Program. Plastic reusable cups were distributed to all employees at WIPP for use in the cafeteria thereby reducing the amount of waste generated.

The Community Outreach subcommittee worked with the NMED to conduct source reduction surveys of local businesses. These source reduction surveys assisted businesses in identifying large volume waste and subsequently integrate waste minimization practices.

A Pollution Prevention Opportunity Assessment (PPOA) was conducted by the Waste Assessments Subcommittee. The PPOA Subcommittee investigated the disposal of fluorescent tubes onsite and alternatives to their disposal as hazardous waste. The PPOA was completed at the end of 1994 and awaits implementation. In addition, an informal survey was conducted on the existing recycling programs onsite to ensure that all employees had the opportunity to participate.

The Hazardous Solvent Substitution Subcommittee concentrated on products that contained extremely hazardous substances. This Subcommittee worked with the Chemical Management Committee to develop a purchase requisition sign-off system to ensure that environmentally sound products were being purchased and that excess products were used promptly.

Other waste minimization activities for 1994 include:

- Recycling of white bond paper, corrugated cardboard, and aluminum cans
- Recharging of toner cartridges
- Puncturing of aerosol cans to reduce hazardous waste volumes

4.3.1 Waste Minimization Committee (continued)

- Recycling of waste oil offsite
- Reusing cold-degreasing solvents at six solvent stations used for cleaning parts
- Reclaiming cold-degreasing solvents offsite
- Using recycled janitorial paper products exclusively
- Recycling of lead-acid batteries offsite

4.3.2 Environmental Training

Environmental training was provided to personnel associated with environmental operations at the WIPP. Training courses ranged from technical topics (e.g. RCRA sampling), to basic ES&H training. These courses were conducted both onsite by WIPP personnel and offsite by various contractors.

4.3.3 WIPP Land Management Plan

On October 30, 1992, the WIPP Land Withdrawal Act (i.e., Public Law 102-579) was signed into law by former President George Bush. The WIPP Land Withdrawal Area is comprised of 10,240 acres (4145 ha) that have been transferred from the Department of Interior to the Department of Energy.

A requirement of the Act was the preparation of a land management plan. The WIPP's *Land Management Plan* (LMP) completed in October 1993, fulfills this requirement. This plan was drafted by the DOE and the BLM in consultation with the State of New Mexico. The LMP assures that future management of the withdrawal area will be consistent with the Federal Land Policy Management Act (FLPMA), the WIPP Land Withdrawal Act, and other applicable laws. The Land Management Plan is in effect through the decommissioning phase of the WIPP facility. A separate plan for the post-decommissioning phase is required by the Act with submittal to Congress within five years from the date of enactment of the Act.

4.3.3.1 Management Goal

The goal of the LMP is to manage the withdrawal area as it has been traditionally managed and to avoid, whenever possible, placing restriction on land use. It is not the intent of the DOE to make

4.3.3 WIPP Land Management Plan (continued)

4.3.3.1 Management Goal (continued)

the withdrawal area an exclusive-use area. However, some restrictions are needed to protect the long-term integrity of the WIPP repository. During operations, the safety and security of the facility must be maintained. The Act gives the DOE the authority to restrict activities in the land withdrawal area to whatever extent the DOE deems necessary to ensure the protection of the facility, the staff, and the public.

As a complement to this land use plan, a concurrent Land Management Implementation Plan (LMIP) and a MOU, executed between the DOE and the BLM as required by the Act, were developed. The LMIP was issued August of 1994, the MOU was signed into effect July 19, 1994. The MOU outlines responsibilities of each agency with regard to requests for the use of the withdrawal area. The MOU also defines the consultation role of other land management agencies adjacent to and in the vicinity of the withdrawal, (including the State of New Mexico and other federal agencies).

Guidelines prescribed in the LMIP provide for the management and oversight of WIPP lands under the jurisdiction of the DOE, in addition to lands outside the WIPP boundary that are used in the operation of the WIPP (e.g. groundwater surveillance well pads outside the withdrawn area). The plan also provides for multiagency involvement in the administration of DOE land management actions. Accordingly, commitments contained in existing permits or agreements (e.g. MOUs) are adhered to when contemplating proposed land use actions. The LMIP provides guidelines for the comprehensive administration and execution of land use decisions to include:

- Environmental Compliance
- Safety
- Maintenance and Work Control
- Energy and Mineral Resources
- Reclamation/Environmental Restoration
- Cultural Resources
- Access/Rights of Way
- Recreation
- Security
- Wildlife
- Grazing

Table 4-1
EMP Sampling Schedule

Type of Sample	Sampling Locations	Sampling Frequency
Liquid Influent	1	Semiannual
Liquid Effluent	1	Semiannual
Airborne Effluent	8	Continuous
Meteorology	2	Continuous
Exposure Rate Meter	1	Continuous
Atmospheric Particulate	7	Weekly
Air Quality	1	Continuous (Discontinued)
Vegetation-Radioanalysis	4	Annual
Beef/Deer	2*	Annual
Game Birds	2	Annual
Rabbits	2	Annual
Soil-Radioanalysis	7	Biennial
Surface Water	8	Annual
Groundwater	14	Annual
Fish	2	Annual
Sediment	6	Biennial
Aerial Photography Salt Impact Studies	Site Wide	Annual
Surface Photography	7	Biannual
Soil Chemistry	7	Quarterly
Wildlife Survey	4	Continuous

* Or as available

CHAPTER 5

ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

Table 4-2

EMP Analytical Array

Type of Sample	Analysis
Liquid Influent	Specific Radionuclides
Liquid Effluent	Specific Radionuclides, Chemical Constituents
Airborne Effluent	Gross α, Gross β, Specific Radionuclides
Meteorology	Temperature, Wind Speed, Wind Direction, Precipitation, Dew Point, Barometric Pressure
Exposure Rate Meter	Penetrating Radiation
Atmospheric Particulates	Gross α, Gross β, TSP, Specific Radionuclide
Air Quality	O_3, CO, H_2S, SO_2, NO_x
Vegetation Radioanalysis	Specific Radionuclides
Beef	Specific Radionuclides
Game Birds	Specific Radionuclides
Rabbits	Specific Radionuclides
Soil Radioanalysis	Specific Radionuclides
Surface Water	Specific Radionuclides
Groundwater	Specific Radionuclides, Chemical Constituents
Fish	Specific Radionuclides
Sediment	Specific Radionuclides

Table 4-2
(continued)
EMP Analytical Array

Type of Sample	Analysis
Aerial Photography	Area of Land Disturbed
Salt Impact Study	
Soil Chemistry	pH, Na, Cl, Mg, Ca, K
Ecology Investigations	
Wildlife Survey	Cooperative Raptor Research and Management Program

TSS = Total Suspended Solids
TSP = Total Suspended Particulates
EC = Electrical Conductivity
pH = Hydrogen - Ion Activity

Specific Radionuclides = ^{238}Pu, $^{239/240}Pu$, ^{241}Pu, ^{233}U, ^{235}U, ^{241}Am, ^{232}Th, ^{226}Ra, ^{228}Ra, ^{210}Po, ^{210}Pb, ^{137}Cs, ^{90}Sr, ^{40}K, ^{7}Be, ^{60}Co, U_{nat} Th_{nat}

Chemical Constituents = Chloride, iron, magnesium, phenols, sodium, sulfate, pH, specific conductance, total organic carbon, total organic halogen, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate, selenium, silver, alkalinity, bromide, iodide, orthophosphate, beryllium, calcium, boron, lithium, potassium, silica, carbon tetrachloride, methalene chloride, trichloroethylene, 1,1,1 trichlorethane, freon-113, TSS, TDS

Chapter 5
Environmental Radiological Program Information

The following subsections provide a description of the various radiological programs constituting the Environmental Monitoring Program at the WIPP. The media that are analyzed radiologically are airborne particulates, soil, surface water, groundwater, and biotics.

5.1 Radioactive Effluent Monitoring

The Radioactive Effluent Monitoring Program (REMP) is described in the WIPP Environmental Monitoring Plan (EMP). This plan defines the scope of the WIPP's effluent and environmental monitoring programs during the operational life of the facility. Figure 5-1, page 5-8 illustrates the primary pathways to the public for radioactive releases from the WIPP site.

The Environmental Regulatory Guide for Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T), (DOE, 1991), requires that monitoring of liquid waste effluent streams be adequate to demonstrate compliance with dose limits in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE, 1990). This order also requires that potential sources of contaminated airborne emissions be monitored. In CY 1994 no radioactive waste was received at the WIPP site, and as a result, no effluent sampling or release data are reported in this document.

5.2 Environmental Radioactivity Monitoring

The following subsections present the monitoring results of the EMP for CY94. These results include monitored subprograms such as aerosols, ambient radiation, terrestrial radioactivity, hydrologic radioactivity, and biotic radioactivity. Table 5-1, pages 5-6 through 5-7, and figures 5-2 through 5-9 illustrate gross alpha and beta analysis of WIPP air filters conducted at the WIPP Low Level Counting Lab (LLCL). The attached appendices (A1-A6) provide analytical results from an offsite laboratory. For certain elements, there is a minor deviation from previous data reported in the *Statistical Summary of the Radiological Baseline Program for the WIPP* (DOE/WIPP 92-037). These outliers ($\geq \pm 2$ standard deviations from the mean) are denoted in Appendix A1, with an asterisk. Data inconsistencies ($<$ 5 percent) are most likely due to laboratory variables pertaining to analytical techniques. These variables are being evaluated to assist in outlier determination. Subsequent analytical data (e.g., CY 1995-1998) will provide supplementary radiological data to support and update established radiological baselines.

5.2.1 Atmospheric Radiation Baseline

During CY 1994, continuous particulate aerosol samplers operated at eight locations, three, within 1000 meters of the facility; four, at local ranches and communities; and one, as a sample control site (Figure 5-10).

The continuous aerosol samplers presently in use maintain a regulated flow rate of approximately 950 milliliters per second (two cubic feet per minute) of air through a 47-millimeter (1.9-inch) glass fiber filter. Table 5-1 depicts the 1994 quarterly average concentrations of the alpha and beta activity on the low-volume aerosol filters from each location and illustrates the mean gross alpha concentrations for all eight sampling locations. Mean gross alpha concentration shows limited fluctuation throughout the year, as illustrated in Table 5-1. These fluctuations appeared to be consistent among all sampling locations.

Gross alpha and beta measurements provide an indication of naturally occurring radionuclide concentrations or changes in a specific radionuclide concentration. These measurements are screened to ensure that important radionuclides are not overlooked when measurements are performed.

Airborne particulate sampling was initiated in July 1985. Weekly filter collections and subsequent radiochemical analyses began in early 1986, except in the Far Field location where data collection began in October 1986. Particulate filters were collected weekly at all locations in CY 1994. These filters were analyzed at WIPP's LLCL where a weekly gross alpha and beta count of each filter was completed.

Appendix A1 provides results from the radiological analysis of CY 1994 air filters.

5.2.2 Ambient Radiation Baseline

A Reuter-Stokes High Pressure Ionization Chamber (HPIC) designed to monitor low levels of gamma radiation in the environment was put into operation in May 1986. In 1988, the unit was moved to the current location at the WIPP Far Field location, which is 1000 meters northwest of the Waste Handling Building. The detector used to measure low levels of gamma radiation, a pressurized ion chamber, measures levels of radiation from 1 to 100 microroentgen per hour (μR/hr). Using the average rate of 7.4 μR/hr, the estimated annual dose is approximately 65

5.2.2 Ambient Radiation Baseline (continued)

millirem. The fluctuations noted are primarily due to calibration of the system and meteorological events (e.g., the high intensity thunderstorms that frequent this area in late summer).

A seasonal drop in ambient radiation has been observed in the first and fourth quarters of each year. As stated in previous reports, this fluctuation may be due to variations in the emission and dispersion of Radon-222 from the soil around the WIPP site. These variations can be caused by meteorological conditions, (i.e., inversions), which would slow the rate of dispersion of radon and its progeny.

5.2.3 Radiological Soil Monitoring

Radiological soil samples were collected, during CY 94, at six separate locations. A template insert allows for the collection of samples at three depths per location that includes:

1. 0 - 2 centimeters
2. 2 - 5 centimeters
3. 5 - 10 centimeters.

Each complete sample was a composite of 10 randomly selected subsamples. As illustrated in Appendix A2, data results do not indicate any unusual levels of environmental radioactivity.

5.2.4 Hydrologic Radioactivity

The hydrologic radioactivity subprogram is designed to establish characteristic radioactivity levels in surface water bodies, bottom sediments, and groundwater. The following discussion of the hydrologic program includes sampling locations, data collected, and time these data were collected during 1993. It also details refinements made to the program since the publication of the *Radiological Baseline Program Sampling Plan* (Reith and Daer, 1985).

5.2.4.1 Radiological Surface Water and Sediment Monitoring

Surface water samples were collected at 12 locations during CY 94. Of these subject locations, sediment samples were collected at 10. The data from the analysis of these samples does not indicate any unusual levels of environmental radioactivity. Analytical results from surface water and sediment samples are illustrated in Appendix A3 and A4 respectively.

5.2.4 Hydrologic Radioactivity (continued)

5.2.4.2 Radiological Groundwater Characterization

Groundwater samples were collected in accordance with the Water Quality Sampling Program (WQSP). The primary objective of the WQSP is to obtain, using rigorous field and laboratory procedures and protocols, representative groundwater data from selected wells. At each wellsite, the well is purged and the groundwater serially analyzed for specific field parameters. Once the field parameters have stabilized denoting a chemical steady state with respect to those parameters analyzed, a final groundwater sample is collected and analyzed for radionuclides. The controlling document for the WQSP is the *WIPP Water Quality Sampling Plan and Procedures Manual* (WP 02-1, Rev 2).

The primary water-bearing units being evaluated by the WQSP are the Culebra and Magenta Dolomite members of the Rustler Formation. In 1994, groundwater data were gathered at nine well locations completed in the Culebra dolomite. Water quality data were also collected from two privately owned wells in the area near the WIPP site. These two private wells provide water for area livestock. An in-depth discussion of groundwater hydrology and a figure showing well locations is presented in Chapter 7, *Groundwater Surveillance*. Results from the radiological analysis of groundwater are provided in Appendix A5.

5.2.5 Biotic Radioactivity

Biotic media used for radiologic analysis consisted of vegetation, fish, rabbit, and deer. Unusually low numbers of resident quail prompted the suspension of sampling quail, after only two specimens had been collected, until numbers increase to the degree that attrition by sampling will not adversely affect the status of the resident population.

Fish samples were collected at two locations; Brantley Lake and the Pecos River. Low population numbers of rabbits resulted in the collection of only two specimens (road kills) for analysis. Several deer, however, were killed on roads adjacent to the WIPP, thus providing adequate availability for tissue collection and subsequent analysis. Vegetation was collected at six locations that are analogous to soil sample locations.

Appendix A6 provides preliminary data regarding the radiological analysis of biotic vegetation, quail, fish, rabbits, and deer samples.

5.3 Assessment of Potential Dose to the Public

In 1994, no waste was received at the WIPP; therefore, the public could not be exposed to radiation due to WIPP operations. Documentation of naturally occurring background radiation is discussed in Chapter 5, *Environmental Radiological Program Information* and Chapter 7, *Ground Water Surveillance,* of this report.

ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

TABLE 5-1

ACTIVITY CONCENTRATIONS IN QUARTERLY AVERAGES OF THE LOW VOLUME AEROSOL FILTERS (Bq/ml)

FIRST QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	2.13 E-10	1.068E-09
Smith Ranch	1.90 E-10	1.07 E-09
Mills Ranch	2.72 E-10	1.03 E-09
WIPP Far Field	2.26 E-10	1.05 E-09
WIPP South	2.84 E-10	1.09 E-09
WIPP East (1)	2.39 E-10	1.01 E-09
Eunice	3.02 E-10	9.70 E-10
South East Control	2.11 E-10	1.00 E-09

SECOND QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	8.80 E-11	8.99 E-10
Smith Ranch	4.77 E-11	9.10 E-10
Mills Ranch	9.31 E-11	9.73 E-10
WIPP Far Field	8.06 E-11	9.16 E-10
WIPP South	9.17 E-11	9.54 E-10
WIPP East (1)	9.06 E-11	9.14 E-10
Eunice	8.30 E-11	8.13 E-10
South East Control	7.57 E-11	8.45 E-10

THIRD QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	1.52 E-10	1.07 E-09
Smith Ranch	1.20 E-10	1.04 E-09
Mills Ranch	1.69 E-10	1.11 E-09
WIPP Far Field	1.84 E-10	1.09 E-09
WIPP South	1.75 E-10	1.05 E-09
WIPP East (1)	1.56 E-10	1.05 E-09
Eunice	1.76 E-10	1.16 E-09
South East Control	1.23 E-10	9.98 E-10

TABLE 5-1
(CONTINUED)

FOURTH QUARTER 1994

LOCATION	ALPHA	BETA
Carlsbad	1.71 E-10	1.27 E-09
Smith Ranch	1.40 E-10	1.25 E-09
Mills Ranch	1.74 E-10	1.13 E-09
WIPP Far Field	1.53 E-10	1.07 E-09
WIPP South	1.72 E-10	1.16 E-09
WIPP East (1)	1.51 E-10	1.18 E-09
Eunice	3.13 E-10	5.45 E-10
South East Control	1.40 E-10	1.15 E-09

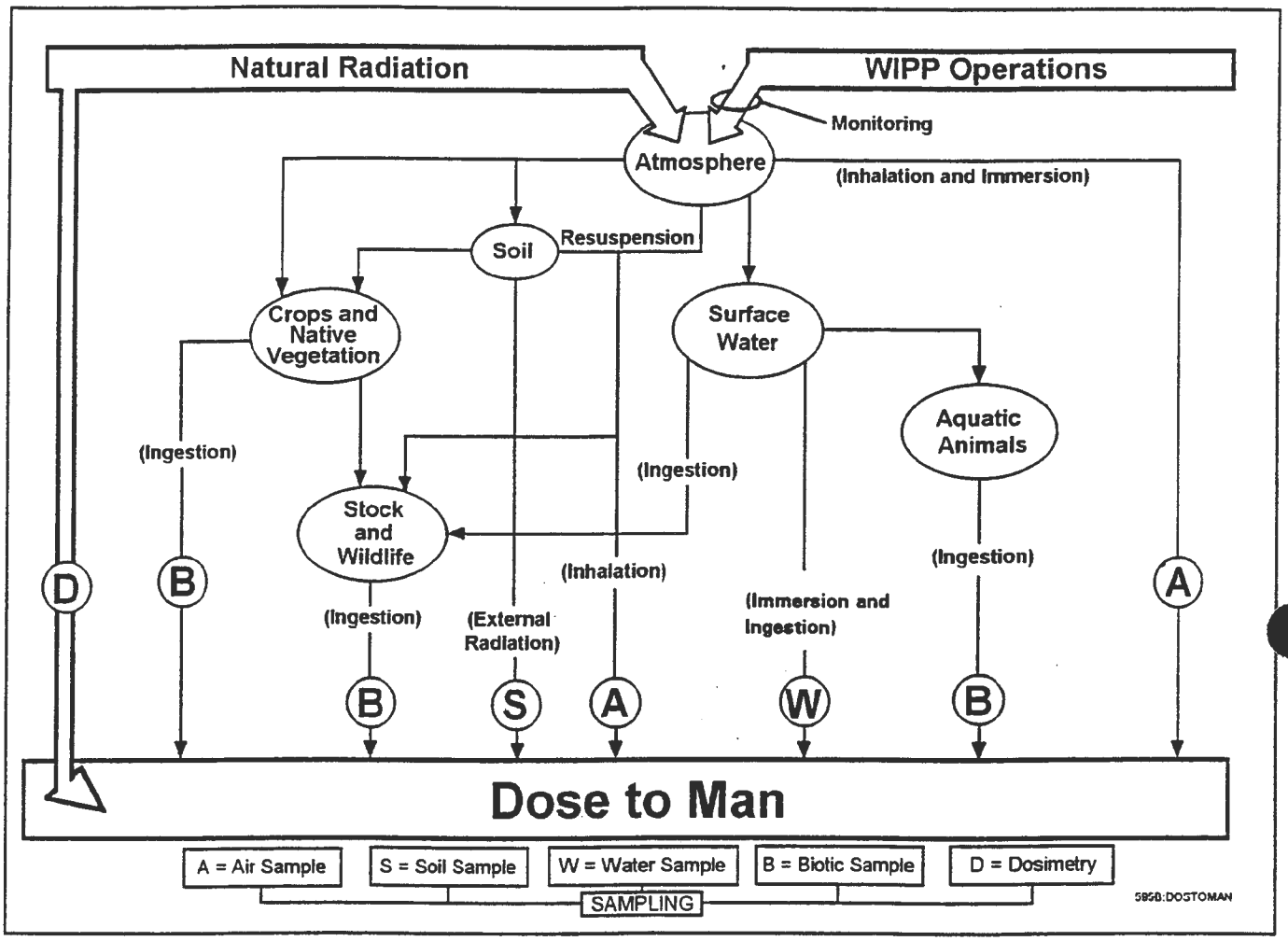


Figure 5-1
Primary Pathways to Man for Radioactive Releases from the WIPP Site

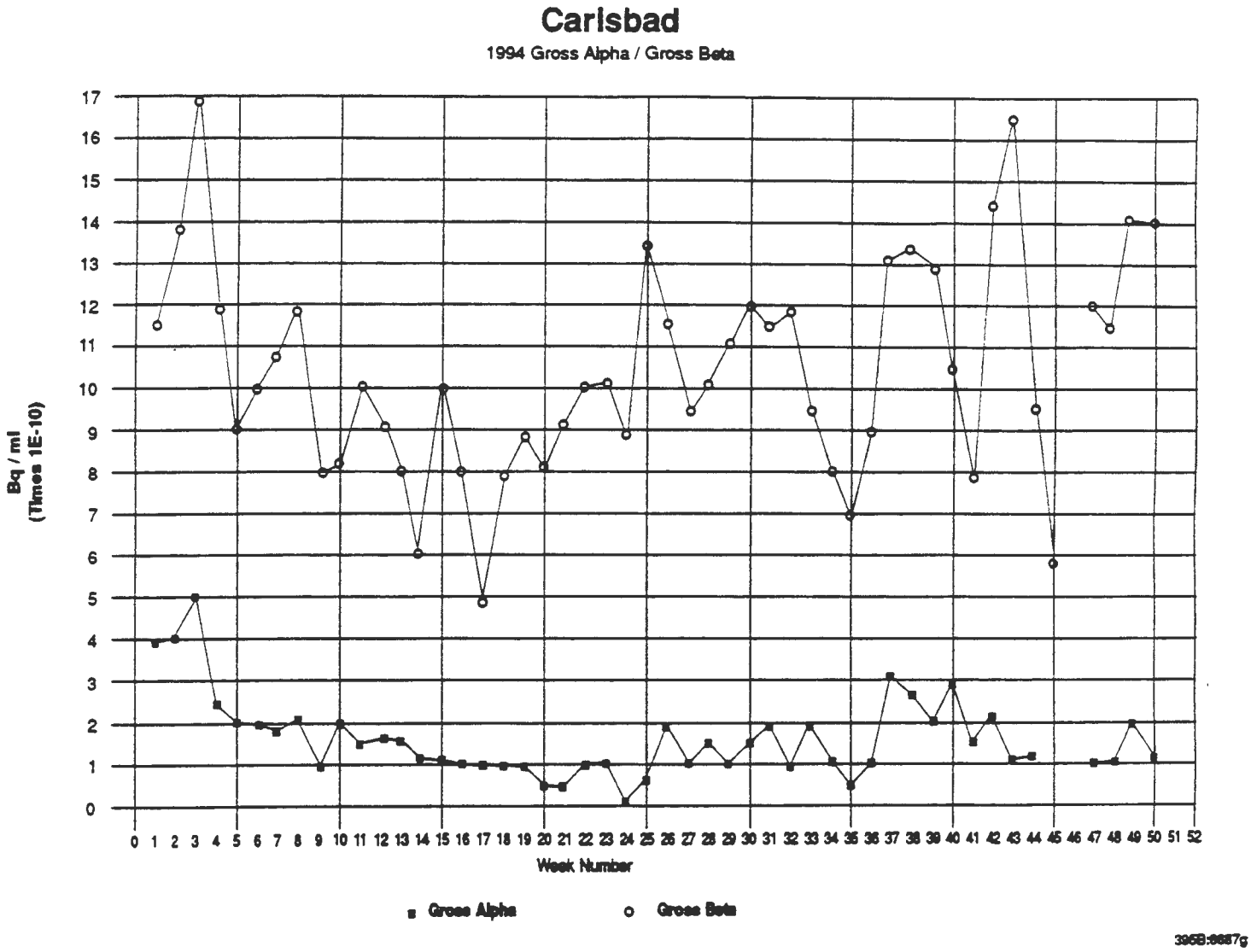


Figure 5-2
1994 Gross Alpha/Beta
Carlsbad

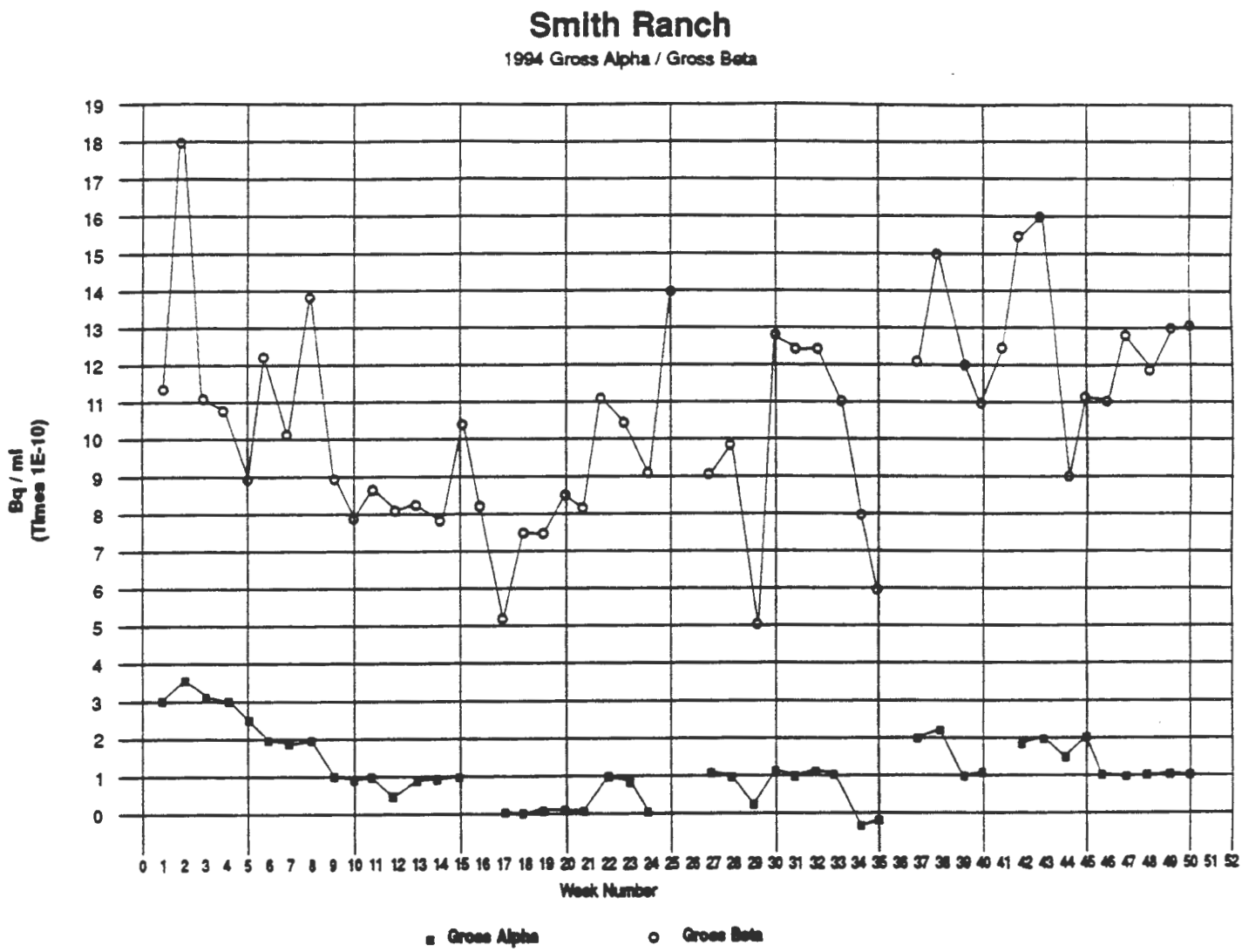


Figure 5-3
1994 Gross Alpha/Beta
Smith Ranch

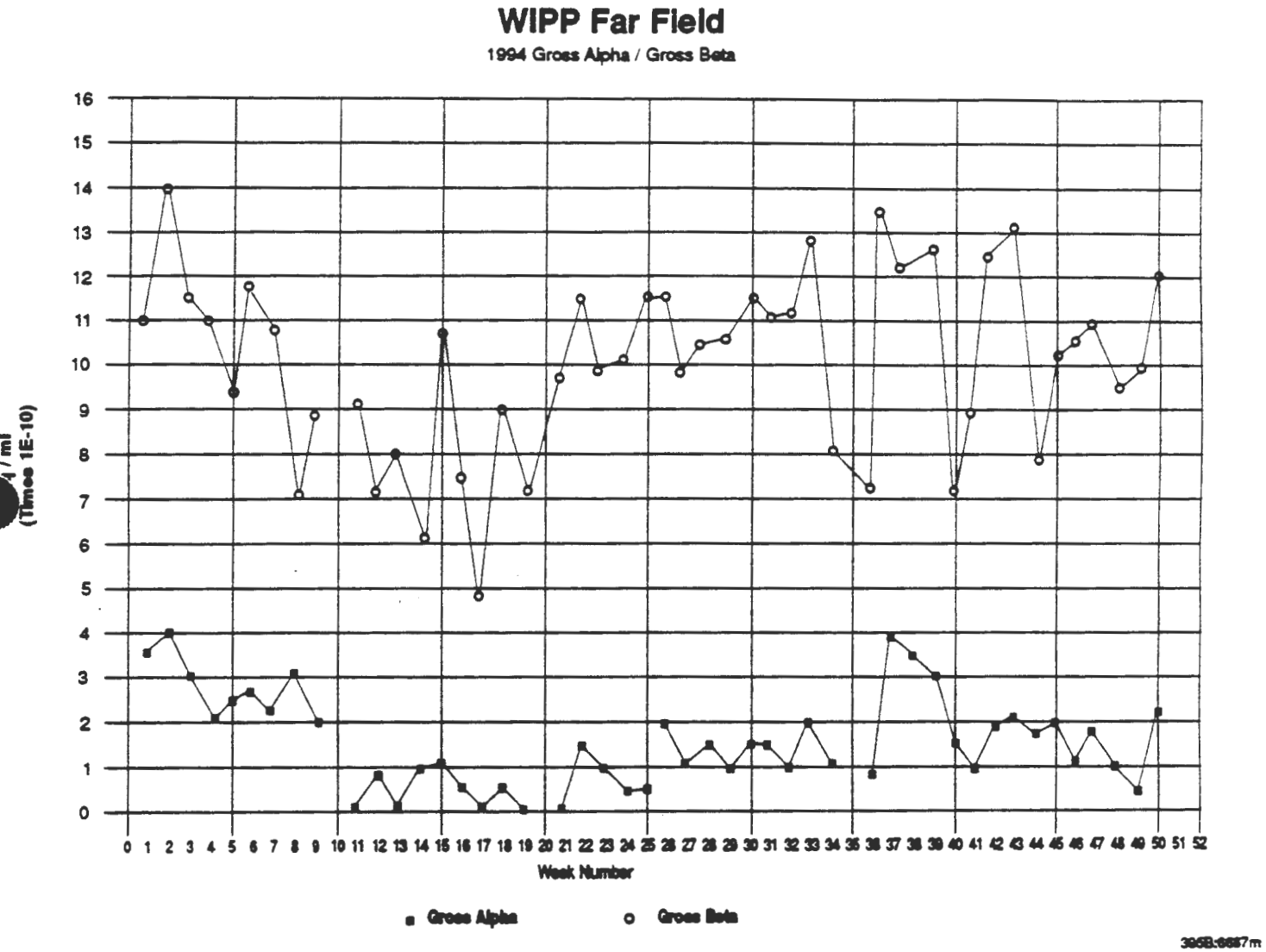


Figure 5-4
1994 Gross Alpha/Beta
WIPP Far Field

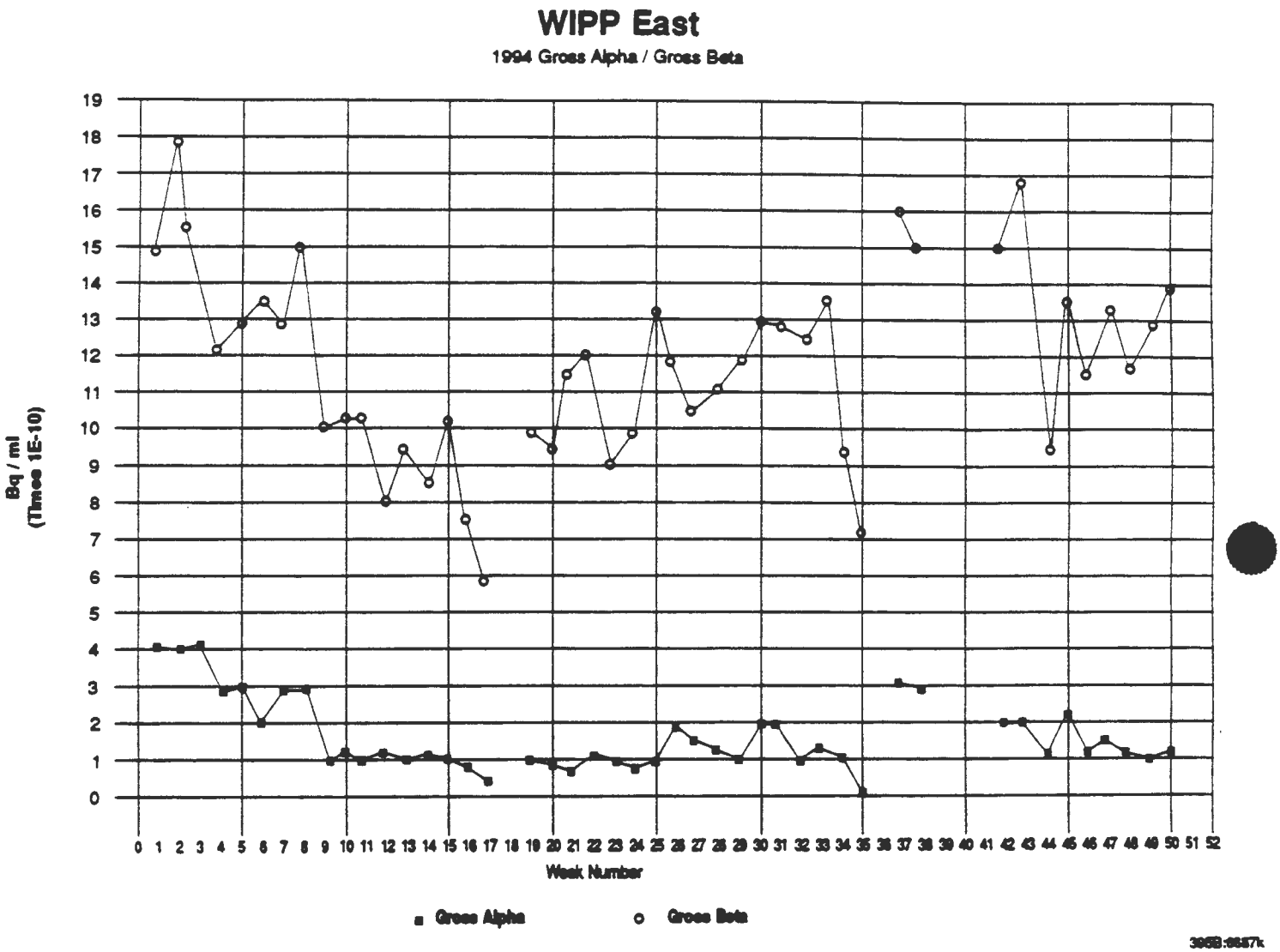


Figure 5-5
1994 Gross Alpha/Beta
WIPP East

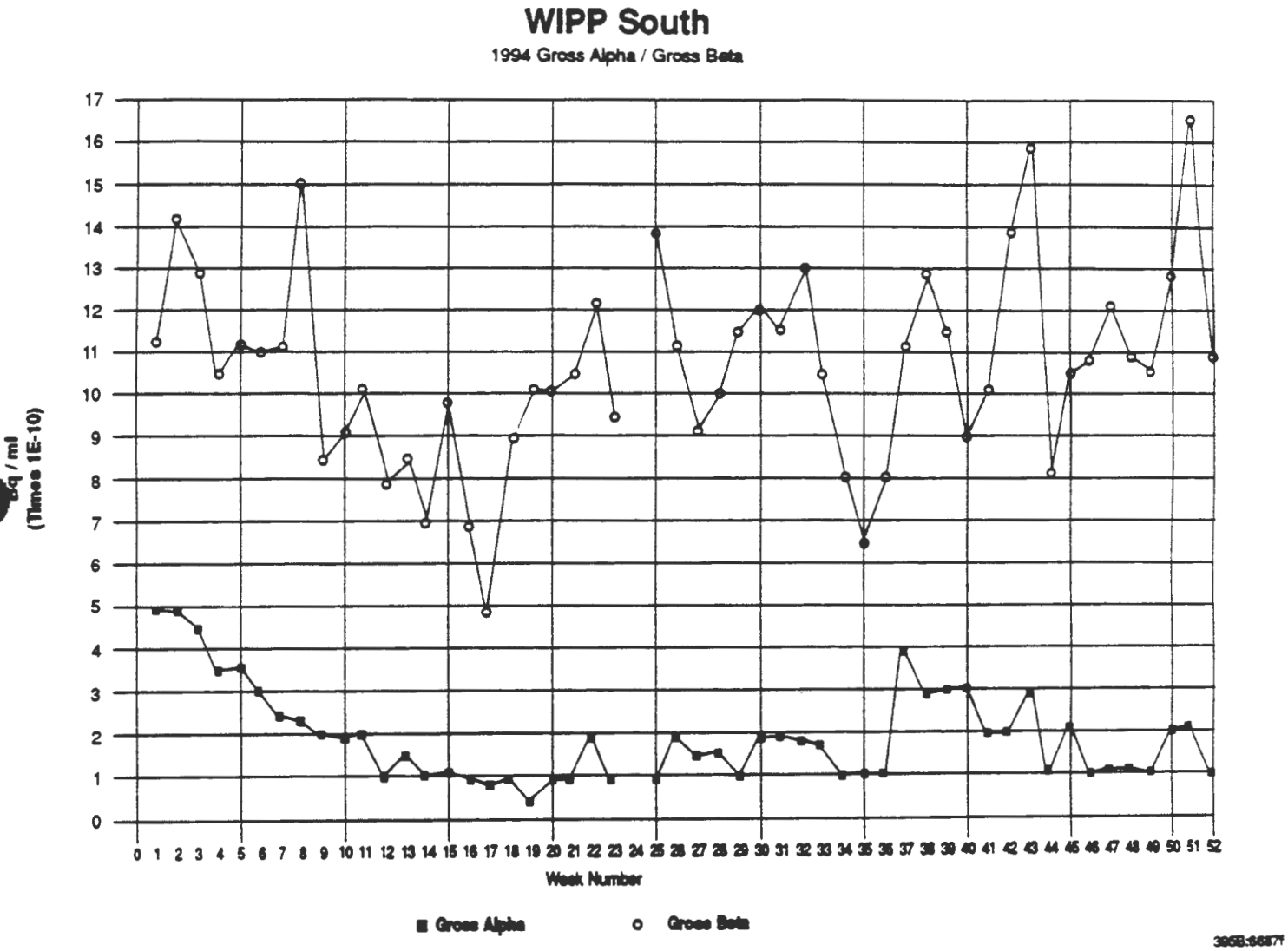


Figure 5-6
1994 Gross Alpha/Beta
WIPP South

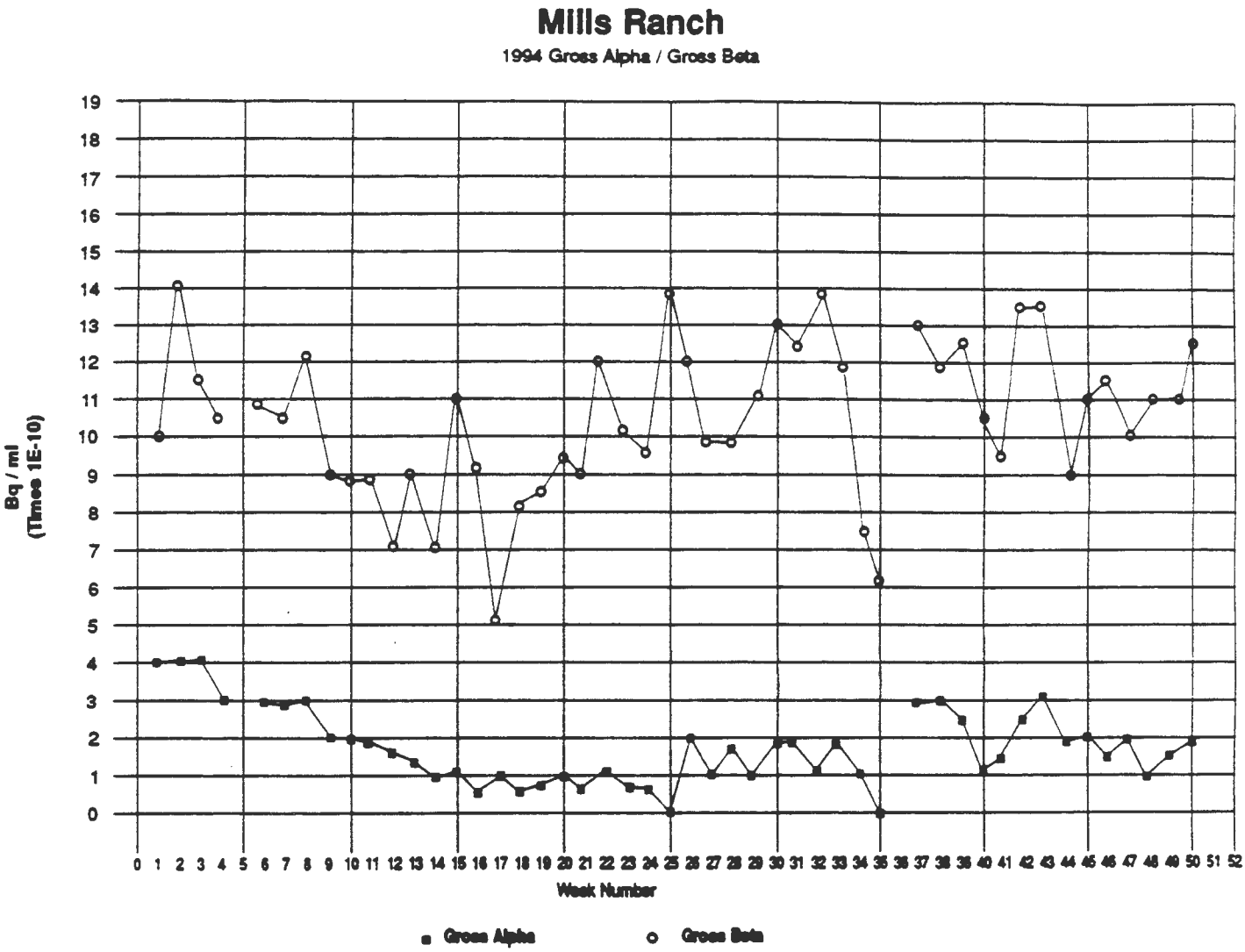


Figure 5-7
1994 Gross Alpha/Beta
Mills Ranch

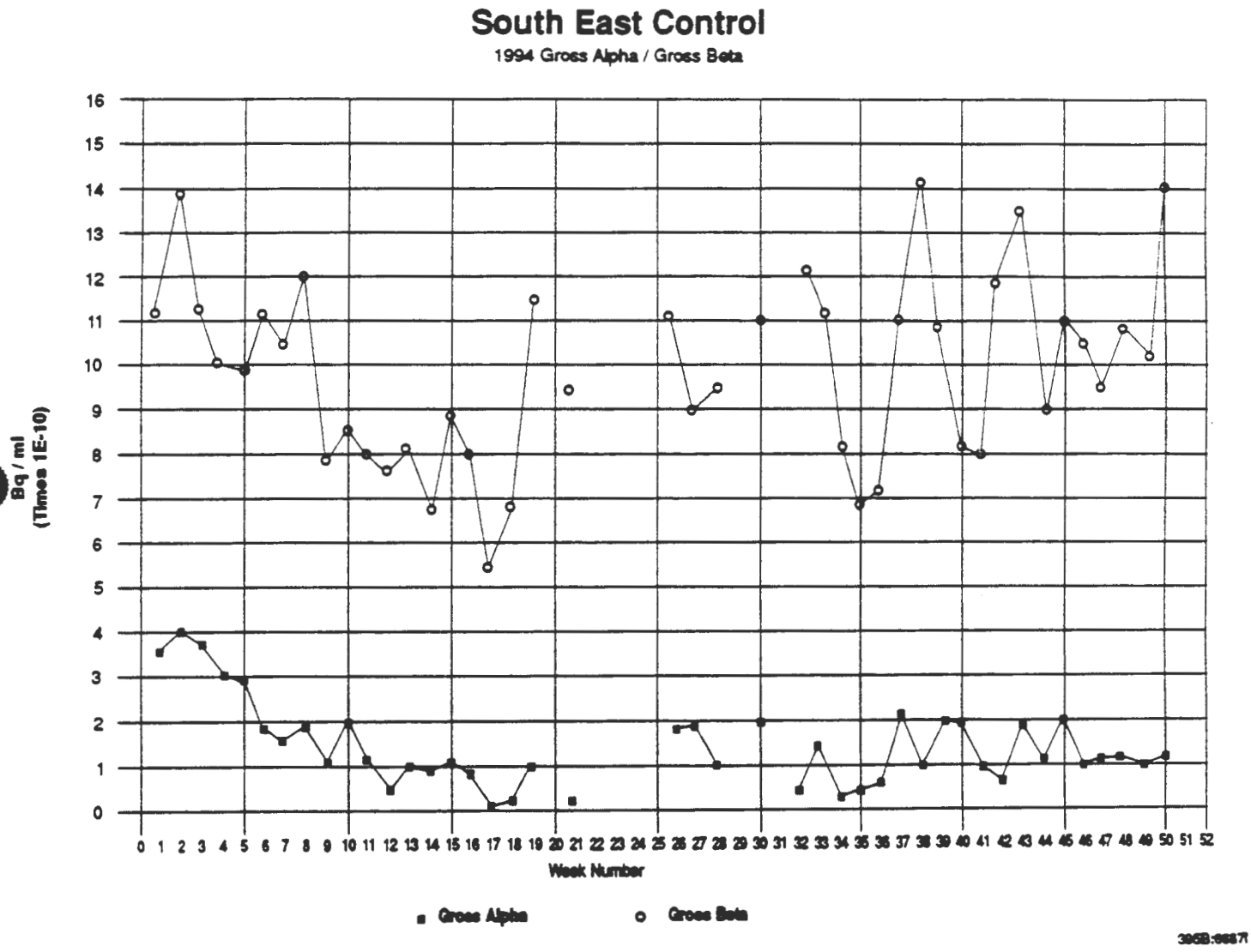


Figure 5-8
1994 Gross Alpha/Beta
Southeast Control

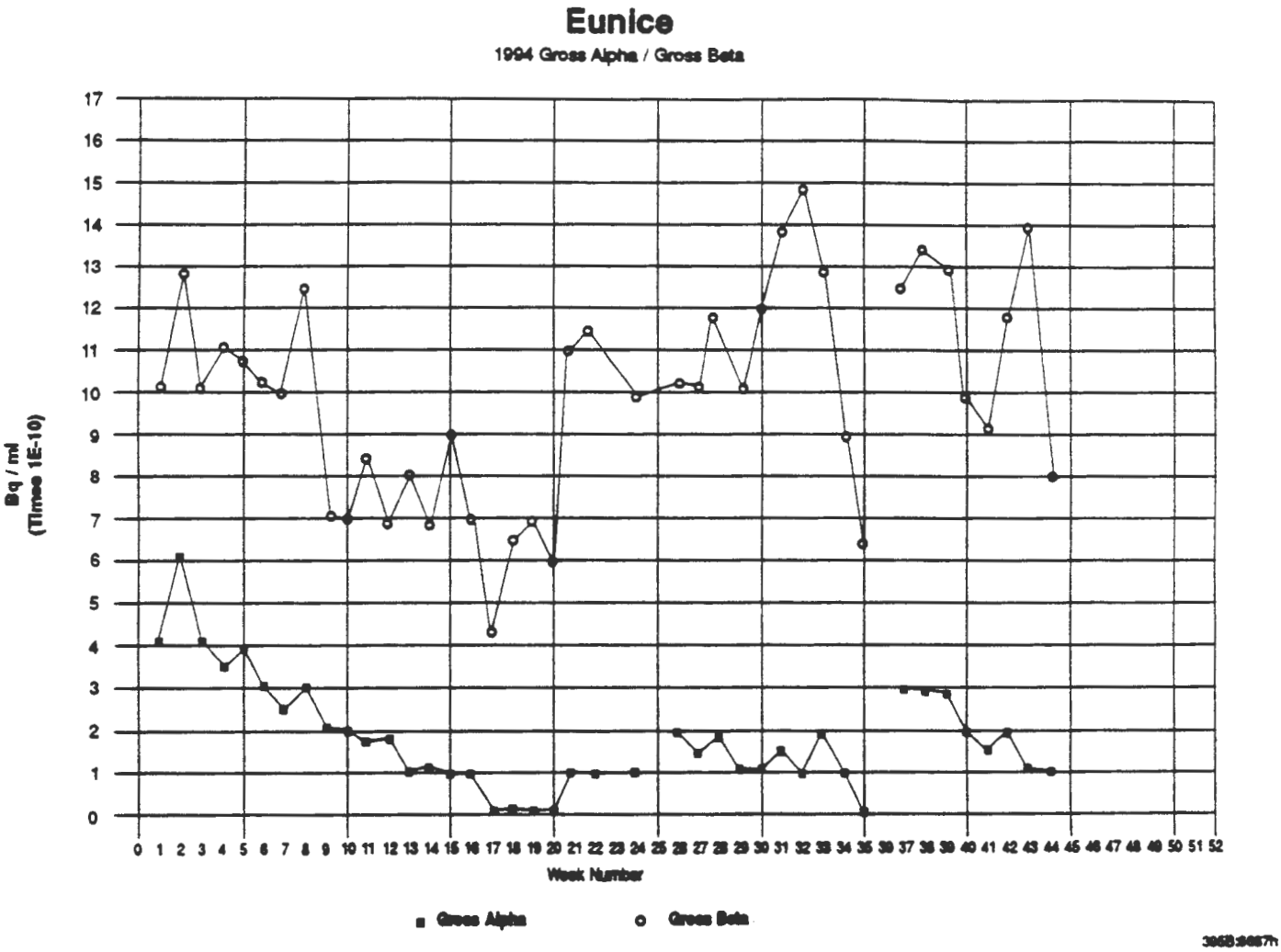


Figure 5-9
1994 Gross Alpha/Beta
Eunice

CHAPTER 6

ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

Chapter 6
Environmental Nonradiological Program Information

This chapter of the ASER presents and discusses Nonradiological Environmental Sampling (NES) data collected between January 1, 1994, and December 31, 1994. Ecological monitoring at the WIPP include the following six subprograms: meteorological monitoring, air quality monitoring, wildlife population monitoring, surface disturbance and soil monitoring, vegetation monitoring, and water quality monitoring. In addition to the NES programs, Volatile Organic Compounds (VOCs) are monitored to comply with provisions of the WIPP's current No Migration Determination (NMD) and liquid effluent monitoring is conducted in accordance with *Sewage Systems Discharge Monitoring and Compliance* (DP-831) criteria. The results of the environmental monitoring activities and discussions of significant findings are presented in this report.

6.1 Principal Functions of Nonradiological Sampling

The principal functions of the NES are to:

- Detect and quantify the impacts of construction and operational activities from the WIPP on the surrounding ecosystem.
- Continue to administer and update an ecological database for the Los Medaños Area.
- Investigate unusual or unexpected elements in the ecological databases.
- Provide environmental data that are important to the mission of the WIPP project, but which have not or will not be acquired by other programs.

6.2 Meteorology

A principle component of the NES is a primary meteorological (MET) station located 600 meters northeast of the Waste Handling Building. The main function of the MET is to generate data for modeling atmospheric conditions. The station documents standard meteorological measurements of wind speed, wind direction, and temperatures, with dew point and precipitation monitored at ground level. These parameters are measured continuously and the data are stored in the Central Monitoring System (CMS).

6.2 Meteorology (continued)

In addition to the primary meteorological station, the Atmospheric Monitoring Station (AMS) is located 1000 meters northwest of the Waste Handling Building. At the AMS a secondary meteorological station measures and records temperature and barometric pressure at ground level and wind speed and wind direction at 10 meters (30 feet).

6.2.1 Climatic Data

The mean annual temperature for the WIPP area in 1994 was 18°C (64°F). The mean monthly temperatures for the WIPP area ranged from 6°C (43°F) during January to 31°C (88°F) in June. Generally, maximum temperatures occur in June through September, while minimum temperatures occur in December through February as illustrated in Figure 6-3, page 6-15.

The first freezing day of the 1994-95 winter season occurred October 21, with 0°C (32°F). The last freezing day of the 1994-95 winter season was April 23, with a temperature of -3°C (27°F). The maximum temperature recorded was 50°C (122°F) on June 26.

The annual rate of precipitation at the WIPP site for 1994 was 16.58 cm (6.53 in), which is 7.29 cm (2.87 in) below last year's rate. The annual precipitation for 1994 was 31 percent less than that recorded for 1993 and 74 percent less than CY 1992, resulting in profound drought conditions. Figure 6-1, page 6-13, displays the monthly precipitation at the WIPP.

6.2.2 Wind Direction and Wind Speed

The predominate wind direction in the WIPP area was from the southeast sector (135°). However, winds occurring in late spring were primarily from the west. Various weather systems move through this area briefly altering the predominate southeasterly winds and sometimes resulting in violent convectional storms. Wind speed noted as calm (less than 0.5 meters per second [mps]) occurred 7 percent of the time. Winds of 1.4 through 2.7 mps were the most prevalent over 1994, accounting for 25.5 percent of the time. Figure 6-2, page 6-14, displays the annual wind data at the WIPP for CY 1994.

6.3 Environmental Photography

Surface photography was conducted at seven ecological study plots from 1984 through 1993. Photographs are used to document year-to-year surface impacts at the study plots and are archived

6.3 Environmental Photography (continued)

for future reference. The use of environmental photographs, with the exception of aerial photography, was postponed during 1994 pending reassessment. Because archival photographs showed no obvious negative impacts to the surface environment from WIPP activities, this endeavor was deferred for at least one calendar year.

6.4 Air Quality Monitoring

During CY 1994, five classes of pollutant gases are monitored continuously 1000 meters (0.6 mile) northwest of the exhaust shaft at the WIPP site. These gases are sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), hydrogen sulfide (H_2S), and oxides of nitrogen (NO, NO_2, NO_x). The data generated indicates these gases to be at the lower limit of detection--that is, below the baseline concentrations set by the State of New Mexico.

The permissible New Mexico State Standard for the gases monitored at the WIPP are listed below:

Gases	PPM	Intervals
Sulphur Dioxide (SO_2)	**0.02 ppm** **0.10 ppm**	**Annual Average** **24-hour Average**
Carbon Monoxide (CO)	**8.70 ppm**	**Per Eight Hour Average**
Ozone (O_3)	**0.06 ppm**	**Per One Hour Average**
Hydrogen Sulfide (H_2S)	**0.10 ppm**	**Per One-Half Hour Average**
Nitrogen Dioxide (NO_2)	**0.10 ppm**	**24-Hour Average**

Results from CY 1994 demonstrated SO_2, H_2S, and NO_x data values at or below the lower level of detection limits.

During CY 1994, monitoring for ambient levels of noxious gas emissions at the AMS was discontinued per DOE authorization. The AMS was not used to gather regulatory or compliance data, nor was it capable of monitoring point source emissions for demonstrating compliance with mandated air permits.

6.4 Air Quality Monitoring (continued)

The WIPP has completed all regulatory sampling identified in the air permit and does not plan to conduct any additional sampling. Based on permit modeling and current requirements on the backup diesel generators, the WIPP does not anticipate the need for any regulatory air monitoring involving the AMS.

Weekly measurements of Total Suspended Particulates (TSPs) (micrograms per cubic meter) are made from the particulates collected onto glass fiber filters, by the low-volume continuous air sampler at the Far-Field air sampling location. These filters can load with dust particles due to the arid climate of this area; however, this poses no health concern.

6.5 Wildlife Population Monitoring

Since 1985, population density measurements of birds and small nocturnal mammals were performed to annually assess the effects of WIPP activities on wildlife populations. Typically, comparative data analysis was conducted between two outlying or "control" plots and two experimental plots situated in proximity to WIPP operations. A Hantavirus investiation during CY 1994, prompted the temporary postponement of small nocturnal mammal surveys. Re-implementation of these surveys is contingent on the results from the Hantavirus study.

6.5.1 Cooperative Raptor Research and Management Program

The ASER normally encompasses one calendar year's events, however, this section provides a comparison of three consecutive years' data. This three-year investigation is based upon commitments contained in the BLM/DOE Raptor Research Interagency Agreement and by request from external regulatory agencies such as the New Mexico Department of Game and Fish.

CY 1994 culminated a three-year evaluation and reorganization of the Raptor Research and Management Program (CRRMP). With the advent of an Interagency Agreement between the Carlsbad Area Office of the BLM and the WIPP in 1992, the research emphasis of the Raptor Program was modified from questions of a purely scientific nature to questions having direct applications to conservation and resource management. The following provides a summary of results and data comparisons from observations conducted during CY 1992, 1993, and 1994.

6.5.1 Cooperative Raptor Research and Management Program (continued)

During CY 1992, concerns were posed to WIPP researchers by the BLM regarding the status of resident populations of Harris' Hawks. Information disseminated prior to this time contended that a "precipitous decline" had been incurred by the regional population. This suggested decline, however, contradicted reports of the increasing range of the Harris' Hawk, in particular, the expanding northward progression of the species. The diametric opinions related primarily to assertions that the reported declines were attributable to human interference in the areas where the research was being conducted. By way of an Interagency Agreement, the BLM requested an assessment be conducted. The assessment would examine the extent and diversity of the local raptor population, the extent of human impacts on the raptor population, and provide recommendations to incorporate into future management strategies such as BLM Resource Management Plans (RMP) and BLM Habitat Management Plans (HMP).

In an effort to evaluate the dimensionality of the regional population of Harris' Hawks WIPP researchers, in cooperation with BLM biologists, conducted assays encompassing over 25,000 acres (50,600 ha). The survey results indicated that the regional population of Harris' Hawks was more widespread and extensive than previously assumed. During the initial investigation, 74 distinct groups of Harris' Hawks were identified with active nests confirmed in 53. Nest site locations were approximated with hand-held Loran Navigators and Global Positioning System (GPS) instruments. Locations were expressed in latitude/longitude coordinates and logged into an AutoCad program for plotting on maps. Maps with nest locations were remanded to the BLM for incorporation in their resource planning objectives. Accordingly, nest locations became the first priority in the research design.

Twenty delegate groups were subjectively chosen for monitoring in CY 1992. These delegate groups were indicative of the diverse preference of Harris' Hawks to nest substrates and territories. During the first year of the investigation, good-to-average precipitation rates (16.21 in.) and corresponding high prey densities influenced the success of delegate nests that fledged a mean of 2.3 offspring (n=20), an unusually high recruitment rate. Availability of preferable nest substrates, prey densities, habitat alteration/loss, and persecution were the principal limiting factors during this year's investigations.

During 1993, a year of below normal precipitation (9.4 in.), 13 of the 20 delegate groups reinitiated nesting activities and fledged an average of one nestling per nest. WIPP biologists focused primarily on evaluating the impacts of human-related activities on four distinct groups of Harris'

6.5.1 Cooperative Raptor Research and Management Program (continued)

Hawks residing in close proximity to either the WIPP site or areas where activities associated with WIPP were being conducted. The most successful nests during this season were those located in the proximity of agricultural or analogous-type habitat that sustained a vegetative density conducive to higher prey densities. In addition to Harris' Hawk nest sites, nest site locations of divergent species (e.g., Swainson's Hawks, Chihuahuan Raven) were also identified. As with 1992 data, nest locations were approximated with Loran Navigators and provided to the BLM for incorporation into its land use determinations (e.g., oil and gas activities).

CY 1994 was a record-setting year for low precipitation rates (6.53 inches) and high temperatures. The WIPP recorded a high temperature of 122 degrees Fahrenheit on June 26. Of the original 20 delegate groups identified for investigation during 1992, only seven made spring nest attempts and all but two had eggs addle in the nest. This resulted in an average of 0.28 nestlings fledged per nest attempt. A mean of 0.1 offspring fledged per subject group graphically illustrates the disparity between the 1992 and 1994 data. Two nestlings fledged from separate spring nests, however, they have not been observed since two days post-fledging.

Large groups, consisting of as many as 13 mature adult Harris' Hawks are becoming increasingly more common. Mader (1972), was one of the first to document the Harris' Hawks inclination to hunt cooperatively. Subject groups usually consist of breeding adults and related immatures (Dawson and Manaan 1989, 1991b). WIPP biologists surmised that the organization of multiple collectives, consisting of adults, is an inherent response to drought conditions and concurrent low prey availability. Combining the efforts of multiple, experienced hunters greatly increases the likelihood of successful kills. This response to adverse environmental conditions has also been observed in geographically divergent populations of Harris' Hawks (e.g. Arizona).

The New Mexico falconry community participated in the 1994 evaluations by providing assistance in the development of a non-intrusive skeletal measurement technique for sex determination of the Harris' Hawks. The falconers provided an array of measurements from known egg layers and semen donors to WIPP biologists, who then validated the measurement protocol. This cooperative arrangement provided a more accurate, extensive, and less intrusive means for the field collection of data regarding sex determination, in addition to providing an alternative to more aggressive protocol (e.g. laparotomy and/or necropsy). Subsequently the discipline of raptor research has a reliable, safe field procedure for sex determination of Harris' Hawks. The applicability of this protocol to other species of raptors is being investigated.

6.5.1 Cooperative Raptor Research and Management Program (continued)

During 1995, WIPP biologists will examine the relatedness of entities within groups of Harris' Hawks by way of DNA electrophoretic analysis. In addition, investigations into the widely debated territorial demeanor of the species will be conducted to ascertain the historical status of Harris' Hawk territories (e.g. how long have subject territories been established) and the dimensionality (e.g. size and configuration) of subject territories. This data should provide greater insight into the ecology and life history of the species thus affording for the development and progression of more accurate and reliable methods for the conservation and management of the species.

6.5.2 Breeding Bird Densities

During CY 1994, censusing of birds (e.g. emlen transects and 25 mile breeding bird surveys) was discontinued. Nearly 10 years of data revealed no discernable impacts from WIPP activities on densities and distributions of breeding birds. The majority of bird species encountered during these surveys were transients (migrants), consisting primarily of smaller songbirds that pass through the area seasonally. Although migratory birds represent a significant order of birds from the standpoint of population numbers and diversity, the information they provide is not evaluated using them as radiological sentinels. Assessments of environmental conditions using migrating birds as bioindicators are of much merit; however, a re-evaluation of the program resulted in the theory that species that permanently reside in the immediate vicinity of the WIPP would provide more accurate evaluations regarding the impacts of activities associated with the WIPP on the peripheral environment. As resident quail are accessed for radiological biotic analysis, they were chosen as the logical species for an intensive ecological inquiry.

From 1984 through 1993, WIPP avian surveys have identified 98 species that inhabit or migrate through the areas. Extensive avian studies in southeastern New Mexico suggest that there could be up to 300 species onsite. Insect-dependant species continue to predominate onsite nesting species. The most common are Barn Swallows (*Hirundo rustica*) and Western King Birds (*Tyrannus verticalis*).

The usefulness of birds as monitors of radionuclides or any other form of environmental contaminant is proportional to the degree of knowledge regarding their basic ecology, biology, natural history, and particularly, movement and behavior in the area being studied. Failure to take into consideration the behavior, for instance, of a biomonitor such as birds, can result in a possible misinterpretation of data obtained from well-designed, well-intended studies of contaminant body

6.5.2 Breeding Bird Densities (continued)

burdens (Furness and Greenwood 1993). As considerable data has been accrued at the WIPP, pertaining to the radiological analysis of skeletal-muscular tissue in quail, WIPP biologists plan to augment the data by investigating the facets of life history and behavior of resident populations.

Resident quail populations are more tolerant and tend to be more adaptable in response to environmental disturbances, thus providing a more accurate indicator of regional ecological conditions. As the WIPP traps resident quail for radiological tissue analysis, a program is being developed to enhance data collection by investigating the ecology and life history of the quail species of the area. Relationships between quail production and climate, predation, and the effects of hunting in the immediate area will be considered in the final analysis. This information will assist investigators in the following ways: (1) by eliminating seasonal responses of migratory species; and (2) by allowing the opportunity to monitor the influences of WIPP activities on the year-round ecology of resident populations that are concurrently accessed for radiological appraisals.

6.5.3 Small Nocturnal Mammal Population Densities

The reportable presence of the Hantavirus in West Texas and other neighboring states prompted the suspension of small nocturnal mammal appraisals. The appraisals are to be resumed after evidence, to ascertain the status (presence or absence) of the Hantavirus in local populations of small mammals, had been collected and evaluated. Midway through the CY 1993 census period, outbreaks of the virus, not only in New Mexico, but every state bordering New Mexico, was reported.

The primary pathogen for the disease is a virus, endemic in particular populations of mice common to the genus *Peromyscus* (e.g. Brush Mice, Cactus Mice, Deer Mice). In order to legitimately sample small nocturnal mammals, near the WIPP, for the presence of the virus, two personnel from the Environmental Monitoring section of the WIPP attended training seminars. Conducted by the Centers for Disease Control (CDC), in conjunction with the University of New Mexico and the Museum of Southwestern Biology, the training provided instruction in the appropriate protocol for blood extraction techniques and specimen handling. Safety procedures and precautions were implemented using CDC etiquette for blood serum extraction and appropriate preservation techniques for perishable samples.

Hantavirus sampling required five months of preparation and two weeks of subsequent trapping sessions. Approximately 200 traps were set and baited with small grains (e.g., milo, millet) nightly

6.5.3 Small Nocturnal Mammal Population Densities (continued)

for eight nights, resulting in a total of 1600 individual trap attempts. Trapping protocols were modified from the standard practices of alternating trapping grids to focusing on the control grid nearest the WIPP site. Additionally, traps were positioned along proximal roads and near outlying buildings (e.g., meteorological tower building) to increase the likelihood of captures by concentrating efforts in areas conducive to rodent activity. Twenty eight animals were captured and sampled for a success rate of .018 captures per trap night. WIPP personnel extracted blood samples only, no tissue samples were acquired. Specimens were preserved in liquid nitrogen and shipped in dry ice to maintain sample integrity. Diversity of nocturnal species encountered included Ord Kangaroo Rat (*Dipodomys ordi*), Southern Plains Woodrat (*Neotoma micropus*), Silky Pocket Mouse (*Perognathus flavus*), and Cactus Mouse (*Peromyscus eremicus*).

The capture of diurnal species was infrequent as traps were typically baited late in the day, however, several Spotted Ground Squirrels (*Spermophilus spilosoma*) were captured, sampled, and released. The abnormally low numbers of captures, in comparison to previous years trapping events, correlates to the extreme drought conditions during CY 1994. Moreover, in contrast to the previous years' events, no Grasshopper Mice (*Onychomys leucogaster*) were captured.

Analysis of blood samples extracted by WIPP personnel, tested negative for the presence of Hantavirus.

6.6 Surface and Subsurface Soil Monitoring

Surface and subsurface soil monitoring was conducted during CY 1994. A detailed discussion of the nonradiological soil monitoring program is available in the report titled *Summary of the Salt Impact Studies at the WIPP, 1984 to 1990* (DOE/WIPP 92-038). Analytical results from the nonradiological soil sampling program are presented in Appendix B.

6.7 Vegetation Monitoring

Because of drought conditions during CY 1994, the plant community of the Los Medaños area globally exhibited distinctive signs of physiological stress (e.g. stem and leaf necrosis, chlorosis). As no discernable variations in stress could be identified, delineating subtle variations in plants growing near salt tailings piles in comparison to plants growing varying distances from the tailings, evaluations of the effects of salt on proximal plant communities was postponed for at least one

6.7 Vegetation Monitoring (continued)

calendar year. Data collected to date indicate "marginal" to "no negative" impacts on the surrounding plant communities in the form of eolian salt deposition from the mine tailings. The nature of the salt is to become compacted and solidified by the heavy machinery and moisture.

Runoff is collected in the catchment basin, where it is evaporates into the atmosphere and is absorbed into the soil. Any resulting salt crust is then weathered and partially dispersed to the surrounding area. This represents only a minimal deposit. Interestingly, wildlife has been observed using the salt tailings as a source of salt, similar to cattle using salt licks.

6.8 Volatile Organic Compounds (VOC) Monitoring

As stated in Section 3.2.3, **Resource Conservation and Recover Act (RCRA) page 3-7,** the WIPP has developed and implemented a VOC monitoring program to satisfy the air monitoring requirements of the NMD for the WIPP (55 FR 47700). The data resulting from this program are reported in the NMD annual reports submitted to the EPA.

The WIPP VOC Monitoring Program is referenced in the EMP for the WIPP (DOE/WIPP 94-024). Implementing documents specific to the VOC monitoring program include the *VOC Monitoring Plan* (WP 12-6) and *Volatile Organic Compounds Monitoring Quality Assurance Program Plan* (WP 12-7). The *VOC Monitoring Plan* (WP 12-6) is currently under revision. These revisions will reflect present VOC Monitoring activities to support the No-Migration Variance Petition for the Disposal Phase.

6.9 Reclamation of Disturbed Lands

Reclamation activities during CY94 consisted of the decommissioning of numerous existing fenced areas that had been constructed during much of the initial site characterization studies in the late 1970s. In addition to the exclosures, re-bar that had been emplaced within these study areas, to delineate sampling points, was removed to alleviate safety hazards to personnel and livestock. Problem areas (e.g. drainages, eroded slopes, etc.) in existing reclamation sites received additional stabilization measures which include seeding and the spreading of straw. Existing fences left in place, were repaired as necessary.

6.10 Seismic Activity

Geologic structures and tectonism of the Permian Basin are associated with large-scale basin, inter-basin, and basin-margin subsidence or emergence that occurred during the Paleozoic era. The WIPP facility is about 60 miles from the western margin of the Permian Basin. The basin is a broad structural feature made up of a series of Paleozoic sedimentary basins whose last episodes of major subsidence occurred during late Permian time. The area today is characterized by the basin filled with thick evaporite layers and bordered by the Amarillo uplift to the north, the Marathon thrust belt to the south, and the Diablo Platform, Sacramento and Guadalupe Mountain orogenies to the west.

All major tectonic elements of the Permian Basin were completely formed before deposition of the Permian salt-bearing rocks, and the region has been relatively stable since that time. Deep-seated faults are rare, except along the west margin of the basin and no indications of younger deep-seated faults are noted. On June 16, 1978, an earthquake near Snyder, Texas lead researchers to conclude that the earthquake may have been induced from secondary oil recovery operations and hydrocarbon production. The depth of the earthquake closely approximated the bottom of drillholes located in the gas-producing area.

Historically, the seismic information for the WIPP facility region before 1962 was based on chronicles of the effects of those tremors on people, structures, and land forms. Seismicity, prior to 1962, reported in New Mexico, occurred in the Rio Grande area between Albuquerque and Socorro and was associated with a structure known as the Rio Grande Rift. These earthquakes had intensities of Modified Mercalli V or greater, based upon the perceptions of people experiencing these quakes.

Since 1962, virtually all seismic information is based on instrumental data recorded at various seismograph stations. Currently, seismicity is being monitored at the New Mexico Institute of Mining and Technology (NMIMT), Socorro, using data from a seven-station network located at the WIPP (Figure 6-4). The stations are telemetered to the NMIMT Seismological Observatory in Socorro. Readings from the WIPP network stations are combined with readings from an additional New Mexico Tech network which is located in Socorro in the central Rio Grande rift. The annual mean for the operational efficiency of seismic monitoring stations is 94.5 percent.

There were a total of 24 earthquakes located within 300 kilometers of WIPP in 1994. The maximum intensity for an earthquake during CY 1994 registered at a magnitude of 2.7 and was located 34 km south of Snyder,Texas. The nearest earthquakes to the WIPP site were at distances

6.10 Seismic Activity (continued)

greater than 100 kilometers. Earthquake activity within 300 km of the WIPP site remained below normal during 1994. Seismicity near the site has been registered as high as 5.0 in magnitude.

6.11 Liquid Effluent Monitoring

On January 16, 1992, the NMED issued the Discharge Plan (DP-831) for the WIPP sewage facility. The approved Discharge Plan superseded an Emergency Discharge Permit issued in January, 1992. In addition to sewage effluent, the Discharge Plan allows for the disposal of 1500 gallons a day of nonhazardous brines generated by seepage into shaft sumps and from the pumping of observation wells at the site. Characterization samples were collected throughout 1994 to demonstrate that site-generated brines are nonhazardous and can be disposed in the sewage evaporation pond. The DOE submits quarterly Discharge Monitoring Reports (DMRs) to the NMED to demonstrate compliance with the inspection, monitoring, and reporting requirements identified in the plan. No effluent limits were established in DP-831. The NMED Groundwater Protection and Remediation Bureau established a list of analytes to be sampled on a quarterly basis to be used as indicators of sewage system performance. Figures 6-5 through 6-8 depict analytical results from DP-831 sampling activities.

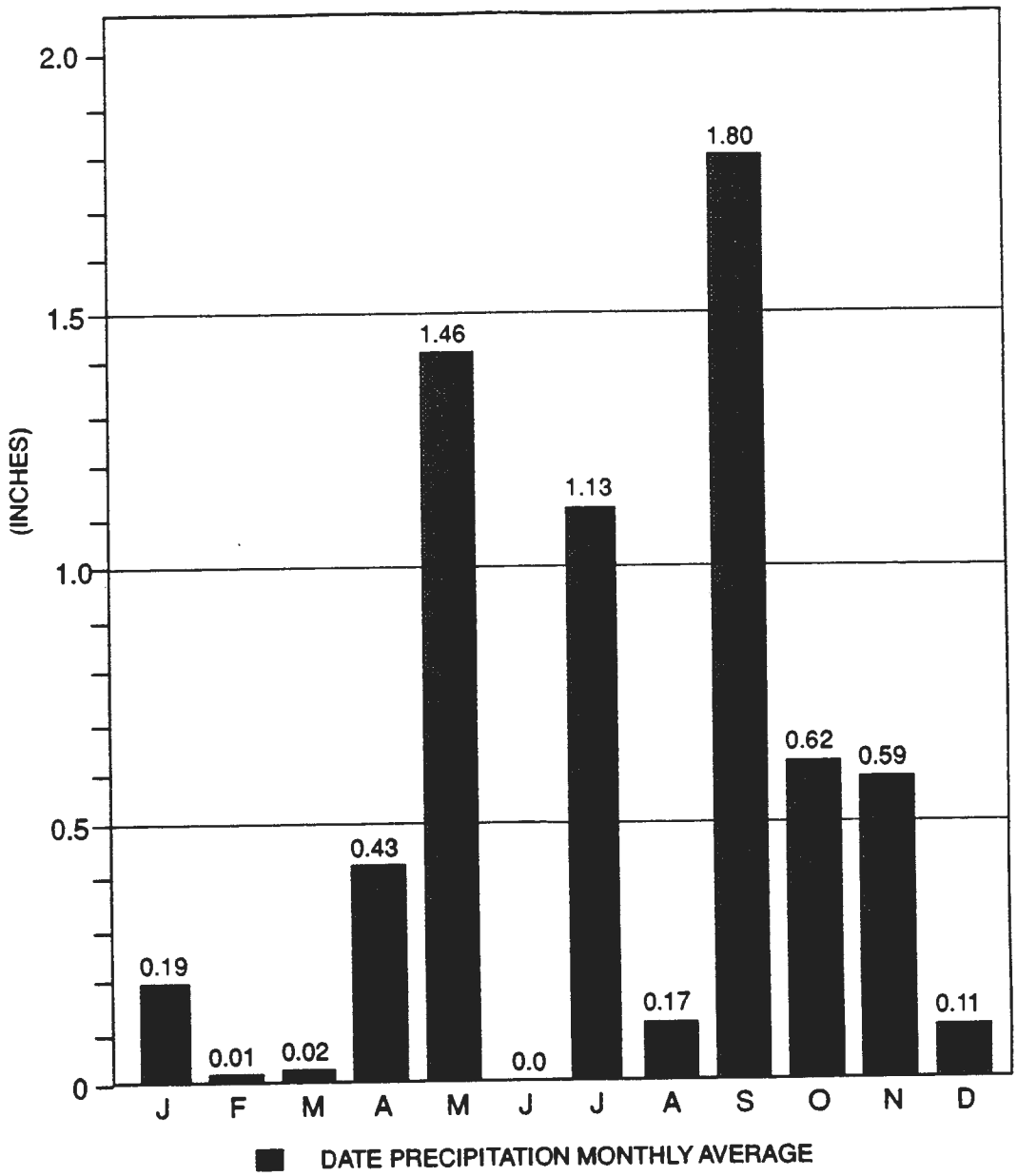


Figure 6-1
1994 Precipitation

WIND ROSE
for the Period
01/01/94 through 12/31/94

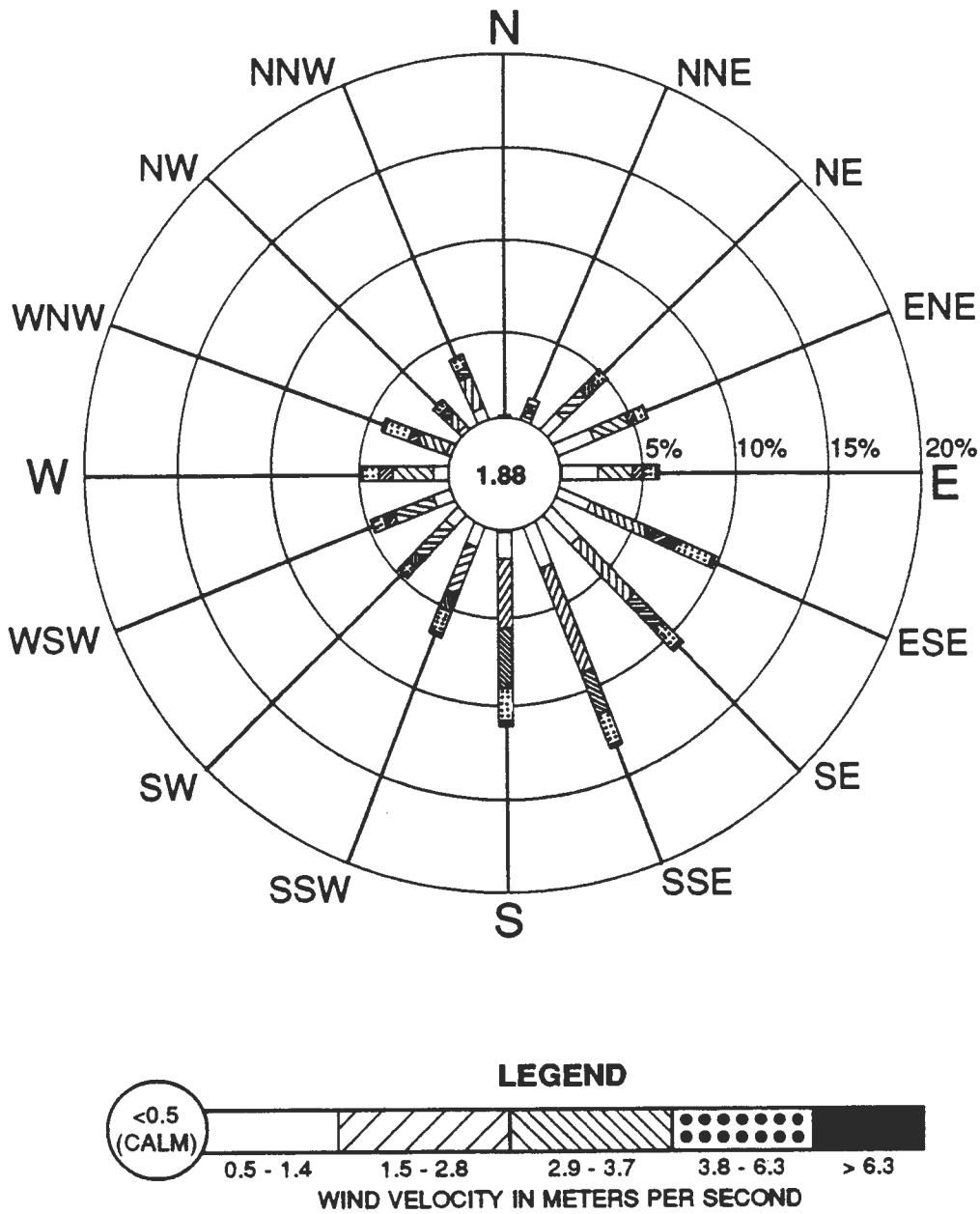


Figure 6-2
Annual Windrose

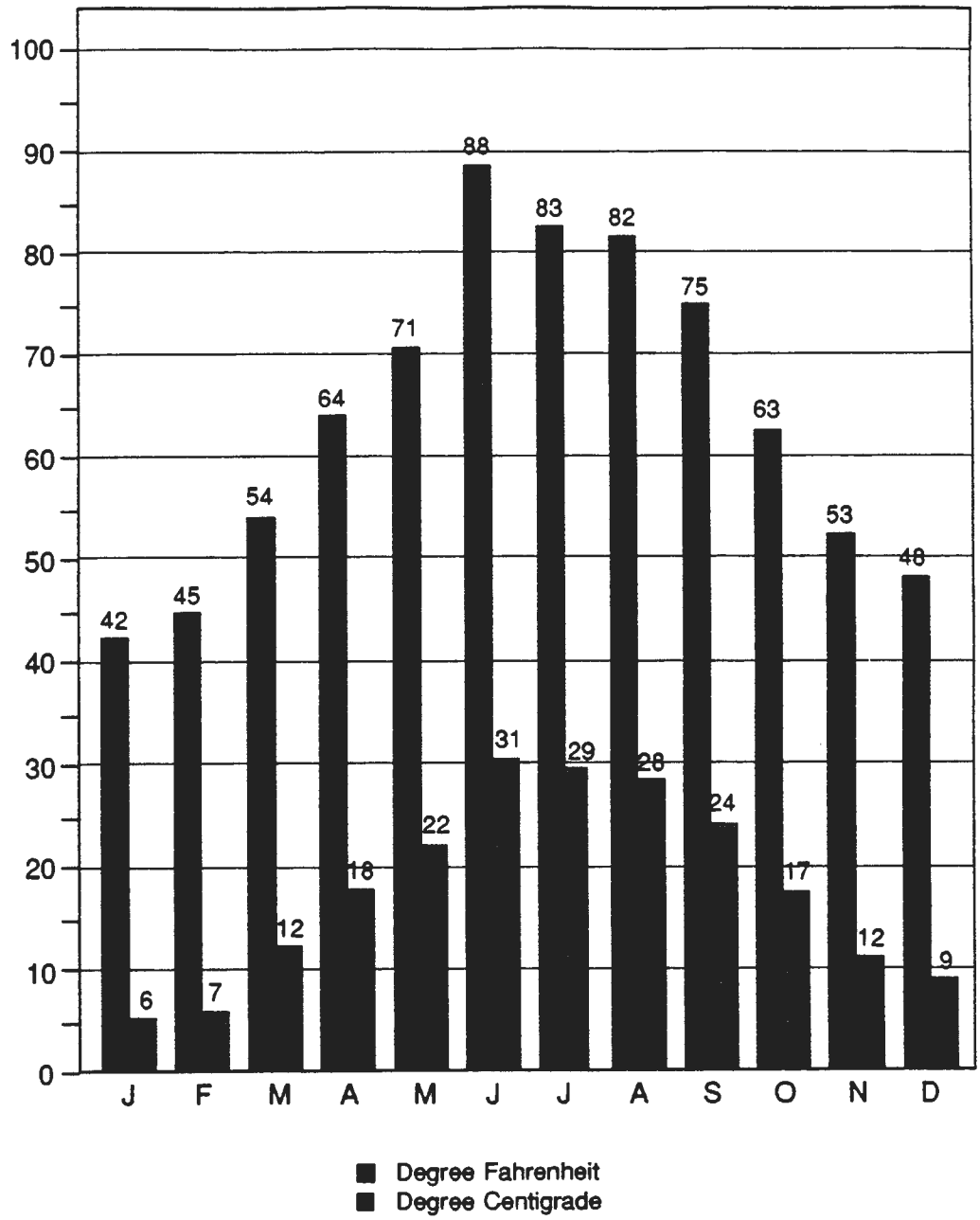
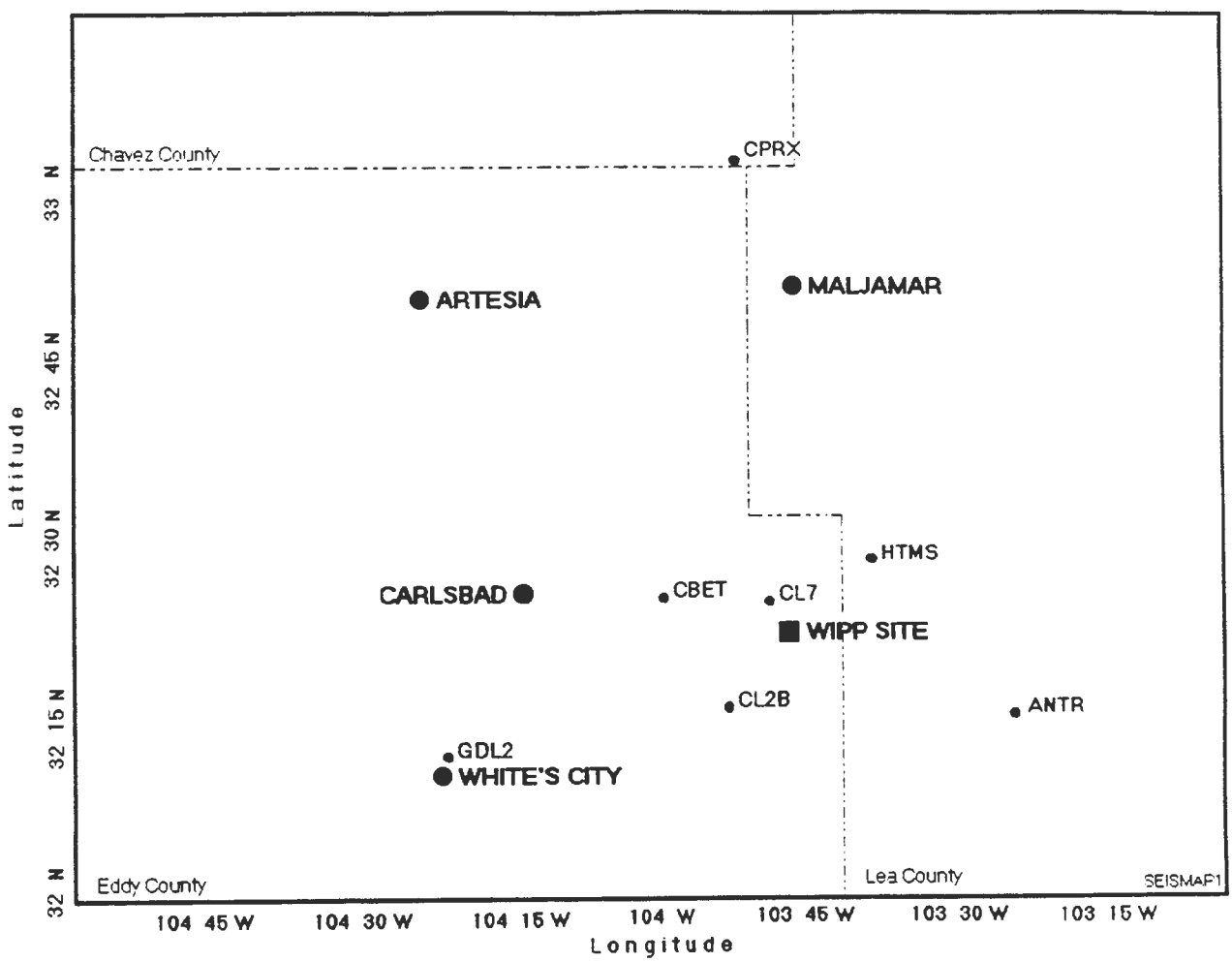


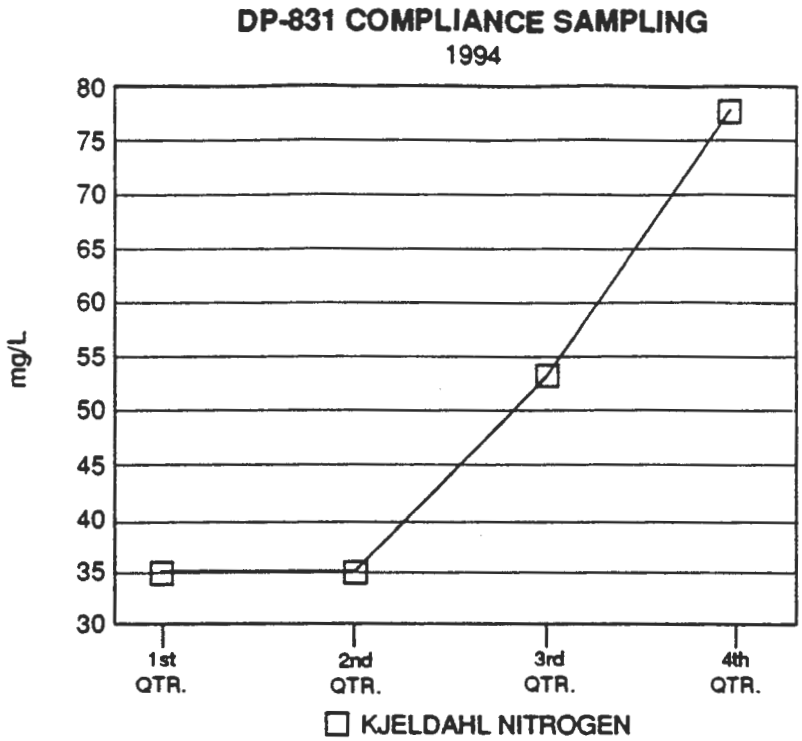
Figure 6-3
1994
Average Monthly Temperatures



Definitions of Aconyms

ANTR - Antelope Ridge
CBET - Carlsbad East Tower
CL2B - Carlsbad Station 2B
CPRX - Caprock
GDL2 - Guadalupe Mountains
HTMS - Hat Mesa
CL7- Carlsbad Station 7

Figure 6-4
WIPP Seismograph Station Locations



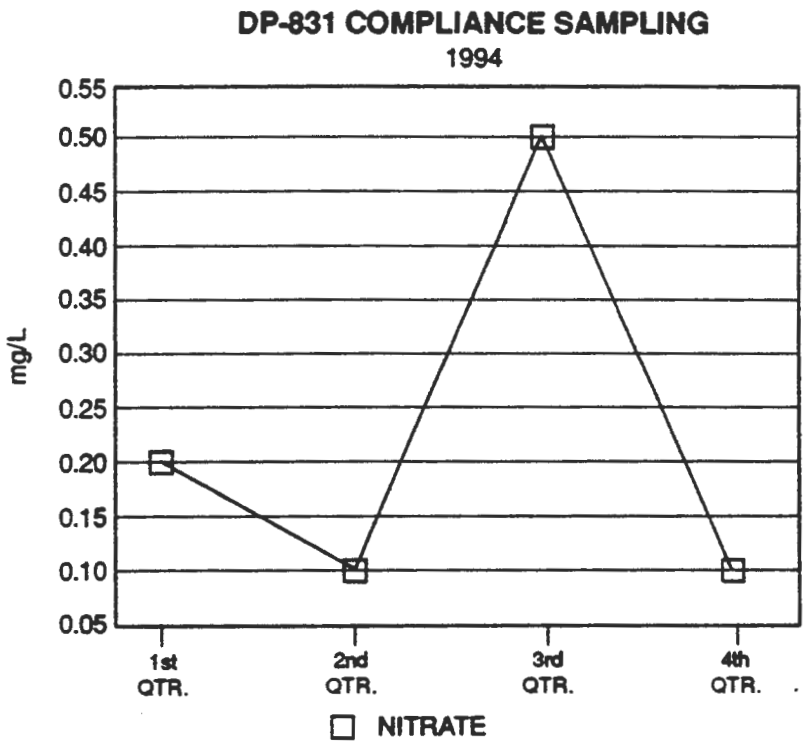
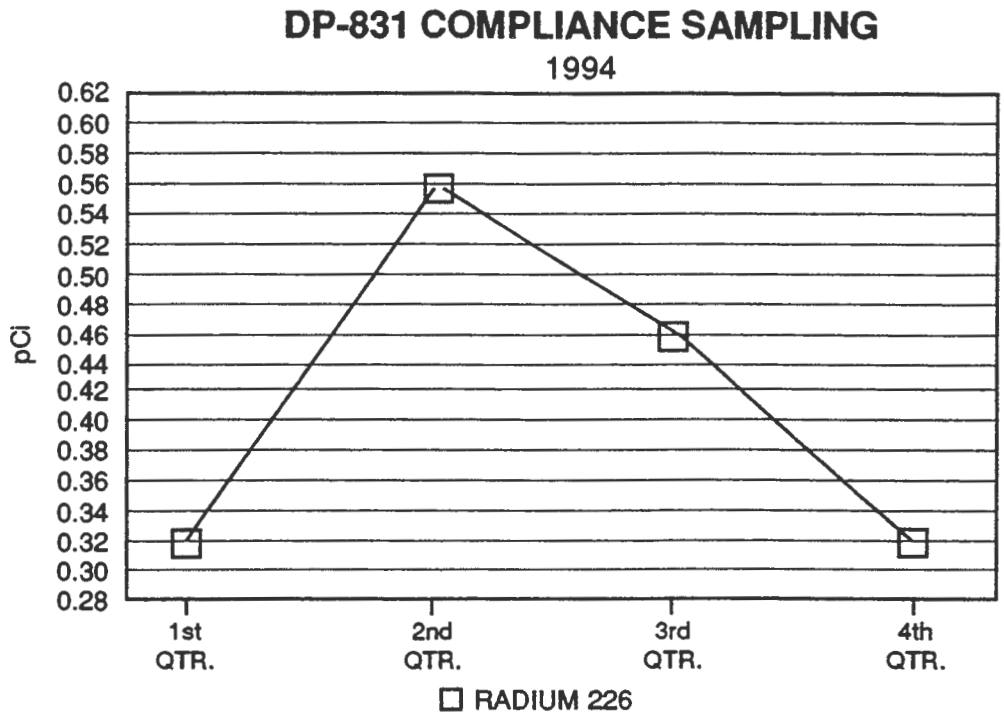


Figure 6-5
DP-831 Compliance Sampling Analysis
Kjeldahl Nitrogen and Nitrates



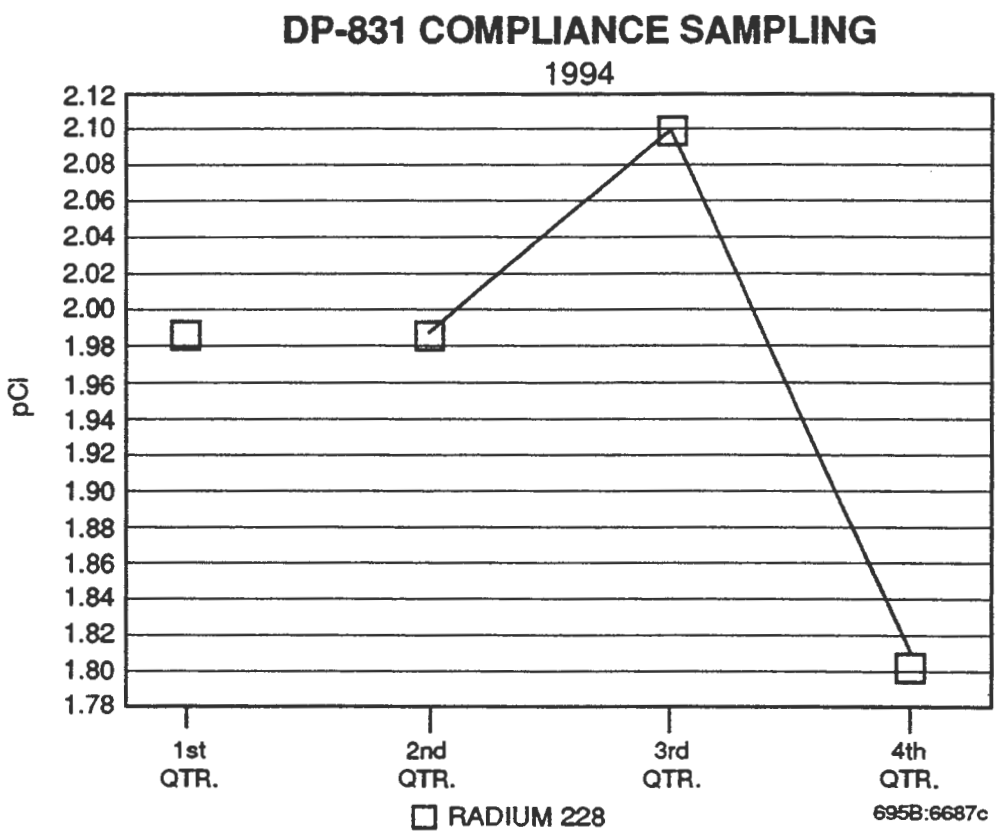
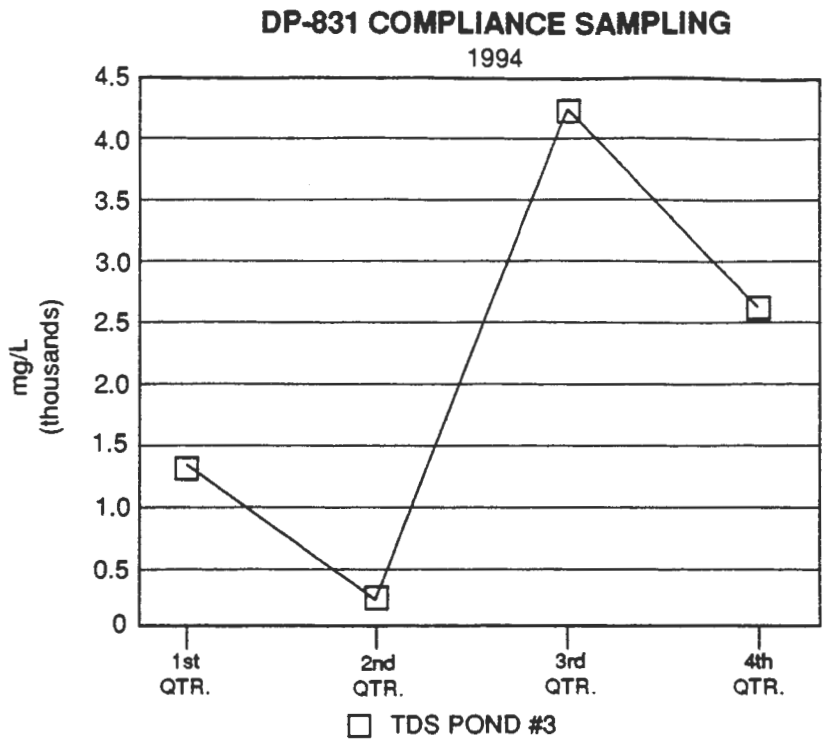


Figure 6-6
DP-831 Compliance Sampling Analysis
Radium 226 and 228



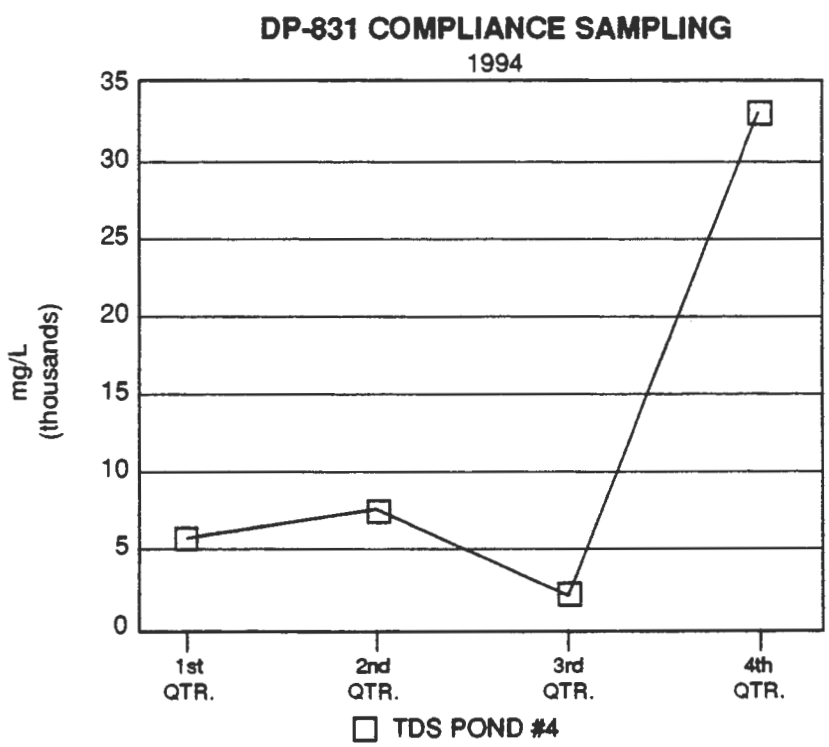


Figure 6-7
DP-831 Compliance Sampling Analysis
TDS - Ponds 3 and 4

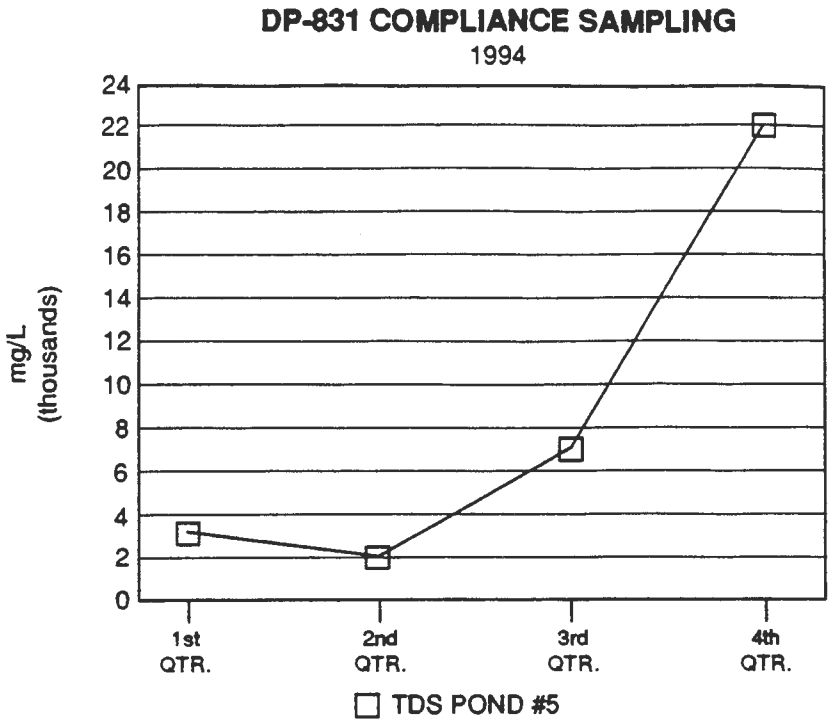


Figure 6-8
DP-831 Compliance Sampling Analysis
TDS - Ponds 5

CHAPTER 7

GROUNDWATER SURVEILLANCE

Chapter 7
Groundwater Surveillance

Current groundwater surveillance activities at the WIPP are outlined in the WIPP *Groundwater Monitoring Program Plan and Procedure Manual* (WP 02-1 Rev 2). This monitoring plan is a Quality Assurance (QA) document that contains program plans for each of the activities performed by groundwater surveillance personnel. In addition, WP 02-1, Rev 2 provides detailed procedures for performing specific activities such as pumping system installations, field parameter analysis and document, and QA records management. Groundwater surveillance activities are also defined in the EMP.

The objective of the Groundwater Surveillance Program (GSP) is to determine the physical and chemical characteristics of groundwater, maintain surveillance of groundwater levels surrounding the WIPP facility, both before and throughout the operational lifetime of the facility, and fulfill the requirements set forth in DOE order 5400.1, *General Environmental Protection Program.*

Background water quality data were collected from 1985 through the 1990 sampling period as reported in DOE/WIPP 92-013, *Background Water Quality Characterization Report for the Waste Isolation Pilot Plant.* This background data will be compared to water quality data collected throughout the operational life of the facility. Pre-operational data gathered in the interim period will be used to strengthen the background data, to evaluate the need to make adjustments to comparison criteria, and to determine future regulatory needs and land-use decisions.

The data obtained by the Water Quality Sampling Program (WQSP) in 1994 supported two major programs at the WIPP: Site Characterization and Performance Assessment in compliance with 40 CFR 191. Each of these programs requires a unique set of analyses and data. Particular sample needs are defined by each program. In addition to the characterization of groundwater, the WQSP supported radionuclide monitoring for the Environmental Analysis and Compliance Section of WIPP. Results of radionuclide sampling are discussed in Chapter 5, *Envrionmental Radiological Program Information,* pages 5-3 through 5-4. The NMED and the EEG were on hand at each sampling event to collect samples for independent evaluation.

The WIPP is located within the Pecos Valley section of the Southern Great Plains physiographic province (Powers et al., 1978). Geologic and lithologic descriptions of the area surrounding the WIPP site can be found in documents such as the EMP, DOE/WIPP 90-008 *Groundwater Protection Management Program Plan*, and USGS 83-4016 (Mercer, 1983). Industries in the vicinity which

Groundwater Surveillance (continued)

could potentially contribute to the pollution of the groundwater are potash mining, oil and gas exploration/production, and cattle ranching.

The Culebra is the most significant water-bearing unit within the vicinity of the WIPP. No known hydrologic connection exists between the repository horizon and the Culebra. Surveillance of hydrological characteristics in the Culebra provides data which can be used to detect changes in water characterization. It also provides additional data for use in hydrologic models designed to predict long term performance of the repository. Data is gathered from 58 well bores; 6 of which are equipped with production-inflated packers to allow groundwater level surveillance of more than one producing zone through the same well bore.

Groundwater Quality data were gathered from nine wells completed in the Culebra. The water quality sampling process has been developed using logistics from groundwater wells originally constructed for characterization, not intended for groundwater monitoring activities. The WIPP site has been given a conditional No-Migration determination and is not required to have a groundwater monitoring program. The original wells are, therefore, being used for surveillance. Most of the wells are constructed with J-55 or K-55 iron casing. In order to decrease the sampling bias created by well construction deficiencies, combined with the low transmissibilities of the formations involved, a labor intensive sampling process has been initiated. Because of the time involved in collection of representative samples, the predetermined wells are sampled only once per year. Sampling episodes are referred to as a "sampling round." Each yearly sampling round consists of the collection of two types of samples: (1) serial samples and (2) final samples. Serial samples are taken periodically while the well is being purged. Key physical and chemical parameters (known as field parameters) are analyzed and compared with past serial sampling data until a chemical steady state has been reached. A chemical steady state is usually defined as +\- 5 percent of the average of the three to five preceding parameter measurements made on the final day of serial sampling from preceeding sampling rounds. Stabilization of these field parameters is a function of purging and is used as an indicator to determine if the groundwater is representative of the zone being sampled. A final sample is collected, once it has been determined that the pumped groundwater has achieved a representative state, and is sent off site to a contract laboratory for analysis. Groundwater surveillance activities during CY 1994 consisted of two separate programs: Groundwater Quality Sampling and Groundwater Level Measurements. These two programs will be discussed below:

7.1 Groundwater Quality

Sampling for groundwater quality was performed at nine well sites during CY 1994 (Figure 7-1, page 7-7). Each well was purged a minimum of 24 hours prior to the commencement of the serial sampling phase. Field analysis for Eh, pH, Specific Gravity, Specific Conductance, Alkalinity, Chloride, Divalent Cations, and Total Iron were performed on a periodic basis during the serial sampling. These field parameters were used as indicators, during the purging process to better determine when the formation water being pumped had reached a representative state. Normally this process required seven to ten days to complete. Following the field analysis of the final serial sample, samples were collected and shipped to an independent, contracted, laboratory for analysis. Parameters of analysis by the contracted laboratory are listed in Table 7-1, page 7-7.

The total gallons of water removed from the Culebra as a result of groundwater surveillance activity was approximately 28,547 gallons throughout the year. The results of final sample analysis show relative consistency when compared to background data. Tables 7-1.1 through 7-1.9, pages 7-9 through 7-17, contain average results of data collected from the Culebra dolomite during 1994 as compared to background data for major constituents of the background matrix. None of the waste stream Volatile Organic Compounds for which analysis were run showed any detectable concentrations.

Water quality of the Culebra in the vicinity of the WIPP is naturally poor and is not suitable for human consumption or for agricultural purposes. The water contains naturally high concentrations of total dissolved solids (TDS) and mineral constituents primarily of chloride, calcium, magnesium, sodium and potassium (Mercer, 1983). The high concentration of TDS results in water of generally poor quality. This has historically posed problems for laboratories performing analysis because the water interferes with the normal operation of standard laboratory equipment such as Atomic Absorption (AA) or Iductively Coupled Argon Plasma (ICAP), causing detection limits to be inconsistent.

7.2 Groundwater Level Surveillance

In October 1988, WIPP was tasked with conducting a Groundwater Level Surveillance Program. Fifty eight well bores were utilized to perform surveillance of six water bearing zones in the WIPP area. The two zones of primary interest are the Culebra and Magenta. Forty six measurements are taken in the Culebra; 10, in the Magenta. Two measurements are taken in the Rustler/Salado contact and Dewey Lake formation; one measurement each is taken in Bell Canyon, Forty-niner, and

7.2 Groundwater Level Surveillance (continued)

unnamed lower member. Locations of groundwater level surveillance sites are pictured in Figure 7-2, page 7-18.

Groundwater elevation measurements in the Culebra indicate that the generalized directional flow of groundwater is north to south in the vicinity of WIPP (Figure 7-3, page 7-19). However, caution should be used when making assumptions based on groundwater level data alone, studies in the Culebra have shown that fluid density variations in the Culebra can affect flow direction (Crawley, 1988 and Davies, 1989). One should also be aware that the fractured media of the Culebra, coupled with variable fluid densities, can cause localized flow patterns to have little or no relationship to general flow patterns (Mercer 1983, Crawley 1988).

Regional groundwater levels taken in the Culebra showed no significant increase or decrease in the water level elevation over the period of January 1994 through December 1994. Localized groundwater elevations near the site showed higher than normal increases in water levels, probably due to shaft grouting activities completed in the latter part of 1993. The groundwater levels in the following wells were effected by shaft grouting activities :

- ERDA - 9
- H-01
- H-02a
- H-02b2
- H-02c
- H-03b2
- H-03b3
- H-14
- H-15
- WIPP-12
- WIPP-18
- WIPP-19
- WIPP-21
- WIPP-22

Groundwater levels in the above listed wells ranged from 1½ to 14 feet increases during the calendar year 1994.

7.2 Groundwater Level Surveillance (continued)

Moderate decreases in three wells, H-04b, H-09b, and H-11b3 may have been influenced by pumping events to obtain water quality data during the latter part of the year. Two other wells, DOE-1 and Cabin Baby Federal Number 1, were influenced by an obstruction in the well casing in DOE-1 and a leaky bridge plug below the Culebra in Cabin Baby. Both problems were corrected in September and October of 1994. Groundwater flow directions in the Magenta appear to be generally from an east to west direction across the WIPP site (Figure 7-4, page 7-20). No studies have been performed in the Magenta to determine spacial variations in the fluid densities of the magnitude studied in the Culebra. It is probable that density variations do occur in the Magenta; therefore, the potential may exist that flow patterns in the Magenta may be affected by variations in fluid density. Also, flow through the fractured media of the Magenta may dictate the behavior of localized flow patterns.

Regional groundwater level measurements taken in the Magenta dolomite indicate that water levels are increasing. All of the wells monitored for groundwater levels in the Magenta dolomite showed a trend for increasing water-level elevations. Two wells, H-01 and H-02b1, showed higher than normal increases; however, these wells are close to the site and were probably influenced by the shaft grouting activities in 1993.

7.3 Program Changes

In September and October 1994 the Department of Energy installed six new wells in the Culebra dolomite for the purpose of water quality sampling (Figure 7-5, page 7-21). The new wells are constructed to EPA standards and have the potential to meet detection monitoring standards. Recommended EPA drilling methods were used to minimize the introduction of foreign materials into the well bore and prevent contamination of the aquifer. The addition of the new wells to the program is expected to improve the quality of the data collected and reduce the time and cost of sampling. The results of the first samples taken from the new wells are expected to be reported in the 1995 Site Environmental Report.

A significant program change developed when Cabin Baby was turned over to private enterprise for the purpose of re-entry for oil and gas development. The request for re-entry was denied by the Bureau of Land Mangement, and the status of Cabin Baby as a monitoring well is pending.

TABLE 7-1
PARAMETERS ANALYZED
DURING
CALENDAR YEAR 1994

SPECIFIC CONDUCTANCE	BORON
SULFATE	CADMIUM
TOTAL DISSOLVED SOLIDS	CALCIUM
TOTAL SUSPENDED SOLIDS	CHROMIUM
DENSITY	IRON
pH	LEAD
ALKALINITY	LITHIUM
BROMIDE	MAGNESIUM
CHLORIDE	MERCURY
FLUORIDE	POTASSIUM
IODIDE	SELENIUM
NITROGEN, NO3 (AS N)	SILICA
TOTAL ORGANIC CARBON	SILVER
TOTAL ORGANIC HALOGENS	SODIUM
PHENOL, TOTAL	CARBON TETRACHLORIDE
ORTHOPHOSPHATE (AS P)	METHYLENE CHLORIDE
ARSENIC	TRICHLOROETHYLENE
BARIUM	1,1,1-TRICHLOROETHANE
BERYLLIUM	FREON-113

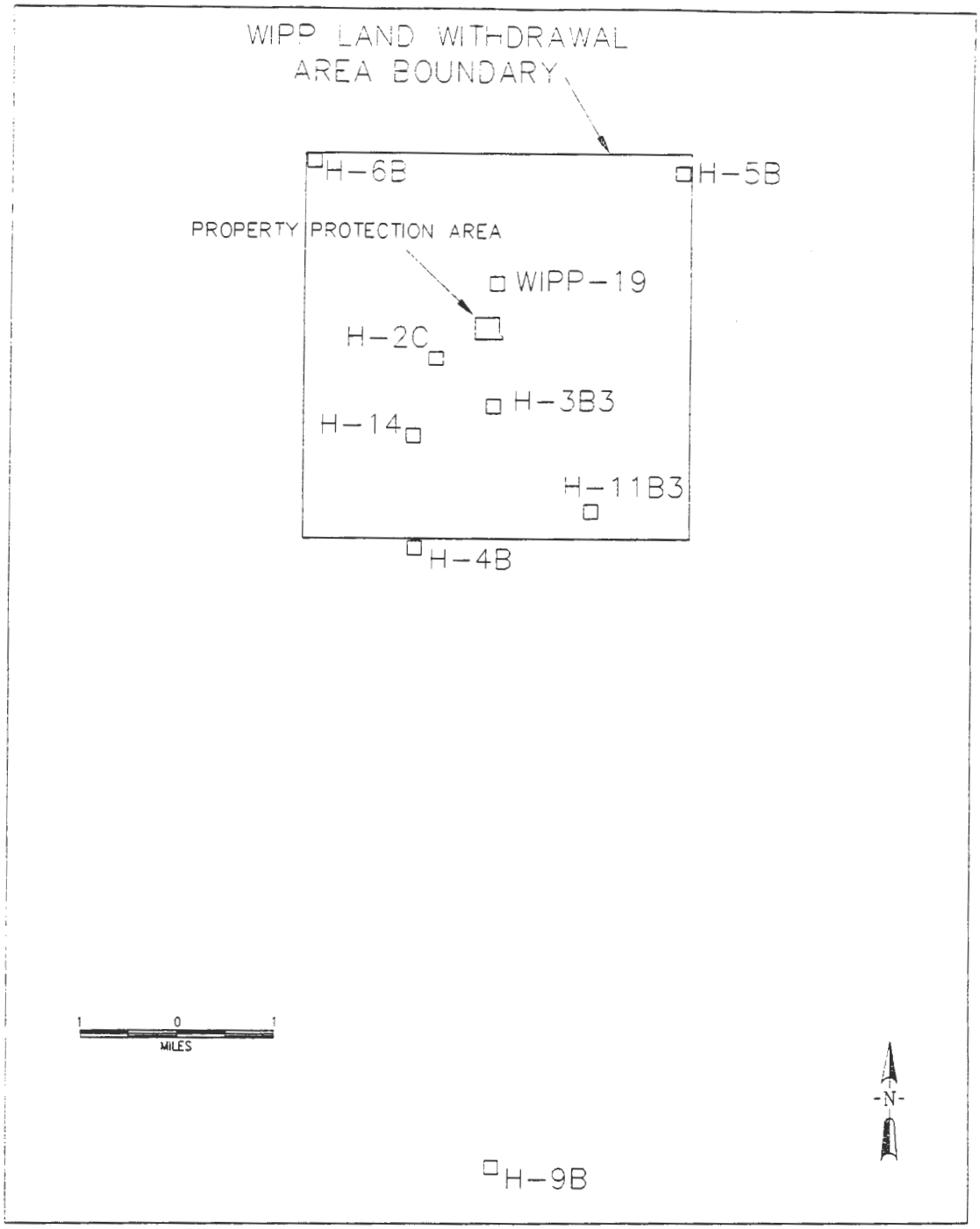


FIGURE 7-1 WATER QUALITY SAMPLING PROGRAM SAMPLE WELLS 1994

TABLE 7-1.1
H-02c, CULEBRA
ROUND 6 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	12.20	9-12
CALCIUM	751	589-841
IRON	1.32	0-1.9
LITHIUM	0.246	0.26-0.72
MAGNESIUM	239	152-181
POTASSIUM	112	86-119
SODIUM	2,190	0-5,270
ALKALINITY	47.0	52-60
BROMIDE	11.2	0-5
CHLORIDE	3,210	2,396-6,737
FLUORIDE	<3.0	[illegible] 2.2
pH	7.63	7.38-8.04
SULFATE	3,035	2,061-3,806
TOTAL DISSOLVED SOLIDS	11,000	7,612-15,689
ARSENIC	<0.006	≤0.014
BARIUM	0.011	<0.05
BERYLLIUM	0.0055	<0.05
CADMIUM	<0.0013	≤0.08
CHROMIUM	<0.005	≤0.4
LEAD	<0.013	≤0.5
MERCURY	<0.002	<0.0002
SELENIUM	<0.006	<0.05
SILICA	9.77	6.1-14
SILVER	<0.013	≤0.20
IODIDE	4.44	1-9
NITRATE AS (N)	<0.10	≤0.30
PHENOLICS	<0.1	≤0.097
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	2.70	5-7
TOTAL ORGANIC HALOGEN	0.0323	≤0.14

TABLE 7-1.2
H-03b3, CULEBRA
ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	24.4	19-32
CALCIUM	1,485	1,193-1,527
IRON	<2.00	0.14-0.47
LITHIUM	0.40	0.15-0.82
MAGNESIUM	768	710-826
POTASSIUM	408	372-534
SODIUM	16,550	16,140-17,900
ALKALINITY	39.6	46-54
BROMIDE	27.8	7-41
CHLORIDE	31,100	26,742-30,838
FLUORIDE	<3.00	1.5-1.6
pH	7.74	6.85-7.66
SULF[illegible]	5,297	4,537-4,823
TOTAL DISSOLVED SOLIDS	54,900	53,130-55,170
ARSENIC	<0.006	<0.10
BARIUM	<0.04	≤0.06
BERYLLIUM	<0.02	≤0.15
CADMIUM	<0.0013	≤0.07
CHROMIUM	<0.01	0.007-0.4
LEAD	<0.013	≤0.50
MERCURY	<0.002	<0.001
SELENIUM	<0.006	<0.50
SILICA	8.09	4.5-13
SILVER	<0.013	≤0.10
IODIDE	<2.00	<2.0
NITRATE AS (N)	<1.00	<0.20
PHENOLICS	<0.10	≤0.033
PHOSPHATE AS (P)	<0.02	≤0.06
TOTAL ORGANIC CARBON	2.65	≤2.0
TOTAL ORGANIC HALOGEN	0.033	0.14-0.42

TABLE 7-1.3
H-04b, CULEBRA
ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	16.7	14-21
CALCIUM	723	604-741
IRON	<2.00	0.40-0.55
LITHIUM	0.39	0.25-0.58
MAGNESIUM	443.5	385-468
POTASSIUM	195	179-261
SODIUM	5,750	5,625-6,255
ALKALINITY	48.0	51-72
BROMIDE	38.5	31-83
CHLORIDE	9,175	1,968-12,099
FLUORIDE	<3.00	1.7-2.2
pH	7.30	6.30-7.82
SULFATE	5,595	4,447-6,513
TOTAL DISSOLVED SOLIDS	19,600	17,010-23,050
ARSENIC	<0.006	<0.10
BARIUM	<0.04	<0.10
BERYLLIUM	<0.02	<0.05
CADMIUM	<0.0017	<0.005
CHROMIUM	<0.01	≤0.30
LEAD	<0.013	<0.05
MERCURY	<0.002	≤0.0017
SELENIUM	<0.006	<0.05
SILICA	12.4	5.6-14
SILVER	0.013	<0.10
IODIDE	<2.00	≤2.0
NITRATE AS (N)	<0.10	<0.10
PHENOLICS	<0.10	<0.026
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	2.77	3.0-5.0
TOTAL ORGANIC HALOGEN	0.4315	0.06-0.64

TABLE 7-1.4
H-05b, CULEBRA
ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	33.9	28-35
CALCIUM	1,490	1,205-1,875
IRON	<2.0	1.8-3.2
LITHIUM	0.80	0.6-1.3
MAGNESIUM	1,880	1,586-2,094
POTASSIUM	1085	1,014-1,362
SODIUM	49,800	44,526-55,955
ALKALINITY	31.1	39-47
BROMIDE	68.2	24-99
CHLORIDE	86,050	84,085-91,835
FLUORIDE	<3.0	0.7-1.2
pH	7.06	6.88-7.11
SULFATE	9,085	5,914-7,646
TOTAL DISSOLVED SOLIDS	157,000	142,508-164,093
ARSENIC	<0.10	<0.1
BARIUM	<0.02	<0.5
BERYLLIUM	<0.02	<0.05
CADMIUM	<0.0018	≤0.11
CHROMIUM	<0.005	≤0.3
LEAD	<0.013	≤1.0
MERCURY	<0.002	≤0.0005
SELENIUM	<0.05	≤7.3
SILICA	5.43	<21
SILVER	0.024	≤0.1
IODIDE	1.82	<2.0
NITRATE AS (N)	0.27	≤0.4
PHENOLICS	<0.10	≤0.51
PHOSPHATE AS (P)	<0.02	<0.13
TOTAL ORGANIC CARBON	<0.5	≤4.0
TOTAL ORGANIC HALOGEN	0.58	≤7.6

TABLE 7-1.5
H-06b, CULEBRA
ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	9.15	7.7-10.7
CALCIUM	2,390	1,702-2,138
IRON	<2.00	0.2-0.6
LITHIUM	7.50	0.3-0.7
MAGNESIUM	1,110	791-1,085
POTASSIUM	463	330-556
SODIUM	19,700	14,230-17,710
ALKALINITY	75.3	91-101
BROMIDE	24.4	12-62
CHLORIDE	35,400	28,816-34,462
FLUORIDE	<3.00	1.2-1.5
pH	6.99	6.18-7.37
SULFATE	3,402	3,093-3,527
TOTAL DISSOLVED SOLIDS	62,250	56,831-64,569
ARSENIC	<0.005	<0.5
BARIUM	0.04	<0.1
BERYLLIUM	<0.02	0.05
CADMIUM	<0.001	<0.05
CHROMIUM	<0.005	0.22-0.45
LEAD	<0.013	≤0.83
MERCURY	<0.0002	≤0.0012
SELENIUM	<0.005	≤1.3
SILICA	15.3	8.3-25
SILVER	<0.015	≤0.1
IODIDE	<2.0	<2.0
NITRATE AS (N)	<0.20	≤0.2
PHENOLICS	<0.10	0.004-0.016
PHOSPHATE AS (P)	<0.02	≤0.02
TOTAL ORGANIC CARBON	0.73	≤7.0
TOTAL ORGANIC HALOGEN	0.50	0.16-3.0

TABLE 7-1.6
H-09b, CULEBRA
ROUND 5 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	<0.13	0.5-0.9
CALCIUM	634	554-672
IRON	<0.5	≤0.11
LITHIUM	0.15	0.15-0.23
MAGNESIUM	144	128-155
POTASSIUM	6.49	6.8-8.6
SODIUM	131	96-163
ALKALINITY	93.8	120
BROMIDE	<2.00	0.5-1.3
CHLORIDE	172.5	155-210
FLUORIDE	<3.00	2.5-3.7
pH	7.17	6.99-7.81
SULF E	2,075	1,382-1,918
TOTAL DISSOLVED SOLIDS	2,545	3,091-3,409
ARSENIC	<0.006	<0.01
BARIUM	0.011	<0.2
BERYLLIUM	<0.005	<0.05
CADMIUM	<0.0013	≤0.05
CHROMIUM	<0.01	<0.1
LEAD	<0.013	<0.50
MERCURY	<0.002	≤0.0041
SELENIUM	<0.006	<0.5
SILICA	28.4	12-30
SILVER	<0.013	≤0.1
IODIDE	<2.00	<2.0
NITRATE AS (N)	0.18	0.11-0.5
PHENOLICS	<0.18	<0.05
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	<0.5	≤3.0
TOTAL ORGANIC HALOGEN	0.06	≤0.22

TABLE 7-1.7
H-11b3, CULEBRA
ROUND 8 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	26.4	29-31
CALCIUM	1,685	1,329-1,655
IRON	0.96	< 1.0
LITHIUM	0.885	0.5-0.6
MAGNESIUM	1,280	1,038-1,272
POTASSIUM	807	654-990
SODIUM	39,800	35,169-45,432
ALKALINITY	47.4	44-58
BROMIDE	46.1	18-90
CHLORIDE	65,500	57,063-72,497
FLUORIDE	< 3.00	1.0-1.2
pH	7.29	6.95-7.22
SULFATE	7,110	5,843-7,397
TOTAL DISSOLVED SOLIDS	118,580	113,705-123,095
ARSENIC	< 0.006	≤ 0.15
BARIUM	0.014	< 0.10
BERYLLIUM	0.005	< 0.05
CADMIUM	< 0.0013	0.06-0.09
CHROMIUM	< 0.01	0.32-.40
LEAD	0.013	≤ 0.60
MERCURY	< 0.002	< 0.0004
SELENIUM	< 0.006	< 0.50
SILICA	6.30	4.1-15
SILVER	< 0.013	0.1-0.2
IODIDE	< 2.00	< 2.0
NITRATE AS (N)	< 0.1	< 0.30
PHENOLICS	< 0.10	≤ 0.02
PHOSPHATE AS (P)	< 0.02	≤ 0.04
TOTAL ORGANIC CARBON	0.89	≤ 3.0
TOTAL ORGANIC HALOGEN	0.91	≤ 1.5

TABLE 7-1.8
H-14, CULEBRA
ROUND 7 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	9.81	11
CALCIUM	1,627	1,504-2,129
IRON	1.20	0.1-0.8
LITHIUM	0.47	.039-0.56
MAGNESIUM	497	451-613
POTASSIUM	224	233-257
SODIUM	3,360	2,750-4,184
ALKALINITY	32.8	35-43
BROMIDE	10.9	9-18
CHLORIDE	8,872	6,954-9,779
FLUORIDE	<3.00	0.1-2.6
pH	7.54	5.89-8.50
SULFATE	2,825	1,209-2,291
TOTAL DISSOLVED SOLIDS	18,925	14,066-19,867
ARSENIC	<0.006	<0.05
BARIUM	0.041	<0.05
BERYLLIUM	<0.014	<0.05
CADMIUM	<0.0022	≤0.05
CHROMIUM	<0.01	0.2-0.4
LEAD	<0.013	≤0.5
MERCURY	<0.002	≤0.0004
SELENIUM	<0.006	<0.05
SILICA	11.00	5.5-14
SILVER	<0.013	≤0.1
IODIDE	<2.00	<2.0
NITRATE AS (N)	<.10	≤0.40
PHENOLICS	<0.10	0.068-0.14
PHOSPHATE AS (P)	<0.02	≤0.05
TOTAL ORGANIC CARBON	1.27	≤2.0
TOTAL ORGANIC HALOGEN	0.11	0.08-1.1

TABLE 7-1.9
WIPP-19, CULEBRA
ROUND 9 COMPARISON TO BACKGROUND CHARACTERIZATION

PARAMETER	1994 AVERAGE CONCENTRATION mg/l	BACKGROUND CONCENTRATION INTERVAL mg/l
BORON	35.6	27-34
CALCIUM	2,110	1,441-1,919
IRON	2.46	≤2.0
LITHIUM	0.59	0.3-1.1
MAGNESIUM	1335	961-2,239
POTASSIUM	670	565-913
SODIUM	32,900	23,962-32,658
ALKALINITY	44.4	51-70
BROMIDE	45.3	22-126
CHLORIDE	41,000	33,201-54,520
FLUORIDE	<3.00	0.8-1.1
pH	7.29	6.75-7.33
SULFATE	6,790	5,097-5,763
TOTAL DISSOLVED SOLIDS	76,450	68,389-103,151
ARSENIC	<0.006	<0.5
BARIUM	<0.02	<0.50
BERYLLIUM	<0.03	<0.50
CADMIUM	<0.0016	<0.50
CHROMIUM	<0.005	≤2.0
LEAD	<0.013	<5.0
MERCURY	<0.002	<0.002
SELENIUM	<0.000	<0.50
SILICA	7.25	≤4.40
SILVER	<0.015	<1.0
IODIDE	<2.00	<2.0
NITRATE AS (N)	<0.10	≤0.12
PHENOLICS	<0.1	≤0.019
PHOSPHATE AS (P)	<0.02	≤0.03
TOTAL ORGANIC CARBON	1.10	2-7
TOTAL ORGANIC HALOGEN	.039	0.57-3.2

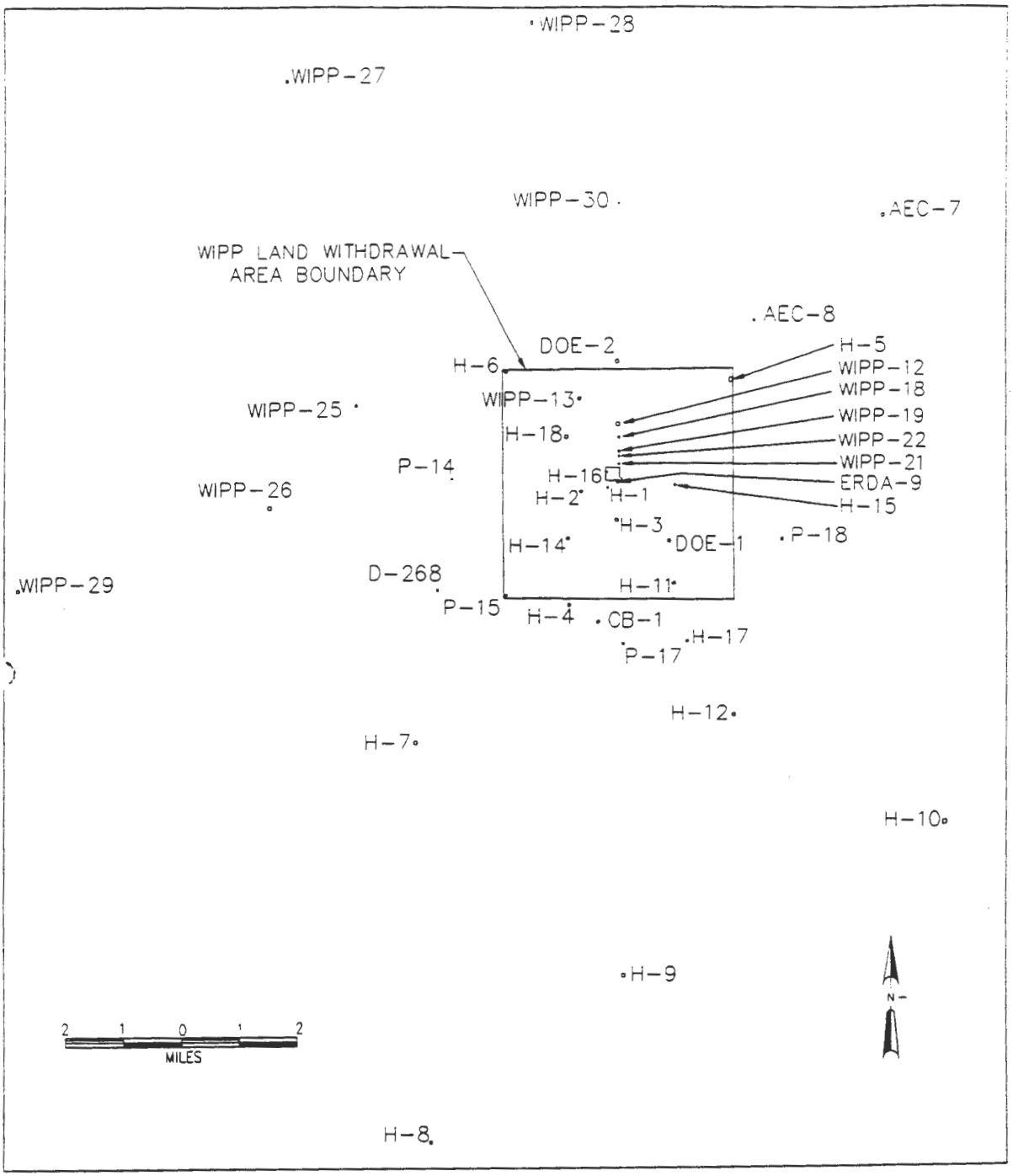


FIGURE 7-2 GROUND WATER LEVEL SURVEILLANCE WELLS

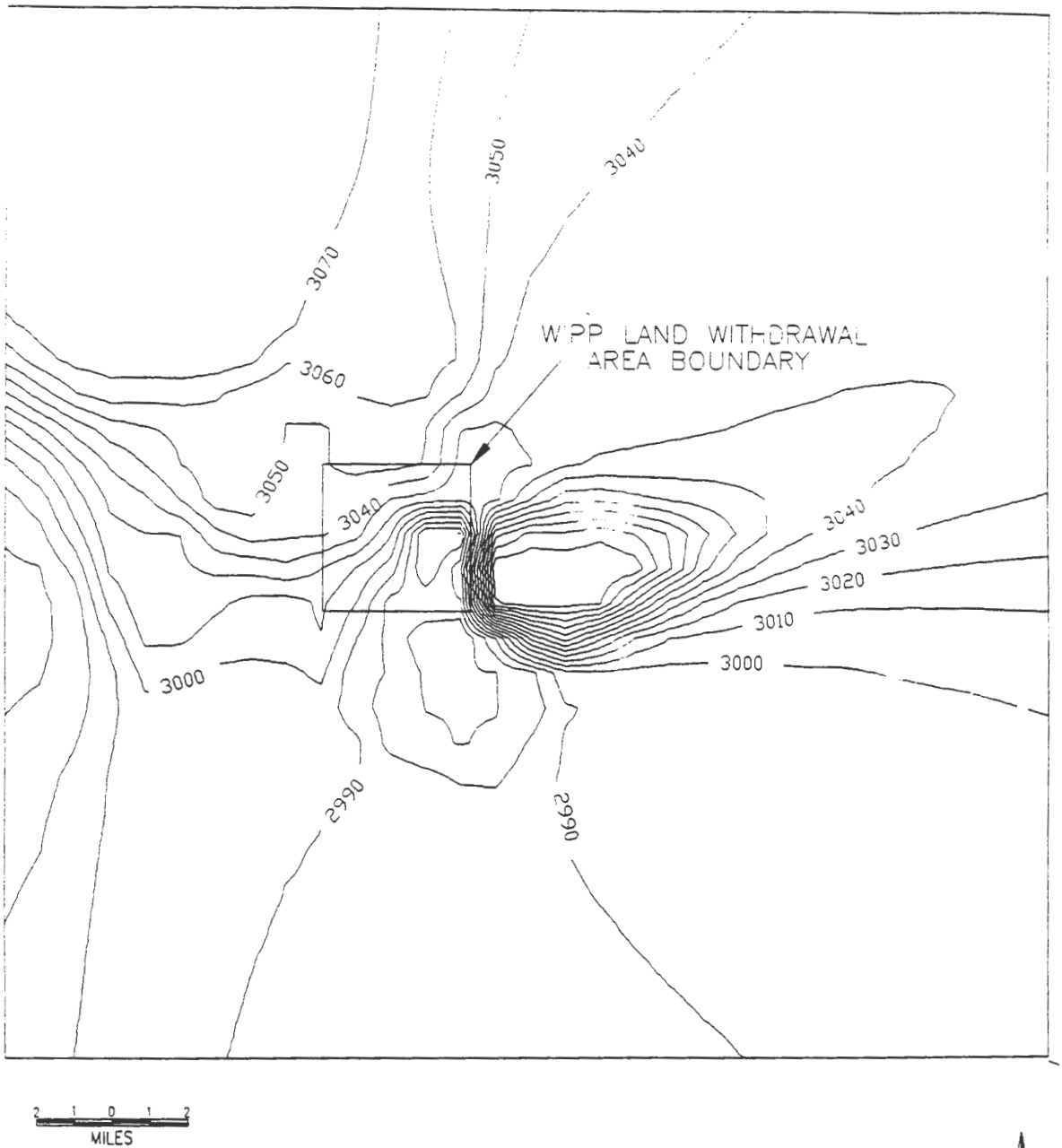


FIGURE 7-3 POTENTIOMETRIC SURFACE OF THE CULEBRA DOLOMITE MEMBER OF THE RUSTLER FORMATION NEAR THE WIPP SITE AS OF 12-94

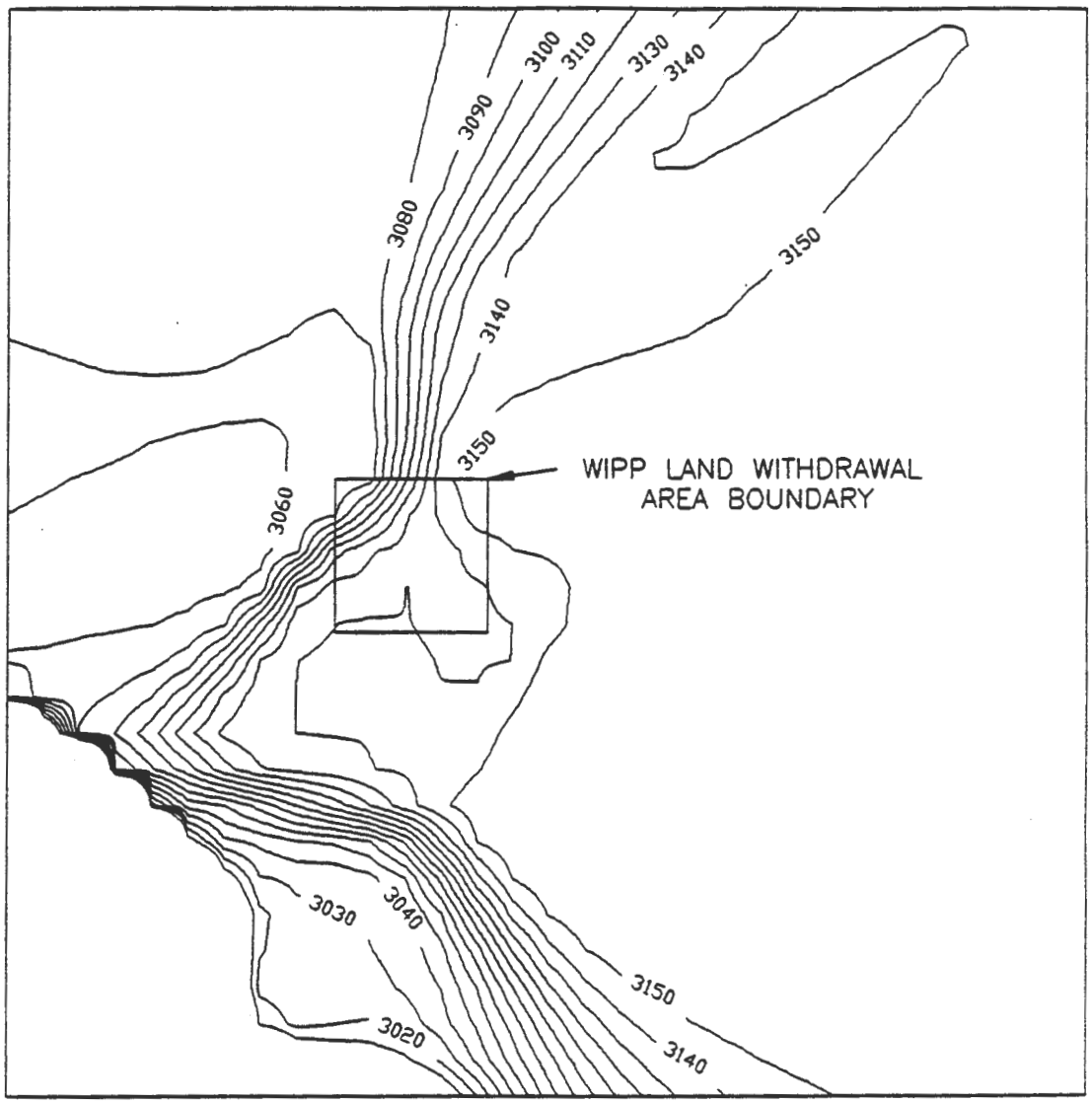


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FIGURE 7-4 POTENTIOMETRIC SURFACE OF THE MAGENTA DOLOMITE MEMBER OF THE RUSTLER FORMATION NEAR THE WIPP SITE AS OF 12-94

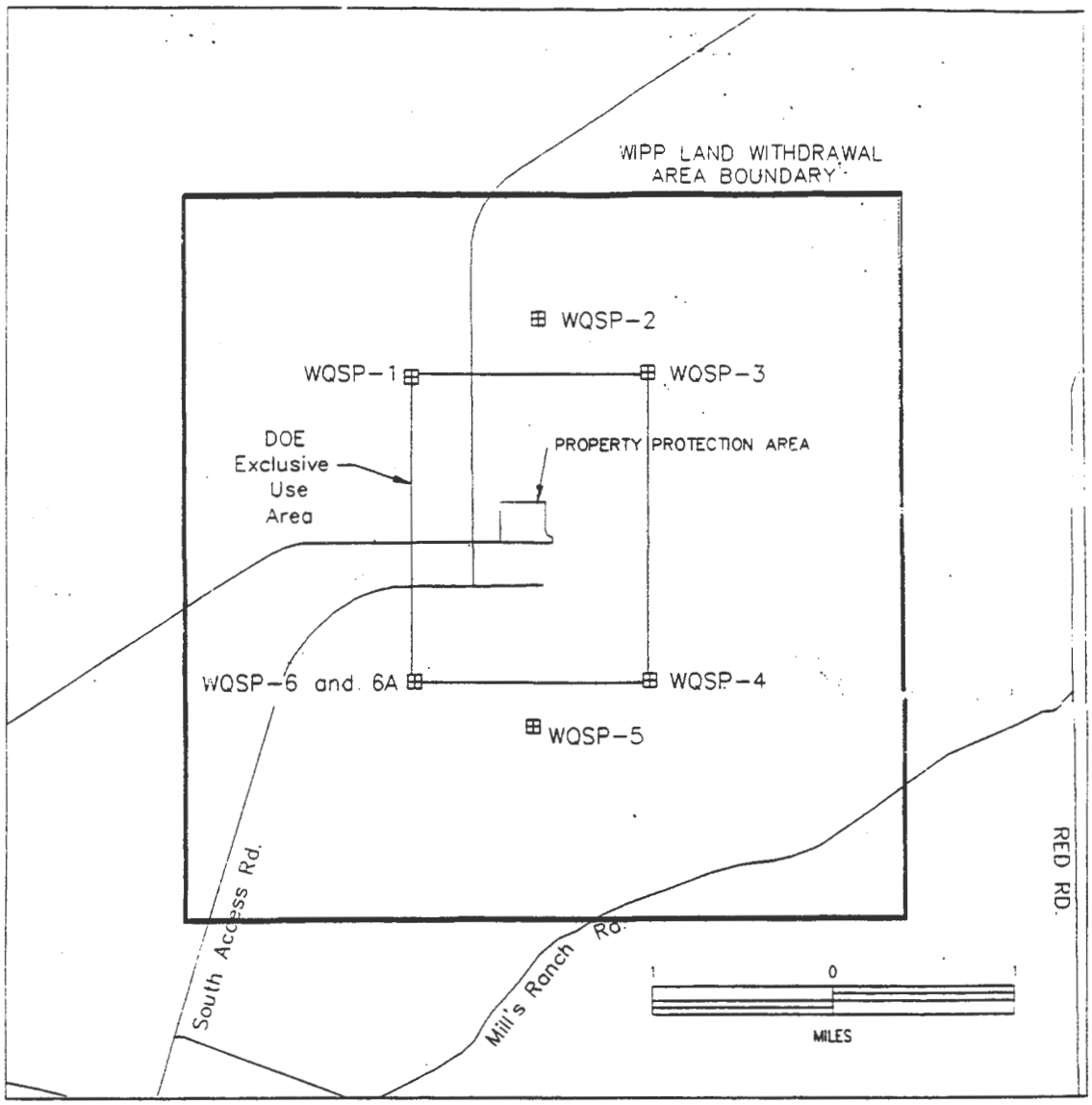

FIGURE 7-5 NEW MONITORING WELL LOCATIONS

⊞ WELL PAD LOCATIONS
(WELL PAD -- 100'X100')

CHAPTER 8

QUALITY ASSURANCE

Chapter 8
Quality Assurance

The purpose of the quality assurance (QA) program is to ensure that processes, activities, and products that potentially impact health, safety, and the environment are appropriately planned, implemented, and assessed. The goal of the QA program is twofold: (1) to provide confidence that the data used in demonstrating regulatory compliance are adequate and (2) to promote continuous improvement in WIPP's operations. The QA program is successful when risks and environmental impacts are identified and minimized, and when safety, reliability, and performance are maximized.

This chapter outlines the QA processes applicable to the radiological and nonradiological environmental monitoring programs. The QA Program is used to monitor the reliability, accuracy, and precision of environmental data, and to detect and correct problems in the sample collection, preparation, analysis, and the data evaluation phases.

A comprehensive QA program has been implemented to ensure that the data collected reflect selected parameters of the environment. The data have been obtained prior to commencement of operations, providing a sound baseline for comparison with operational-phase data. The data will be evaluated to determine future impacts of the WIPP on the environment.

The focus of this program includes the following areas:

- Sample collection at specified locations in accordance with approved procedures. These procedures are based on established and accepted practices.

- Procedure review and revision to minimize uncertainties introduced through sampling and analysis, while maintaining comparability and continuity between past and future data.

- Verification of data through a continuing program of analytical laboratory quality control, including the performance of interlaboratory cross-checks, duplicate and split sample radiological analysis, and sample splits provided to the EEG, and to the NMED.

Quality Assurance (continued)

Requirements and guidance sources for QA Program content include the following: Title 10 CFR 830.120, *Nuclear Safety Management, Quality Assurance*; (CAO-94-1012), *DOE Carlsbad Area Office Quality Assurance Program Description*; (ASME NQA-1), *Quality Assurance Program Requirements for Nuclear Facilities*; (DOE Order 5700.6C), *Quality Assurance*, (DOE/EH-0173T), *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, and SW-846, *Test Methods for Evaluating Solid Waste*.

8.1 Sample Collection Methodologies

The WID follows approved sampling plans and procedures in the collection and handling of samples used in environmental monitoring. The sampling plans and procedures specify proper sampling techniques for the particular sample medium.

Elements of sample QA include specifying the following:

- Method used to select sampling sites
- Specific sampling methods to be used
- Containers, preservatives, transportation, and storage requirements
- Labeling requirements
- Preparatory measures for sampling equipment and containers
- Preservation methods and allowable hold times, including transportation
- Sample chain-of-custody
- Documentation used to record sample history, sampling conditions, and analyses

Sampling procedures are contained in the following documents:

- *WIPP Groundwater Monitoring Program Plan and Procedure Manual* (WP 02-1)
- *WIPP Environmental Procedures Manual* (WP 02-3)
- *Nonradioactive Hazardous Materials Environmental Compliance Manual* (WP 02-5)
- *Quality Assurance Project Plan for WIPP Site Effluent and Hazardous Materials Sampling* (WP 02-EM1)
- *WIPP Site Effluent and Hazardous Materials Sampling Plan* (WP 02-EM2)
- *WIPP VOC Operating Procedures Manual* (WP 12-VC)
- *Quality Assurance Project Plan for Sampling Emissions of Radionuclides to the Ambient Air at the WIPP* (DOE-WIPP 93-042)

8.1 Sample Collection Methodologies (continued)

Chapter 11 of the EMP defines the policies and practices that are followed to ensure the data are accurate, complete, representative, and comparable. The data collected in the Nonradiological Environmental Surveillance monitoring programs are analyzed as stated in DOE/EH-0023 (Corley et al., 1981). Section 8.0 of the EMP discusses, at length, the statistical procedures used to analyze the data.

8.2 Revision of Procedures

Written procedures are essential in providing instruction to field personnel for sample collection. As data are collected, and records are generated, these procedures form the basis for an auditable program. The Q&RA Department and the Environmental Compliance Assessment Program (ECAP) periodically conduct assessments of environmental monitoring activities to determine the degree of compliance and effectiveness in implementation of the procedures.

In addition to independent assessment, one of the responsibilities of data collection personnel is to assess collection and analysis methodologies on a routine and ongoing basis. Field procedures, analytical procedures, and laboratory methodologies are periodically assessed for adequacy and effectiveness. Processes that require improvement are modified according to established document control procedures. The EEG and the NMED act as the performance based check-point to ensure that radiological sampling procedures are adequately implemented and that data are comparable among the WIPP, EEG, and the NMED samples.

8.3 Interlaboratory Comparisons

The WIPP is in the process of upgrading its analytical capabilities. As part of the process, each LLCL staff member received over 184 hours of training in detector theory, gamma spectroscopy, and gamma spectroscopy software. To support the LLCL, the WIPP is developing a radiochemistry laboratory. Environmental sample preparation and radiochemical separation will be performed in the laboratory. In 1994, WIPP personnel had the opportunity to obtain valuable experience with radiochemical procedures and methods through collaborative work conducted, with the EEG Radiochemistry Laboratory in Carlsbad, New Mexico.

8.3 Interlaboratory Comparisons (continued)

The collaborative efforts resulted in the completion of three tasks:

1. Testing of radiochemical separation procedures for americium, plutonium, thorium, and strontium.

2. Comparison of radionuclide mounting methods.

3. Study of liquid scintillation quenching effect of salt loading.

Sample preparation was conducted at the EEG laboratory and sample counting was done at the WIPP LLCL.

Results from the testing of separation procedures and comparison of mounting methods were used by the WIPP LLCL personnel for the selection of radiochemistry methods and procedures. The study of the quenching effect of salt loading on liquid scintillation (LS) counting efficiency provided valuable information on the types of corrections which need to be made when performing LS counting on samples containing salt content. The results of the salt loading study were presented at the 40th Conference on Bioassay, Analytical, and Environmental Radiochemistry in October 1994. Staff from the WIPP LLCL participated in both the DOE Environmental Measurements Laboratory Quality Assessment Program (DOE-EML QAP) and the Environmental Protection Agency's Performance Evaluation Study Program (EPA PESP). Participation in these programs provides a means for LLCL staff to upgrade analytical methodology, as well as provide hands-on experience in analysis of environmental samples for radionuclides. These programs provide the simulated environmental samples which contain known amounts of one or more radionuclides. The samples are prepared and distributed to laboratories. Using standard analytical methods specific to that laboratory, the samples are then statistically analyzed and compared with known values. Results are reported electronically.

Because the LLCL lacks sample preparation facilities, performing analysis on a wide variety of sample matrices is limited. In 1994, these sample matrices included air filters and water samples. The analysis performed on the air filters were gross alpha/beta and gamma spectroscopy. The analysis performed on the water matrix were tritium and gamma spectroscopy. It is expected that in 1995, a 550 square-foot laboratory space will be made available for radiological sample preparation

8.3 Interlaboratory Comparisons (continued)

and chemical separation. The LLCL will be renamed the Radiochemistry Laboratory (RL) due to the commencement of radiochemical analytical capabilities.

Neither the DOE EML-QAP nor the EPA-PESP set criteria for judging the "pass/fail" status of a laboratory. The following standard, from the draft ANSI N13.30, *Performance Criteria for Radiobioassay*, is used by the staff of WIPP LLCL.

$$-0.25 \leq Br \leq 0.5$$

Relative bias is calculated using the following equation:

$$Br = (\text{reported results} - \text{known value}) \div (\text{known value})$$

8.4 Analytical Laboratory Quality Assurance and Quality Control

During CY 1994 the WIPP extended contracts to the following analytical laboratories: Ross Analytical Services Inc. in Strongsville, Ohio; Accu-Labs in Golden, Colorado; and Datachem Laboratories in Salt Lake City, Utah. The contract laboratories are required to follow established Quality Assurance/Quality Control (QA/QC) procedures as specified in the contract statement of work. Successful bidders performing environmental analyses are required to be on the Qualified Suppliers List (QSL) and must undergo program reviews and assessments.

Laboratory QA/QC includes the following:

- Reviewing and approving of the laboratory QA plan
- Qualifying and training staff
- Specifying acceptable tolerances in data quality
- Performing internal laboratory QC
- Analyzing blind samples
- Calibrating and maintaining analytical equipment
- Reporting on the performance of measurement systems and data quality
- Reporting the performance of demonstration programs

8.5 Data Handling

Field data are collected and recorded in data books, organized by sample location and sampling round. Separate data books are prepared for sampling, field notes, and contract laboratory data. If samples are sent to more than one laboratory for analysis, then each lab has its own data book. Samples are collected and sent to the laboratory for analysis, accompanied by QC samples. Analytical results are verified through specifying method blanks, duplicates, spikes, and trip blanks. The Principle Investigator (PI) reviews the QC data against specified limits to determine whether the data set is suitable for inclusion in the report. The data are reported in the ASER.

8.6 Records Management

Documents and records generated under the CAO QA program are specified, prepared, reviewed, approved, controlled, and maintained in accordance with the *Carlsbad Area Office Quality Assurance Program Description (QAPD)*. The QAPD provides a single reference for all WIPP project participants in meeting records management requirements as specified in DOE orders and regulations. Further records management requirements and procedures are provided in the *Carlsbad Area Office Information Management Plan* (CAO-94-1001).

All original records are maintained in fire resistant file cabinets until they are transmitted to the CAO Central Records Facility (CRF) for permanent filing. All records, including raw data, calculations, computer programs, or other data manipulation media are subject to review and verification under the WIPP QAP and the ECAP. The Environmental Monitoring Section is responsible for validating these records before transmitting them to the CAO Central Records Facility in accordance with an approved Records Inventory Disposition Schedule (RIDS).

Records (i.e., reports of analyses and sample receipt forms transmitted by contract analytical laboratories) are dated upon receipt and a copy made for QC review. Specific record and data management procedures including those referencing data manipulations are implemented according to the approved quality assurance project plan or work plan.

The WIPP complies with the *National Emission Standards for Hazardous Air Pollutants* (NESHAP) record-keeping requirements issued under 40 CFR 61, Subpart H, which addresses atmospheric radionuclide emissions. Unless regulations are amended in the future, records developed pursuant to these criteria (i.e., Medical, Health and Safety Records) will be maintained at least 30 years as specified in DOE Order 1324.2A, *Records Disposition* (DOE, 1992), Chapter V, Attachment 1, Schedule 25.

8.6 Records Management (continued)

Consistent record keeping for all aspects of the Environmental Monitoring Programs is a part of QA requirements. The EMP lists the required records, reports, and laws, regulations, or DOE Orders that contain the requirements.

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CHAPTER 9

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Chapter 9
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APPENDIX A

1994

RADIOLOGICAL ENVIRONMENTAL

SAMPLE ANALYSIS

APPENDIX A1

AIR

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SMR Air Sampling 1st Quarter Smith Ranch	Beryllium-7	2.60E-07	2.90E-07
	Potassium-40	1.20E-08	1.20E-08
	Cobalt-60	6.40E-10	6.20E-10
	Cesium-137	-2.8E-10	6.00E-10
	Lead-210	7.60E-08	1.50E-08
	Radium-226	1.40E-08	9.00E-09
	Radium-228	2.70E-09	2.40E-09
	Americium-241	3.20E-11	3.80E-13
	Thorium-228	9.70E-10	8.10E-10
	Thorium-230	8.30E-10	8.50E-10
	Thorium-232	4.10E-10	4.70E-10
	Uranium-233/234	1.90E-10	4.60E-11
	Uranium-235	1.20E-11	2.00E-11
	Uranium-238	1.70E-10	4.00E-11
	Plutonium-238	4.90E-12	1.70E-13
	Plutonium-239/240	9.70E-12	1.30E-13
	Plutonium-241	-1.5E-08	3.30E-09
	Strontium-90	-2.0E-10	4.80E-10
	Polonium-210	1.20E-08	5.20E-10
AC-SMR Air Sampling 2nd Quarter Smith Ranch	Beryllium-7	2.20E-07	1.90E-07
	Potassium-40	1.20E-08	1.10E-08
	Cobalt-60	-5.5E-10	9.10E-10
	Cesium-137	-1.6E-10	8.70E-10
	Lead-210	2.40E-08	1.40E-08
	Radium-226	3.00E-08	1.50E-08
	Radium-228	2.90E-09	2.80E-09
	Americium-241	3.70E-10	7.70E-13
	Thorium-228	1.40E-10	1.00E-10

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SMR Air Sampling 2nd Quarter Smith Ranch (continued)	Thorium-230	1.70E-09	3.30E-10
	Thorium-232	7.90E-11	1.00E-10
	Uranium-233/234	2.40E-10	6.50E-11
	Uranium-235	1.90E-11	2.30E-11
	Uranium-238	1.50E-10	5.20E-11
	Plutonium-238	1.70E-11	2.00E-13
	Plutonium-239/240	1.70E-11	2.00E-13
	Plutonium-241	-3.7E-09	3.10E-09
	Strontium-90	-1.0E-10	6.00E-10
	Polonium-210	1.00E-08	1.40E-09
AC-SMR Air Sampling 3rd Quarter Smith Ranch	Beryllium-7	1.70E-07	6.60E-08
	Potassium-40	1.10E-08	1.60E-08
	Cobalt-60	2.20E-10	5.90E-10
	Cesium-137	-5.1E-10	7.60E-10
	Lead-210	7.20E-08	1.40E-08
	Radium-226	1.20E-08	9.70E-09
	Radium-228	3.80E-09	2.70E-09
	Americium-241	2.10E-10	1.40E-12
	Thorium-228	4.10E-11	8.90E-11
	Thorium-230	2.70E-10	1.40E-10
	Thorium-232	9.60E-11	8.00E-11
	Uranium-233/234	3.30E-10	5.90E-11
	Uranium-235	1.60E-11	1.90E-11
	Uranium-238	3.50E-10	6.00E-11
	Plutonium-238	-4.0E-12	1.70E-13
	Plutonium-239/240	1.90E-11	2.00E-13
	Plutonium-241	-1.4E-08	2.70E-09
	Strontium-90	-4.0E-10	5.40E-10
	Polonium-210	1.20E-08	8.00E-10

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SMR Air Sampling 4th Quarter Smith Ranch	Beryllium-7	1.80E-07	4.00E-08
	Potassium-40	1.70E-09	1.10E-08
	Cobalt-60	-4.9E-10	6.90E-10
	Cesium-137	2.00E-10	7.00E-10
	Lead-210	4.00E-08	1.30E-08
	Radium-226	4.60E-09	1.40E-08
	Radium-228	3.50E-09	2.70E-09
	Americium-241	1.40E-10	4.30E-13
	Thorium-228	8.70E-11	7.50E-11
	Thorium-230	2.60E-10	1.00E-10
	Thorium-232	1.60E-10	7.30E-11
	Uranium-233/234	1.40E-10	4.10E-11
	Uranium-235	6.00E-12	1.20E-11
	Uranium-238	1.20E-10	3.70E-11
	Plutonium-238	0.0E+0	0.0E+0
	Plutonium-239/240	1.20E-11	1.50E-13
	Plutonium-241	5.00E-09	1.80E-09
	Strontium-90	7.10E-11	5.40E-10
	Polonium-210	7.90E-09	1.00E-09
AC-WEE Air Sampling 1st Quarter WIPP East	Beryllium-7	2.80E-07	2.90E-07
	Potassium-40	2.30E-08	1.40E-08
	Cobalt-60	-3.1E-10	6.10E-10
	Cesium-137	2.90E-11	6.30E-10
	Lead-210	6.00E-08	1.40E-08
	Radium-226	6.30E-09	1.50E-08
	Radium-228	3.30E-09	2.10E-09
	Americium-241	1.00E-11	3.10E-13
	Thorium-228	5.20E-11	8.40E-11
	Thorium-230	2.90E-10	1.20E-10

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WEE Air Sampling 1st Quarter WIPP East (continued)	Thorium-232	1.50E-10	8.20E-11
	Uranium-233/234	1.50E-10	5.20E-11
	Uranium-235	2.60E-11	2.40E-11
	Uranium-238	9.10E-11	4.20E-11
	Plutonium-238	-3.0E-12	9.70E-14
	Plutonium-239/240	2.00E-11	1.50E-13
	Plutonium-241	-9.7E-09	2.00E-09
	Strontium-90	3.10E-11	5.20E-10
	Polonium-210	1.30E-08	8.40E-10
AC-WEE Air Sampling 2nd Quarter WIPP East	Beryllium-7	1.60E-07	1.30E-07
	Potassium-40	3.40E-09	1.20E-08
	Cobalt-60	3.80E-10	6.50E-10
	Cesium-137	5.10E-10	7.30E-10
	Lead-210	4.10E-08	1.30E-08
	Radium-226	2.10E-09	1.20E-08
	Radium-228	2.20E-09	2.30E-09
	Americium-241	6.10E-11	3.50E-13
	Thorium-228	1.70E-10	9.50E-11
	Thorium-230	5.60E-10	1.60E-10
	Thorium-232	1.30E-10	8.70E-11
	Uranium-233/234	3.40E-10	6.00E-11
	Uranium-235	3.40E-11	2.60E-11
	Uranium-238	2.50E-10	5.20E-11
	Plutonium-238	-1.0E-12	1.20E-13
	Plutonium-239/240	4.70E-11	2.40E-13
	Plutonium-241	-7.9E-09	2.10E-09
	Strontium-90	1.20E-09	6.60E-10

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WEE Air Sampling 2nd Quarter WIPP East (continued)	Polonium-210	9.90E-09	6.50E-10
AC-WEE Air Sampling 3rd Quarter WIPP East	Beryllium-7	1.70E-07	6.60E-08
	Potassium-40	7.00E-09	1.40E-08
	Cobalt-60	-5.0E-11	6.30E-10
	Cesium-137	3.80E-11	6.90E-10
	Lead-210	5.80E-08	1.50E-08
	Radium-226	1.10E-08	1.60E-08
	Radium-228	3.30E-09	2.50E-09
	Americium-241	5.40E-11	4.50E-13
	Thorium-228	6.90E-11	6.90E-11
	Thorium-230	4.30E-10	1.20E-10
	Thorium-232	1.00E-10	5.60E-11
	Uranium-233/234	2.30E-10	6.30E-11
	Uranium-235	-1.0E-11	2.90E-11
	Uranium-238	1.00E-10	4.60E-11
	Plutonium-238	0.0E+0	1.40E-13
	Plutonium-239/240	5.90E-12	1.40E-13
	Plutonium-241	-4.7E-09	2.10E-09
	Strontium-90	-1.0E-11	4.60E-10
	Polonium-210	2.60E-09	6.70E-10
AC-WEE Air Sampling 4th Quarter WIPP East	Beryllium-7	1.70E-07	3.70E-08
	Potassium-40	5.80E-09	1.00E-08
	Cobalt-60	-4.0E-10	7.30E-10
	Cesium-137	7.80E-10	8.00E-10
	Lead-210	4.20E-08	1.30E-08
	Radium-226	2.80E-08	1.40E-08
	Radium-228	2.70E-09	2.60E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WEE Air Sampling 4th Quarter WIPP East (continued)	Americium-241	5.70E-11	2.80E-13
	Thorium-228	4.70E-11	5.90E-11
	Thorium-230	2.40E-10	7.80E-11
	Thorium-232	1.10E-10	4.80E-11
	Uranium-233/234	1.80E-10	5.20E-11
	Uranium-235	3.20E-12	1.40E-11
	Uranium-238	8.00E-11	3.00E-11
	Plutonium-238	4.80E-12	2.10E-13
	Plutonium-239/240	-5.0E-12	9.00E-14
	Plutonium-241	9.90E-09	2.80E-09
	Strontium-90	-2.0E-10	4.90E-10
	Polonium-210	7.50E-09	9.60E-10
AC-WFF Air Sampling 1st Quarter WIPP Far Field	Beryllium-7	1.60E-07	2.80E-07
	Potassium-40	9.90E-09	1.40E-08
	Cobalt-60	1.70E-10	6.20E-10
	Cesium-137	-2.3E-10	6.50E-10
	Lead-210	3.90E-08	1.20E-08
	Radium-226	6.80E-09	1.30E-08
	Radium-228	2.70E-09	2.20E-09
	Americium-241	-1.0E-11	1.90E-13
	Thorium-228	9.10E-11	6.30E-11
	Thorium-230	4.00E-10	1.30E-10
	Thorium-232	9.90E-11	5.80E-11
	Uranium-233/234	1.60E-10	4.90E-11
	Uranium-235	9.30E-12	2.00E-11
	Uranium-238	5.50E-11	3.00E-11
	Plutonium-238	5.00E-12	1.20E-13
	Plutonium-239/240	5.00E-12	9.90E-14
	Plutonium-241	-5.1E-09	1.90E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WFF Air Sampling 1st Quarter WIPP Far Field (continued)	Strontium-90	3.50E-10	5.40E-10
	Polonium-210	1.10E-08	8.10E-10
AC-WFF Air Sampling 2nd Quarter WIPP Far Field	Beryllium-7	2.10E-07	1.80E-07
	Potassium-40	4.10E-08	1.40E-08
	Cobalt-60	-1.0E-10	6.70E-10
	Cesium-137	4.20E-10	6.60E-10
	Lead-210	3.60E-08	1.30E-08
	Radium-226	9.60E-09	1.40E-08
	Radium-228	3.00E-09	2.40E-09
	Americium-241	-5.9E-09	2.90E-12
	Thorium-228	6.10E-11	6.60E-11
	Thorium-230	4.40E-10	1.30E-10
	Thorium-232	1.10E-10	6.40E-11
	Uranium-233/234	9.30E-09	3.60E-10
	Uranium-235	6.70E-10	1.10E-10
	Uranium-238	1.40E-09	3.60E-10
	Plutonium-238	6.70E-12	9.30E-14
	Plutonium-239/240	-6.5E-09	2.10E-12
	Plutonium-241	-7.8E-08	3.00E-09
	Strontium-90	2.50E-10	5.80E-10
	Polonium-210	1.20E-08	7.70E-10
AC-WFF Air Sampling 3rd Quarter WIPP Far Field	Beryllium-7	2.30E-07	6.90E-08
	Potassium-40	9.20E-09	1.30E-08
	Cobalt-60	6.40E-10	5.70E-10
	Cesium-137	1.90E-10	6.80E-10
	Lead-210	5.30E-08	1.40E-08
	Radium-226	4.70E-09	1.40E-08
	Radium-228	1.90E-09	2.30E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WFF Air Sampling 3rd Quarter WIPP Far Field (continued)	Americium-241	4.40E-11	4.00E-13
	Thorium-228	1.00E-10	7.90E-11
	Thorium-230	4.80E-10	1.70E-10
	Thorium-232	5.60E-11	8.40E-11
	Uranium-233/234	-2.0E-11	3.00E-11
	Uranium-235	-1.0E-11	1.90E-11
	Uranium-238	-2.0E-11	2.80E-11
	Plutonium-238	5.20E-12	7.10E-14
	Plutonium-239/240	2.30E-11	1.70E-13
	Plutonium-241	-7.7E-09	1.80E-09
	Strontium-90	1.30E-10	6.60E-10
	Polonium-210	1.10E-08	8.10E-10
AC-WFF Air Sampling 4th Quarter WIPP Far Field	Beryllium-7	1.60E-07	3.70E-08
	Potassium-40	1.20E-08	8.10E-09
	Cobalt-60	1.90E-10	6.10E-10
	Cesium-137	-2.0E-11	8.00E-10
	Lead-210	3.60E-08	1.10E-08
	Radium-226	1.20E-08	1.10E-08
	Radium-228	1.40E-09	2.80E-09
	Americium-241	9.60E-11	3.20E-13
	Thorium-228	1.30E-10	6.40E-11
	Thorium-230	2.80E-10	8.20E-11
	Thorium-232	8.90E-11	4.90E-11
	Uranium-233/234	1.90E-10	4.70E-11
	Uranium-235	-3.0E-12	2.00E-11
	Uranium-238	1.10E-10	3.40E-11
	Plutonium-238	-3.0E-12	1.00E-13
	Plutonium-239/240	-5.0E-12	7.00E-14
	Plutonium-241	5.50E-09	1.60E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WFF Air Sampling 4th Quarter WIPP Far Field (continued)	Strontium-90	-1.0E-10	5.50E-10
	Polonium-210	6.00E-09	7.80E-10
AC-SEC Air Sampling 1st Quarter South East Control	Beryllium-7	1.80E-07	2.90E-07
	Potassium-40	4.60E-09	1.30E-08
	Cobalt-60	5.60E-10	5.80E-10
	Cesium-137	5.70E-10	6.90E-10
	Lead-210	3.70E-08	1.20E-08
	Radium-226	6.90E-09	1.40E-08
	Radium-228	2.60E-09	2.10E-09
	Americium-241	6.00E-11	4.10E-13
	Thorium-228	1.10E-10	9.50E-11
	Thorium-230	5.00E-10	1.90E-10
	Thorium-232	3.20E-11	7.70E-11
	Uranium-233/234	1.90E-10	4.40E-11
	Uranium-235	-3.0E-12	1.60E-11
	Uranium-238	1.10E-10	3.40E-11
	Plutonium-238	9.10E-12	1.10E-13
	Plutonium-239/240	6.80E-12	7.70E-14
	Plutonium-241	-8.3E-09	1.60E-09
	Strontium-90	-2.0E-11	4.20E-10
	Polonium-210	6.60E-09	5.50E-10
AC-SEC Air Sampling 2nd Quarter South East Control	Beryllium-7	1.40E-07	1.60E-07
	Potassium-40	3.10E-08	1.30E-08
	Cobalt-60	2.60E-10	1.30E-09
	Cesium-137	6.40E-10	1.30E-09
	Lead-210	2.10E-08	1.70E-08
	Radium-226	4.10E-08	2.00E-08
	Radium-228	1.20E-09	4.60E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SEC Air Sampling 2nd Quarter South East Control (continued)	Americium-241	1.30E-10	5.30E-13
	Thorium-228	1.70E-10	8.70E-11
	Thorium-230	7.30E-10	1.90E-10
	Thorium-232	1.50E-10	8.70E-11
	Uranium-233/234	2.60E-10	9.20E-11
	Uranium-235	1.40E-11	1.90E-11
	Uranium-238	1.70E-10	6.60E-11
	Plutonium-238	0.0E+0	4.60E-13
	Plutonium-239/240	-6.0E-12	1.00E-13
	Plutonium-241	-2.1E-09	3.40E-09
	Strontium-90	4.60E-10	7.70E-10
	Polonium-210	5.40E-09	9.60E-10
AC-SEC Air Sampling 3rd Quarter South East Control	Beryllium-7	2.20E-07	7.60E-08
	Potassium-40	1.70E-08	1.10E-08
	Cobalt-60	-5.7E-10	8.80E-10
	Cesium-137	-3.4E-10	1.00E-09
	Lead-210	3.60E-08	1.40E-08
	Radium-226	7.00E-09	1.80E-08
	Radium-228	1.50E-09	3.50E-09
	Americium-241	1.30E-10	4.60E-13
	Thorium-228	1.30E-10	9.50E-11
	Thorium-230	1.80E-10	1.30E-10
	Thorium-232	1.70E-10	9.80E-11
	Uranium-233/234	1.70E-10	5.40E-11
	Uranium-235	-8.0E-12	2.00E-11
	Uranium-238	1.30E-10	4.30E-11
	Plutonium-238	-2.0E-11	2.00E-13
	Plutonium-239/240	2.20E-11	2.30E-13
	Plutonium-241	2.00E-09	2.50E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SEC Air Sampling 3rd Quarter South East Control (continued)	Strontium-90	1.10E-09	7.30E-10
	Polonium-210	1.10E-08	1.20E-09
AC-SEC Air Sampling 3rd Quarter South East Control 2 of 2	Beryllium-7	2.30E-07	6.70E-08
	Potassium-40	3.30E-09	1.20E-08
	Cobalt-60	1.80E-11	8.30E-10
	Cesium-137	2.40E-10	7.90E-10
	Lead-210	2.40E-08	1.20E-08
	Radium-226	6.40E-09	1.50E-08
	Radium-228	1.80E-09	3.10E-09
	Americium-241	3.20E-10	6.00E-13
	Thorium-228	1.50E-10	1.10E-10
	Thorium-230	3.20E-10	1.50E-10
	Thorium-232	1.10E-10	9.00E-11
	Uranium-233/234	1.30E-10	5.00E-11
	Uranium-235	1.00E-11	2.20E-11
	Uranium-238	1.20E-10	4.10E-11
	Plutonium-238	1.30E-11	2.00E-13
	Plutonium-239/240	3.20E-12	1.10E-13
	Plutonium-241	3.40E-09	1.80E-09
	Strontium-90	3.70E-10	5.90E-10
	Polonium-210	7.60E-09	8.40E-10
AC-SEC Air Sampling 4th Quarter South East Control	Beryllium-7	1.60E-07	3.60E-08
	Potassium-40	1.70E-08	1.20E-08
	Cobalt-60	3.30E-10	6.50E-10
	Cesium-137	-2.7E-10	7.30E-10
	Lead-210	4.90E-08	1.30E-08
	Radium-226	2.50E-08	1.30E-08
	Radium-228	2.10E-09	2.70E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-SEC Air Sampling 4th Quarter South East Control (continued)	Americium-241	1.50E-10	4.70E-13
	Thorium-228	5.10E-11	7.00E-11
	Thorium-230	2.50E-10	1.00E-10
	Thorium-232	7.60E-11	6.80E-11
	Uranium-233/234	2.80E-10	6.40E-11
	Uranium-235	3.50E-11	2.40E-11
	Uranium-238	1.20E-10	4.40E-11
	Plutonium-238	-4.0E-12	2.00E-13
	Plutonium-239/240	3.80E-12	7.50E-14
	Plutonium-241	9.50E-09	2.40E-09
	Strontium-90	-5.0E-10	4.50E-10
	Polonium-210	6.40E-09	8.50E-10
AC-MLR Air Sampling 1st Quarter Mills Ranch	Beryllium-7	-7.7E-08	3.10E-07
	Potassium-40	9.60E-09	1.30E-08
	Cobalt-60	-1.4E-10	6.50E-10
	Cesium-137	-9.6E-10	7.00E-10
	Lead-210	6.00E-08	6.00E-08
	Radium-226	4.90E-09	1.10E-08
	Radium-228	2.10E-09	2.30E-09
	Americium-241	2.90E-11	3.40E-13
	Thorium-228	1.00E-10	8.20E-11
	Thorium-230	3.60E-10	1.20E-10
	Thorium-232	1.30E-10	7.30E-11
	Uranium-233/234	9.90E-11	4.30E-11
	Uranium-235	0.0E+0	1.90E-11
	Uranium-238	7.00E-11	2.70E-11
	Plutonium-238	4.90E-12	1.70E-13
	Plutonium-239/240	2.00E-11	2.40E-13
	Plutonium-241	-2.2E-08	3.10E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-MLR Air Sampling 1st Quarter Mills Ranch (continued)	Strontium-90	1.50E-11	5.70E-10
	Polonium-210	3.50E-09	4.90E-10
AC-MLR Air Sampling 2nd Quarter Mills Ranch	Beryllium-7	2.70E-07	1.60E-07
	Potassium-40	7.60E-09	1.60E-08
	Cobalt-60	1.90E-10	7.00E-10
	Cesium-137	4.90E-10	7.30E-10
	Lead-210	4.70E-08	1.50E-08
	Radium-226	2.10E-08	1.20E-08
	Radium-228	4.90E-09	2.70E-09
	Americium-241	5.70E-12	1.80E-13
	Thorium-228	7.60E-11	1.00E-10
	Thorium-230	5.00E-10	1.60E-10
	Thorium-232	1.10E-10	7.40E-11
	Uranium-233/234	1.90E-10	5.10E-11
	Uranium-235	4.50E-11	2.70E-11
	Uranium-238	1.30E-10	3.70E-11
	Plutonium-238	-3.0E-12	1.10E-13
	Plutonium-239/240	2.00E-11	1.60E-13
	Plutonium-241	-1.4E-08	2.30E-09
	Strontium-90	6.80E-10	5.80E-10
	Polonium-210	7.60E-09	6.90E-10
AC-MLR Air Sampling 2nd Quarter Mills Ranch 2 of 2	Beryllium-7	1.30E-07	1.50E-07
	Potassium-40	1.10E-08	1.50E-08
	Cobalt-60	-5.5E-10	6.80E-10
	Cesium-137	-5.1E-10	6.90E-10
	Lead-210	3.10E-08	1.30E-08
	Radium-226	5.00E-09	1.50E-08
	Radium-228	3.90E-10	2.50E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-MLR Air Sampling 2nd Quarter Mills Ranch 2 of 2 (continued)	Americium-241	2.40E-10	4.90E-13
	Thorium-228	6.10E-11	7.40E-11
	Thorium-230	3.50E-10	1.10E-10
	Thorium-232	1.50E-10	7.10E-11
	Uranium-233/234	1.50E-10	4.10E-11
	Uranium-235	1.80E-11	1.90E-11
	Uranium-238	9.20E-11	3.10E-11
	Plutonium-238	-3.0E-12	2.00E-13
	Plutonium-239/240	2.00E-11	2.00E-13
	Plutonium-241	-1.4E-09	1.80E-09
	Strontium-90	1.30E-09	6.70E-10
	Polonium-210	7.80E-09	7.80E-10
AC-MLR Air Sampling 3rd Quarter Mills Ranch	Beryllium-7	1.70E-07	6.40E-08
	Potassium-40	7.80E-09	1.20E-08
	Cobalt-60	3.40E-10	6.40E-10
	Cesium-137	-4.0E-10	7.30E-10
	Lead-210	3.00E-08	1.10E-08
	Radium-226	2.50E-09	1.40E-08
	Radium-228	1.50E-09	2.70E-09
	Americium-241	1.20E-10	4.60E-13
	Thorium-228	8.80E-11	5.50E-11
	Thorium-230	2.00E-10	7.50E-11
	Thorium-232	8.10E-11	5.00E-11
	Uranium-233/234	1.50E-10	4.80E-11
	Uranium-235	3.30E-11	2.20E-11
	Uranium-238	1.30E-10	4.20E-11
	Plutonium-238	1.30E-11	1.30E-13
	Plutonium-239/240	3.30E-12	1.40E-13
	Plutonium-241	1.30E-09	1.80E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-MLR Air Sampling 3rd Quarter Mills Ranch (continued)	Strontium-90	4.60E-10	5.60E-10
	Polonium-210	1.10E-08	7.90E-10
AC-MLR Air Sampling 4th Quarter Mills Ranch	Beryllium-7	1.70E-07	3.80E-08
	Potassium-40	3.50E-09	9.10E-09
	Cobalt-60	-2.5E-10	6.50E-10
	Cesium-137	-2.5E-10	7.50E-10
	Lead-210	3.80E-08	1.20E-08
	Radium-226	6.10E-09	1.40E-08
	Radium-228	3.00E-09	2.50E-09
	Americium-241	1.70E-10	4.70E-13
	Thorium-228	8.20E-11	5.30E-11
	Thorium-230	2.60E-10	9.60E-11
	Thorium-232	8.20E-11	4.90E-11
	Uranium-233/234	1.80E-10	5.20E-11
	Uranium-235	0.0E+0	2.00E-11
	Uranium-238	1.20E-10	4.30E-11
	Plutonium-238	0.0E+0	1.70E-13
	Plutonium-239/240	7.30E-12	1.70E-13
	Plutonium-241	1.30E-08	2.40E-09
	Strontium-90	1.30E-10	5.00E-10
	Polonium-210	5.40E-09	9.20E-10
AC-WSS Air Sampling 1st Quarter WIPP South	Beryllium-7	7.90E-08	3.00E-07
	Potassium-40	1.00E-08	1.10E-08
	Cobalt-60	7.40E-10	6.00E-10
	Cesium-137	-1.1E-10	6.00E-10
	Lead-210	4.20E-08	1.30E-08
	Radium-226	9.00E-09	1.30E-08

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WSS Air Sampling 1st Quarter WIPP South (continued)	Radium-228	1.70E-09	2.20E-09
	Americium-241	-5.0E-12	2.80E-13
	Thorium-228	3.80E-11	4.90E-11
	Thorium-230	4.60E-10	1.30E-10
	Thorium-232	6.80E-11	4.90E-11
	Uranium-233/234	1.50E-10	4.40E-11
	Uranium-235	1.00E-11	1.50E-11
	Uranium-238	1.20E-10	3.70E-11
	Plutonium-238	1.40E-11	1.70E-13
	Plutonium-239/240	1.40E-11	1.20E-13
	Plutonium-241	-9.8E-09	2.00E-09
	Strontium-90	1.20E-09	5.60E-10
	Polonium-210	1.00E-08	5.90E-10
AC-WSS Air Sampling 2nd Quarter WIPP South	Beryllium-7	2.60E-07	1.40E-07
	Potassium-40	1.00E-08	1.30E-08
	Cobalt-60	5.10E-10	6.70E-10
	Cesium-137	7.80E-10	7.30E-10
	Lead-210	5.00E-08	1.50E-08
	Radium-226	1.50E-08	1.80E-08
	Radium-228	2.10E-09	2.30E-09
	Americium-241	5.00E-11	3.00E-13
	Thorium-228	8.20E-11	5.10E-11
	Thorium-230	5.60E-10	1.40E-10
	Thorium-232	8.20E-11	5.60E-11
	Uranium-233/234	2.50E-10	6.30E-11
	Uranium-235	-9.0E-12	2.70E-11
	Uranium-238	1.50E-10	4.50E-11
	Plutonium-238	-4.0E-12	7.50E-14
	Plutonium-239/240	3.80E-11	2.40E-13

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WSS Air Sampling 2nd Quarter WIPP South (continued)	Plutonium-241	-1.3E-08	2.70E-09
	Strontium-90	-6.0E-10	5.00E-10
	Polonium-210	6.70E-09	8.00E-10
AC-WSS Air Sampling 3rd Quarter WIPP South	Beryllium-7	2.10E-07	6.30E-08
	Potassium-40	8.50E-09	1.40E-08
	Cobalt-60	-3.0E-11	5.40E-10
	Cesium-137	-3.0E-10	6.70E-10
	Lead-210	6.00E-08	1.40E-08
	Radium-226	8.70E-09	1.50E-08
	Radium-228	3.40E-09	2.30E-09
	Americium-241	2.40E-11	5.30E-13
	Thorium-228	7.60E-11	6.20E-11
	Thorium-230	4.20E-10	1.20E-10
	Thorium-232	4.20E-11	4.70E-11
	Uranium-233/234	2.70E-10	5.30E-11
	Uranium-235	1.80E-11	2.10E-11
	Uranium-238	1.30E-10	3.70E-11
	Plutonium-238	8.30E-12	2.10E-13
	Plutonium-239/240	1.10E-11	1.50E-13
	Plutonium-241	-4.3E-09	2.20E-09
	Strontium-90	3.90E-11	5.30E-10
	Polonium-210	4.40E-09	6.40E-10
AC-WSS Air Sampling 4th Quarter WIPP South	Beryllium-7	1.70E-07	4.80E-08
	Potassium-40	7.30E-09	1.40E-08
	Cobalt-60	-2.2E-10	6.60E-10
	Cesium-137	1.20E-10	6.80E-10
	Lead-210	4.00E-08	1.40E-08
	Radium-226	5.90E-09	1.30E-08
	Radium-228	1.70E-09	2.70E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-WSS Air Sampling 4th Quarter WIPP South (continued)	Americium-241	8.60E-11	3.50E-13
	Thorium-228	9.80E-11	5.80E-11
	Thorium-230	2.60E-10	7.80E-11
	Thorium-232	8.20E-11	4.70E-11
	Uranium-233/234	1.50E-10	3.90E-11
	Uranium-235	1.20E-11	1.60E-11
	Uranium-238	8.10E-11	2.80E-11
	Plutonium-238	2.60E-11	2.00E-13
	Plutonium-239/240	5.70E-12	1.40E-13
	Plutonium-241	1.00E-08	1.80E-09
	Strontium-90	9.90E-10	5.50E-10
	Polonium-210	5.10E-09	7.60E-10
AC-CBD Air Sampling 1st Quarter Carlsbad	Beryllium-7	4.30E-07	2.80E-07
	Potassium-40	8.30E-09	1.20E-08
	Cobalt-60	9.50E-10	5.90E-10
	Cesium-137	4.70E-10	5.80E-10
	Lead-210	4.10E-08	1.20E-08
	Radium-226	1.60E-08	1.50E-08
	Radium-228	3.50E-09	2.30E-09
	Americium-241	1.70E-11	2.50E-13
	Thorium-228	6.40E-11	9.70E-11
	Thorium-230	5.20E-10	1.70E-10
	Thorium-232	1.20E-10	9.00E-11
	Uranium-233/234	1.30E-10	4.10E-11
	Uranium-235	1.10E-11	1.40E-11
	Uranium-238	9.70E-11	3.40E-11
	Plutonium-238	0.0E+0	6.30E-14
	Plutonium-239/240	-2.0E-12	1.20E-13
	Plutonium-241	-6.0E-09	1.60E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-CBD Air Sampling 1st Quarter Carlsbad (continued)	Strontium-90	9.70E-11	4.50E-10
	Polonium-210	1.30E-08	6.80E-10
AC-CBD Air Sampling 2nd Quarter Carlsbad	Beryllium-7	1.60E-07	1.70E-07
	Potassium-40	5.40E-09	1.40E-08
	Cobalt-60	3.40E-10	6.30E-10
	Cesium-137	-2.3E-10	7.30E-10
	Lead-210	4.30E-08	1.30E-08
	Radium-226	1.30E-08	9.90E-09
	Radium-228	4.20E-09	2.60E-09
	Americium-241	4.10E-11	4.40E-13
	Thorium-228	8.60E-11	1.10E-10
	Thorium-230	4.20E-10	1.50E-10
	Thorium-232	1.20E-10	9.00E-11
	Uranium-233/234	1.60E-10	4.50E-11
	Uranium-235	0.0E+0	0.0E+0
	Uranium-238	1.10E-10	3.70E-11
	Plutonium-238	3.70E-12	7.20E-14
	Plutonium-239/240	7.40E-12	1.40E-13
	Plutonium-241	-1.2E-08	2.50E-09
	Strontium-90	-2.0E-10	4.90E-10
	Polonium-210	8.70E-09	7.70E-10
AC-CBD Air Sampling 3rd Quarter Carlsbad	Beryllium-7	1.70E-07	6.10E-08
	Potassium-40	1.70E-08	1.30E-08
	Cobalt-60	-3.0E-11	5.50E-10
	Cesium-137	-4.4E-10	6.80E-10
	Lead-210	6.30E-08	1.30E-08
	Radium-226	1.70E-09	1.30E-08
	Radium-228	1.70E-09	2.10E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-CBD Air Sampling 3rd Quarter Carlsbad (continued)	Americium-241	8.90E-11	4.50E-13
	Thorium-228	9.50E-11	8.70E-11
	Thorium-230	4.50E-10	1.40E-10
	Thorium-232	1.60E-10	8.10E-11
	Uranium-233/234	1.40E-10	5.00E-11
	Uranium-235	7.50E-12	1.80E-11
	Uranium-238	8.50E-11	3.50E-11
	Plutonium-238	1.50E-11	1.50E-13
	Plutonium-239/240	-4.0E-12	1.30E-13
	Plutonium-241	-1.2E-08	2.70E-09
	Strontium-90	-2.0E-10	4.40E-10
	Polonium-210	9.10E-09	9.10E-10
AC-CBD Air Sampling 4th Quarter Carlsbad	Beryllium-7	1.80E-07	4.00E-08
	Potassium-40	1.10E-08	1.30E-08
	Cobalt-60	-5.0E-11	7.50E-10
	Cesium-137	-7.5E-10	8.60E-10
	Lead-210	4.50E-08	1.40E-08
	Radium-226	2.60E-09	1.40E-08
	Radium-228	1.60E-09	2.80E-09
	Americium-241	1.10E-10	4.10E-13
	Thorium-228	1.10E-10	7.70E-11
	Thorium-230	3.40E-10	9.30E-11
	Thorium-232	1.40E-10	7.00E-11
	Uranium-233/234	1.90E-10	4.70E-11
	Uranium-235	0.0E+0	9.00E-12
	Uranium-238	1.10E-10	3.50E-11
	Plutonium-238	3.10E-12	1.40E-13
	Plutonium-239/240	-3.0E-12	1.00E-13
	Plutonium-241	4.50E-09	1.70E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-CBD Air Sampling 4th Quarter Carlsbad (continued)	Strontium-90	2.50E-10	5.30E-10
	Polonium-210	1.00E-08	8.50E-10
AC-EUN Air Sampling 1st Quarter Eunice	Beryllium-7	1.80E-07	6.30E-08
	Potassium-40	4.90E-09	1.10E-08
	Cobalt-60	3.30E-10	6.40E-10
	Cesium-137	2.70E-10	6.80E-10
	Lead-210	7.80E-08	1.50E-08
	Radium-226	2.10E-08	1.10E-08
	Radium-228	-1.1E-09	2.50E-09
	Americium-241	1.90E-10	4.90E-13
	Thorium-228	9.30E-11	1.00E-10
	Thorium-230	3.20E-10	1.40E-10
	Thorium-232	1.20E-10	7.90E-11
	Uranium-233/234	2.00E-10	4.50E-11
	Uranium-235	9.50E-12	1.10E-11
	Uranium-238	1.10E-10	3.50E-11
	Plutonium-238	-2.0E-11	2.00E-13
	Plutonium-239/240	3.20E-12	1.10E-13
	Plutonium-241	-2.0E-09	1.70E-09
	Strontium-90	6.20E-10	5.80E-10
	Polonium-210	8.40E-09	1.20E-09
AC-EUN Air Sampling 2nd Quarter Eunice	Beryllium-7	1.20E-07	1.20E-07
	Potassium-40	1.20E-08	8.10E-09
	Cobalt-60	1.90E-11	7.80E-10
	Cesium-137	2.00E-10	8.60E-10
	Lead-210	2.40E-08	1.50E-08
	Radium-226	3.10E-09	1.50E-08
	Radium-228	1.20E-09	2.80E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-EUN Air Sampling 2nd Quarter Eunice (continued)	Americium-241	1.00E-10	3.90E-13
	Thorium-228	4.90E-11	4.60E-11
	Thorium-230	5.10E-10	1.20E-10
	Thorium-232	1.10E-10	5.90E-11
	Uranium-233/234	2.10E-10	5.20E-11
	Uranium-235	-1.0E-11	2.00E-11
	Uranium-238	1.30E-10	4.00E-11
	Plutonium-238	5.00E-11	3.10E-13
	Plutonium-239/240	5.00E-11	2.60E-13
	Plutonium-241	-1.6E-09	1.70E-09
	Strontium-90	-5.0E-11	4.70E-10
	Polonium-210	8.50E-09	1.00E-09
AC-EUN Air Sampling 3rd Quarter Eunice	Beryllium-7	2.70E-07	9.20E-08
	Potassium-40	3.50E-08	2.00E-08
	Cobalt-60	-7.5E-10	1.40E-09
	Cesium-137	7.50E-11	1.90E-09
	Lead-210	3.10E-08	2.50E-08
	Radium-226	8.10E-09	2.50E-08
	Radium-228	5.10E-10	6.90E-09
	Americium-241	9.10E-11	5.40E-13
	Thorium-228	-9.0E-12	7.00E-11
	Thorium-230	6.10E-10	1.60E-10
	Thorium-232	4.40E-11	4.60E-11
	Uranium-233/234	3.20E-10	9.70E-11
	Uranium-235	-8.0E-12	4.00E-11
	Uranium-238	1.20E-10	5.80E-11
	Plutonium-238	4.20E-11	3.90E-13
	Plutonium-239/240	5.00E-11	3.70E-13
	Plutonium-241	7.50E-09	4.30E-09

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/m^3	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AC-EUN Air Sampling 3rd Quarter Eunice (continued)	Strontium-90	-1.3E-09	9.50E-10
	Polonium-210	1.10E-08	3.40E-09
AC-EUN Air Sampling 4th Quarter Eunice	Beryllium-7	1.40E-07	4.60E-07
	Potassium-40	1.00E-08	8.70E-09
	Cobalt-60	2.40E-10	7.80E-10
	Cesium-137	-6.6E-10	7.50E-10
	Lead-210	3.90E-08	1.20E-08
	Radium-226	4.20E-09	1.10E-08
	Radium-228	-3.6E-10	2.40E-09
	Americium-241	1.90E-10	4.70E-13
	Thorium-228	1.30E-10	8.70E-11
	Thorium-230	1.60E-10	9.60E-11
	Thorium-232	7.10E-11	6.50E-11
	Uranium-233/234	2.00E-10	4.90E-11
	Uranium-235	1.50E-11	1.60E-11
	Uranium-238	1.10E-10	3.80E-11
	Plutonium-238	-3.0E-12	1.00E-13
	Plutonium-239/240	5.30E-12	1.00E-13
	Plutonium-241	1.30E-09	1.50E-09
	Strontium-90	2.80E-11	4.30E-10
	Polonium-210	5.90E-09	5.20E-10

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APPENDIX A2

SOILS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TS-MLR Terrestrial Surface Mills Ranch	Potassium-40	3.0E-01	5.6E-02
	Cobalt-60	-7.0E-04	8.1E-04
	Cesium-137	1.7E-02	4.3E-03
	Lead-210	4.0E-02	1.4E-02
	Radium-226	2.4E-02	1.9E-02
	Radium-228	1.9E-02	4.5E-03
	Americium-241	8.0E-03	2.6E-03
	Thorium-228	1.8E-02	2.7E-03
	Thorium-230	4.8E-02	4.4E-03
	Thorium-232	1.6E-02	2.5E-03
	Uranium-233/234	2.3E-02	2.9E-03
	Uranium-235	1.4E-03	8.6E-04
	Uranium-238	1.9E-02	2.7E-03
	Plutonium-238	7.4E-04	6.2E-04
	Plutonium-239/240	4.1E-03	1.4E-03
	Plutonium-241	-1.8E-01	8.7E-02
	Strontium-90	-4.8E-04	1.3E-03
	Polonium-210	3.1E-02	1.1E-02
TI-MLR Terrestrial Intermediate Mills Ranch	Potassium-40	3.1E-01	5.7E-02
	Cobalt-60	1.9E-04	7.5E-04
	Cesium-137	1.2E-02	3.5E-03
	Lead-210	2.5E-02	1.3E-02
	Radium-226	3.2E-02	2.0E-02
	Radium-228	2.0E-02	6.3E-03
	Americium-241	6.1E-03	1.8E-03
	Thorium-228	1.7E-02	2.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-MLR Terrestrial Intermediate Mills Ranch (continued)	Thorium-230	1.1E-01	7.0E-03
	Thorium-232	1.8E-02	2.9E-03
	Uranium-233/234	3.2E-01	1.1E-02
	Uranium-235	1.9E-02	3.1E-03
	Uranium-238	3.2E-01	1.1E-02
	Plutonium-238	3.7E-04	5.4E-04
	Plutonium-239/240	6.0E-03	1.7E-03
	Plutonium-241	-2.9E-01	1.1E-01
	Strontium-90	-7.7E-04	1.3E-03
	Polonium-210	1.6E-02	1.1E-02
TD-MLR Terrestrial Deep Mills Ranch	Potassium-40	3.3E-01	5.9E-02
	Cobalt-60	1.5E-04	7.5E-04
	Cesium-137	1.2E-02	3.5E-03
	Lead-210	2.7E-02	1.3E-02
	Radium-226	2.3E-02	1.8E-02
	Radium-228	2.2E-02	6.8E-03
	Americium-241	8.0E-03	2.1E-03
	Thorium-228	1.8E-02	3.2E-03
	Thorium-230	3.3E-02	4.3E-03
	Thorium-232	1.8E-02	3.1E-03
	Uranium-233/234	2.4E-02	3.1E-03
	Uranium-235	7.4E-04	7.6E-04
	Uranium-238	2.4E-02	3.0E-03
	Plutonium-238	-1.8E-04	6.0E-04
	Plutonium-239/240	1.8E-04	3.5E-04
	Plutonium-241	-2.8E-01	1.5E-01

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-MLR Terrestrial Deep Mills Ranch (continued)	Strontium-90	3.2E-03	1.9E-03
	Polonium-210	2.0E-02	9.9E-03
TS-SEC Terrestrial Surface South East Control	Potassium-40	1.7E-01	3.4E-02
	Cobalt-60	-1.1E-04	6.9E-04
	Cesium-137	3.1E-03	1.8E-03
	Lead-210	2.2E-02	1.2E-02
	Radium-226	7.6E-03	1.3E-02
	Radium-228	1.6E-02	5.0E-03
	Americium-241	8.3E-03	1.9E-03
	Thorium-228	8.4E-03	2.2E-03
	Thorium-230	2.4E-02	3.6E-03
	Thorium-232	8.3E-03	2.1E-03
	Uranium-233/234	1.5E-02	2.5E-03
	Uranium-235	1.3E-03	9.1E-04
	Uranium-238	1.4E-02	2.3E-03
	Plutonium-238	-2.9E-04	5.7E-04
	Plutonium-239/240	3.4E-03	1.2E-03
	Plutonium-241	-1.7E-01	8.2E-02
	Strontium-90	-9.8E-05	1.8E-03
	Polonium-210	1.6E-02	1.1E-02
TI-SEC Terrestrial Intermediate South East Control	Potassium-40	1.6E-01	3.2E-02
	Cobalt-60	-1.1E-04	7.4E-04
	Cesium-137	2.8E-03	1.5E-03
	Lead-210	2.2E-02	1.1E-02
	Radium-226	1.3E-02	1.4E-02
	Radium-228	9.5E-03	5.4E-03
	Americium-241	6.0E-03	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-SEC Terrestrial Intermediate South East Control (continued)	Thorium-228	7.7E-03	1.8E-03
	Thorium-230	7.3E-02	5.2E-03
	Thorium-232	9.0E-03	1.9E-03
	Uranium-233/234	1.4E-02	2.3E-03
	Uranium-235	3.4E-04	3.9E-04
	Uranium-238	1.3E-02	2.3E-03
	Plutonium-238	0.0E+00	4.7E-04
	Plutonium-239/240	1.1E-03	6.3E-04
	Plutonium-241	-1.6E-01	8.5E-02
	Strontium-90	1.3E-03	1.5E-03
	Polonium-210	1.1E-02	1.0E-02
TD-SEC Terrestrial Deep South East Control	Potassium-40	1.4E-01	3.0E-02
	Cobalt-60	-1.4E-04	7.2E-04
	Cesium-137	4.9E-03	1.7E-03
	Lead-210	6.1E-03	1.1E-02
	Radium-226	1.8E-02	1.5E-02
	Radium-228	1.1E-02	4.2E-03
	Americium-241	6.1E-03	1.8E-03
	Thorium-228	1.1E-02	2.1E-03
	Thorium-230	6.9E-02	5.0E-03
	Thorium-232	7.7E-03	1.7E-03
	Uranium-233/234	1.6E-02	2.6E-03
	Uranium-235	7.7E-04	6.2E-04
	Uranium-238	8.6E-03	1.9E-03
	Plutonium-238	-9.3E-05	3.1E-04
	Plutonium-239/240	1.5E-03	7.7E-04
	Plutonium-241	-2.0E-01	8.0E-02
	Strontium-90	-7.9E-04	1.5E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-SEC Terrestrial Deep South East Control (continued)	Polonium-210	8.8E-03	9.7E-03
TS-SMR Terrestrial Surface Smith Ranch	Potassium-40	2.8E-01	5.1E-02
	Cobalt-60	-4.0E-05	6.7E-04
	Cesium-137	3.8E-03	1.6E-03
	Lead-210	1.3E-02	1.1E-02
	Radium-226	1.4E-02	1.5E-02
	Radium-228	1.3E-02	5.2E-03
	Americium-241	6.1E-03	1.8E-03
	Thorium-228	9.6E-03	4.5E-03
	Thorium-230	2.6E-02	6.8E-03
	Thorium-232	1.3E-02	4.7E-03
	Uranium-233/234	1.1E-02	2.1E-03
	Uranium-235	9.3E-04	7.9E-04
	Uranium-238	1.2E-02	2.1E-03
	Plutonium-238	-1.0E-04	3.5E-04
	Plutonium-239/240	3.1E-04	4.6E-04
	Plutonium-241	-8.9E-02	9.1E-02
	Strontium-90	-4.1E-04	1.5E-03
	Polonium-210	1.4E-02	1.0E-02
TI-SMR Terrestrial Intermediate Smith Ranch	Potassium-40	3.0E-01	5.4E-02
	Cobalt-60	9.9E-05	7.6E-04
	Cesium-137	6.1E-03	2.0E-03
	Lead-210	1.7E-02	1.2E-02
	Radium-226	1.8E-02	1.6E-02
	Radium-228	1.7E-02	3.8E-03
	Americium-241	6.8E-03	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-SMR Terrestrial Intermediate Smith Ranch (continued)	Thorium-228	1.4E-02	2.5E-03
	Thorium-230	2.7E-02	3.3E-03
	Thorium-232	1.6E-02	2.6E-03
	Uranium-233/234	1.4E-02	2.4E-03
	Uranium-235	9.2E-04	7.2E-04
	Uranium-238	1.3E-02	2.2E-03
	Plutonium-238	-1.9E-04	5.3E-04
	Plutonium-239/240	0.0E+00	4.6E-04
	Plutonium-241	-7.2E-02	8.2E-02
	Strontium-90	-1.4E-03	2.7E-03
	Polonium-210	1.4E-02	1.2E-02
TD-SMR Terrestrial Deep Smith Ranch	Potassium-40	3.0E-01	5.5E-02
	Cobalt-60	1.4E-04	7.2E-04
	Cesium-137	4.6E-03	1.7E-03
	Lead-210	1.5E-02	1.3E-02
	Radium-226	1.9E-02	1.8E-02
	Radium-228	1.6E-02	3.9E-03
	Americium-241	7.2E-03	2.4E-03
	Thorium-228	2.1E-02	3.1E-03
	Thorium-230	2.4E-02	3.4E-03
	Thorium-232	1.6E-02	2.7E-03
	Uranium-233/234	1.7E-02	6.3E-03
	Uranium-235	3.5E-03	3.1E-03
	Uranium-238	2.1E-02	7.3E-03
	Plutonium-238	2.7E-04	5.4E-04
	Plutonium-239/240	-4.1E-04	4.6E-04
	Plutonium-241	-9.5E-02	1.2E-01
	Strontium-90	-2.3E-03	2.3E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-SMR Terrestrial Deep Smith Ranch (continued)	Polonium-210	1.5E-02	1.0E-02
TS-WEE Terrestrial Surface WIPP East	Potassium-40	1.9E-01	3.6E-02
	Cobalt-60	-3.5E-04	6.4E-04
	Cesium-137	4.2E-03	1.7E-03
	Lead-210	1.2E-02	1.0E-02
	Radium-226	8.5E-03	1.4E-02
	Radium-228	1.0E-02	5.2E-03
	Americium-241	7.1E-03	1.7E-03
	Thorium-228	6.9E-03	1.7E-03
	Thorium-230	2.4E-02	3.0E-03
	Thorium-232	8.0E-03	1.8E-03
	Uranium-233/234	3.5E-02	3.4E-03
	Uranium-235	1.8E-03	9.5E-04
	Uranium-238	3.7E-02	3.5E-03
	Plutonium-238	-4.9E-04	6.9E-04
	Plutonium-239/240	7.8E-04	5.4E-04
	Plutonium-241	-1.1E-02	8.5E-02
	Strontium-90	-1.9E-03	1.3E-03
	Polonium-210	1.8E-02	1.0E-02
TI-WEE Terrestrial Intermediate WIPP East	Potassium-40	1.8E-01	3.5E-02
	Cobalt-60	3.5E-04	6.8E-04
	Cesium-137	5.6E-03	1.8E-03
	Lead-210	1.6E-02	1.1E-02
	Radium-226	1.7E-02	1.5E-02
	Radium-228	9.5E-03	4.3E-03
	Americium-241	6.0E-03	1.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-WEE Terrestrial Intermediate WIPP East (continued)	Thorium-228	7.6E-03	1.8E-03
	Thorium-230	4.1E-02	4.1E-03
	Thorium-232	7.5E-03	1.8E-03
	Uranium-233/234	8.1E-03	1.9E-03
	Uranium-235	8.1E-04	8.2E-04
	Uranium-238	7.6E-02	1.7E-03
	Plutonium-238	-2.2E-04	5.2E-04
	Plutonium-239/240	2.2E-03	9.9E-04
	Plutonium-241	0.0E+00	0.0E+00
	Strontium-90	-5.9E-04	1.5E-03
	Polonium-210	1.2E-02	1.1E-02
TD-WEE Terrestrial Deep WIPP East	Potassium-40	1.5E-01	3.1E-02
	Cobalt-60	-7.0E-05	5.5E-04
	Cesium-137	3.9E-03	1.7E-03
	Lead-210	6.3E-03	8.5E-03
	Radium-226	8.0E-03	1.2E-02
	Radium-228	7.5E-03	3.3E-03
	Americium-241	6.2E-03	1.6E-03
	Thorium-228	9.1E-03	2.0E-03
	Thorium-230	1.8E-02	2.5E-03
	Thorium-232	8.1E-03	1.7E-03
	Uranium-233/234	8.9E-03	2.1E-03
	Uranium-235	6.4E-04	5.1E-04
	Uranium-238	7.4E-02	1.6E-03
	Plutonium-238	1.2E-04	4.1E-04
	Plutonium-239/240	6.0E-04	6.3E-04
	Plutonium-241	6.5E-03	1.1E-01
	Strontium-90	5.1E-03	1.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-WEE Terrestrial Deep WIPP East (continued)	Polonium-210	7.2E-01	1.1E-02
TS-WFF Terrestrial Surface WIPP Far Field	Potassium-40	1.2E-01	2.6E-02
	Cobalt-60	-7.3E-04	6.2E-04
	Cesium-137	3.6E-03	1.5E-03
	Lead-210	9.3E-03	1.1E-02
	Radium-226	2.0E-03	1.1E-02
	Radium-228	6.1E-03	3.3E-03
	Americium-241	1.6E-02	2.4E-03
	Thorium-228	6.0E-03	1.7E-03
	Thorium-230	2.3E-02	3.1E-03
	Thorium-232	4.9E-03	1.4E-03
	Uranium-233/234	1.6E-02	2.5E-03
	Uranium-235	1.7E-03	1.0E-03
	Uranium-238	1.9E-02	2.8E-03
	Plutonium-238	5.5E-04	7.8E-04
	Plutonium-239/240	3.0E-03	1.2E-03
	Plutonium-241	-1.7E-01	9.8E-02
	Strontium-90	1.3E-03	1.8E-03
	Polonium-210	1.3E-02	1.0E-02
TI-WFF Terrestrial Intermediate WIPP Far Field	Potassium-40	1.3E-01	2.6E-02
	Cobalt-60	9.2E-05	5.4E-04
	Cesium-137	2.7E-03	1.3E-03
	Lead-210	8.2E-03	9.1E-03
	Radium-226	9.1E-03	1.1E-02
	Radium-228	6.0E-03	3.5E-03
	Americium-241	8.0E-03	1.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-WFF Terrestrial Intermediate WIPP Far Field (continued)	Thorium-228	6.3E-03	1.8E-03
	Thorium-230	3.3E-02	3.8E-03
	Thorium-232	6.0E-03	1.6E-03
	Uranium-233/234	1.6E-02	2.5E-03
	Uranium-235	3.7E-04	4.2E-04
	Uranium-238	7.8E-03	1.7E-03
	Plutonium-238	2.0E-04	4.9E-04
	Plutonium-239/240	4.5E-03	1.3E-03
	Plutonium-241	-2.0E-01	8.5E-02
	Strontium-90	1.7E-03	1.7E-03
	Polonium-210	1.2E-02	1.0E-02
TD-WFF Terrestrial Deep WIPP Far Field	Potassium-40	1.5E-01	3.0E-02
	Cobalt-60	4.9E-05	5.3E-04
	Cesium-137	2.6E-03	1.2E-03
	Lead-210	1.2E-02	8.6E-03
	Radium-226	1.1E-02	1.2E-02
	Radium-228	6.2E-03	3.7E-03
	Americium-241	1.2E-02	2.3E-03
	Thorium-228	7.5E-03	1.8E-03
	Thorium-230	2.7E-02	3.3E-03
	Thorium-232	6.6E-03	1.6E-03
	Uranium-233/234	1.4E-02	2.3E-03
	Uranium-235	9.0E-04	6.2E-04
	Uranium-238	7.1E-03	1.6E-03
	Plutonium-238	1.1E-03	9.2E-04
	Plutonium-239/240	1.0E-02	2.1E-03
	Plutonium-241	-1.4E-01	8.8E-02
	Strontium-90	5.7E-04	1.3E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-WFF Terrestrial Deep WIPP Far Field (continued)	Polonium-210	7.5E-03	1.2E-02
TS-WSS Terrestrial Surface WIPP South	Potassium-40	1.6E-01	3.2E-02
	Cobalt-60	-1.7E-04	6.5E-04
	Cesium-137	3.4E-03	1.5E-03
	Lead-210	1.8E-02	1.1E-02
	Radium-226	2.1E-02	1.5E-02
	Radium-228	8.4E-03	4.7E-03
	Americium-241	5.0E-03	1.5E-03
	Thorium-228	7.7E-03	1.7E-03
	Thorium-230	1.9E-02	2.7E-03
	Thorium-232	6.6E-03	1.7E-03
	Uranium-233/234	1.1E-02	2.0E-03
	Uranium-235	4.5E-04	6.2E-04
	Uranium-238	8.0E-03	1.7E-03
	Plutonium-238	1.9E-04	2.6E-04
	Plutonium-239/240	6.5E-04	6.1E-04
	Plutonium-241	-1.5E-01	8.1E-02
	Strontium-90	4.5E-06	1.5E-03
	Polonium-210	2.1E-02	1.1E-02
TI-WSS Terrestrial Intermediate WIPP South	Potassium-40	2.1E-01	3.9E-02
	Cobalt-60	2.0E-04	6.7E-04
	Cesium-137	4.3E-03	1.8E-03
	Lead-210	1.3E-02	1.1E-02
	Radium-226	2.0E-03	1.2E-02
	Radium-228	1.3E-02	3.0E-03
	Americium-241	5.1E-03	1.5E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TI-WSS Terrestrial Intermediate WIPP South (continued)	Thorium-228	8.2E-03	1.8E-03
	Thorium-230	1.5E-02	2.4E-03
	Thorium-232	8.3E-03	1.8E-03
	Uranium-233/234	1.2E-02	2.2E-03
	Uranium-235	1.3E-03	7.8E-04
	Uranium-238	8.1E-03	1.8E-03
	Plutonium-238	-1.1E-04	2.1E-04
	Plutonium-239/240	3.2E-04	3.6E-04
	Plutonium-241	-2.0E-01	8.8E-02
	Strontium-90	2.1E-03	1.5E-03
	Polonium-210	1.3E-02	9.5E-03
TD-WSS Terrestrial Deep WIPP South	Potassium-40	1.7E-01	3.3E-02
	Cobalt-60	2.6E-04	6.4E-04
	Cesium-137	4.6E-03	1.8E-03
	Lead-210	5.6E-03	1.3E-02
	Radium-226	8.7E-03	1.4E-02
	Radium-228	1.2E-02	5.1E-03
	Americium-241	6.5E-03	1.8E-03
	Thorium-228	8.2E-03	2.1E-03
	Thorium-230	2.1E-02	3.3E-03
	Thorium-232	7.5E-03	2.0E-03
	Uranium-233/234	1.0E-02	2.1E-03
	Uranium-235	8.9E-04	7.5E-04
	Uranium-238	8.0E-03	1.8E-03
	Plutonium-238	1.0E-04	2.0E-04
	Plutonium-239/240	2.1E-04	4.0E-04
	Plutonium-241	-1.8E-01	8.4E-02
	Strontium-90	-2.8E-04	1.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
TD-WSS Terrestrial Deep WIPP South (continued)	Polonium-210	7.6E-03	1.1E-02

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APPENDIX A3

SURFACE WATER

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-NOY Surface Water Noya Tank	Potassium-40	9.2E+00	2.3E+00
	Cobalt-60	3.4E-02	1.2E-01
	Cesium-137	9.2E-02	1.3E-01
	Lead-210	7.1E+00	2.4E+00
	Radium-226	2.4E-02	3.5E-03
	Radium-228	1.1E-01	4.6E-02
	Actinium-228	2.6E-01	4.9E-01
	Americium-241	2.4E-02	7.1E-03
	Thorium-228	6.6E-03	4.4E-03
	Thorium-230	4.6E-02	9.3E-03
	Thorium-232	1.4E-03	2.1E-03
	Uranium-233/234	2.2E-02	6.7E-03
	Uranium-235	2.3E-03	2.3E-03
	Uranium-238	1.4E-02	5.2E-03
	Plutonium-238	0.0E+00	1.3E-03
	Plutonium-239/240	9.4E-04	2.3E-03
	Plutonium-241	-1.1E+00	2.4E-01
	Strontium-90	2.8E-02	1.8E-02
	Polonium-210	2.8E-03	3.4E-02
HS-UPR Surface Water Upper Pecos River	Potassium-40	8.9E+00	2.3E+00
	Cobalt-60	1.6E-02	1.5E-01
	Cesium-137	2.0E-02	1.1E-01
	Lead-210	1.3E+00	3.5E+00
	Radium-226	2.6E-03	1.5E-03
	Radium-228	4.3E-02	3.6E-02
	Actinium-228	7.1E-01	6.2E-01
	Americium-241	3.5E-02	9.5E-03
	Thorium-228	5.9E-03	4.6E-03
	Thorium-230	6.8E-02	1.1E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-UPR Surface Water Upper Pecos River (continued)	Thorium-232	4.5E-04	2.7E-03
	Uranium-233/234	2.1E-01	2.0E-02
	Uranium-235	8.3E-03	4.3E-03
	Uranium-238	8.6E-02	1.3E-02
	Plutonium-238	4.9E-04	1.7E-03
	Plutonium-239/240	9.9E-04	2.4E-03
	Plutonium-241	-1.3E+00	2.6E-01
	Strontium-90	3.7E-03	1.3E-02
	Polonium-210	0.0E+00	3.7E-02
HS-ION Surface Water Indian Tank Blind Duplicate sample of Indian Tank	Potassium-40	1.5E+00	2.6E+00
	Cobalt-60	7.6E-03	1.4E-01
	Cesium-137	2.8E-02	1.2E-01
	Lead-210	1.0E+00	3.3E+00
	Radium-226	4.0E-02	4.6E-03
	Radium-228	7.6E-02	4.3E-02
	Actinium-228	4.8E-01	5.1E-01
	Americium-241	3.0E-02	8.4E-03
	Thorium-228	0.0E+00	3.2E-03
	Thorium-230	7.6E-02	1.2E-02
	Thorium-232	2.1E-03	2.9E-03
	Uranium-233/234	2.7E-02	7.7E-03
	Uranium-235	-1.2E-03	3.6E-03
	Uranium-238	1.1E-02	5.1E-03
	Plutonium-238	9.7E-04	3.3E-03
	Plutonium-239/240	-4.9E-03	5.0E-03
	Plutonium-241	-3.1E+00	5.2E-01
	Strontium-90	3.8E-02	1.8E-02
	Polonium-210	4.4E-03	3.2E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-IDN Surface Water Indian Tank	Potassium-40	2.5E+00	2.9E+00
	Cobalt-60	6.7E-03	1.4E-01
	Cesium-137	4.4E-02	1.3E-01
	Lead-210	8.7E+00	2.3E+00
	Radium-226	4.4E-02	4.8E-03
	Radium-228	1.8E-01	5.9E-02
	Actinium-228	3.4E-01	5.0E-01
	Americium-241	2.6E-02	8.0E-03
	Thorium-228	2.2E-02	6.7E-03
	Thorium-230	6.4E-02	1.1E-02
	Thorium-232	3.3E-03	2.8E-03
	Uranium-233/234	3.3E-02	8.1E-03
	Uranium-235	1.2E-03	2.3E-03
	Uranium-238	1.7E-02	6.1E-03
	Plutonium-238	4.8E-04	2.5E-03
	Plutonium-239/240	-4.8E-04	1.6E-03
	Plutonium-241	-5.6E-01	2.7E-01
	Strontium-90	1.5E-02	1.9E-02
	Polonium-210	6.0E-03	4.1E-02
HS-CBD Surface Water Carlsbad	Potassium-40	1.8E+00	2.5E+00
	Cobalt-60	9.9E-02	1.3E-01
	Cesium-137	-1.6E-02	1.2E-01
	Lead-210	5.5E-01	3.5E+00
	Radium-226	6.7E-03	2.1E-03
	Radium-228	8.9E-03	4.4E-02
	Actinium-228	3.5E-01	5.1E-01
	Americium-241	3.3E-02	9.3E-03
	Thorium-228	3.8E-03	2.6E-03
	Thorium-230	3.9E-02	8.7E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-CBD Surface Water Carlsbad (continued)	Thorium-232	1.4E-03	2.8E-03
	Uranium-233/234	8.6E-02	1.4E-02
	Uranium-235	2.8E-03	4.0E-03
	Uranium-238	4.9E-02	9.5E-03
	Plutonium-238	-1.1E-03	2.1E-03
	Plutonium-239/240	1.6E-03	1.8E-03
	Plutonium-241	-1.5E+00	3.1E-01
	Strontium-90	1.5E-02	1.4E-02
	Polonium-210	2.0E-03	3.4E-02
HS-RED Water REd Tank	Potassium-40	7.9E-01	2.4E+00
	Cobalt-60	4.3E-02	1.4E-01
	Cesium-137	-1.2E-01	1.2E-01
	Lead-210	8.0E+00	2.4E+00
	Radium-226	6.8E-03	2.0E-03
	Radium-228	3.6E-02	3.9E-02
	Actinium-228	4.3E-01	5.1E-01
	Americium-241	2.8E-02	7.8E-03
	Thorium-228	2.4E-03	3.6E-03
	Thorium-230	6.2E-02	1.1E-02
	Thorium-232	4.7E-04	2.1E-03
	Uranium-233/234	1.2E-02	5.6E-03
	Uranium-235	-5.8E-04	2.0E-03
	Uranium-238	9.9E-03	4.5E-03
	Plutonium-238	-2.8E-03	2.2E-03
	Plutonium-239/240	9.2E-04	1.8E-03
	Plutonium-241	-1.3E+00	2.4E-01
	Strontium-90	1.1E-02	1.5E-02
	Polonium-210	2.4E-03	3.8E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-FWT Surface Water Fresh Water Tank	Potassium-40	7.1E+00	2.1E+00
	Cobalt-60	1.7E-01	1.6E-01
	Cesium-137	-3.6E-02	1.1E-01
	Lead-210	7.9E+00	2.3E+00
	Radium-226	3.1E-03	1.7E-03
	Radium-228	1.6E-02	3.5E-02
	Actinium-228	4.3E-01	5.7E-01
	Americium-241	3.7E-02	1.0E-02
	Thorium-228	7.5E-03	5.3E-03
	Thorium-230	4.5E-02	9.6E-03
	Thorium-232	0.0E+00	1.4E-03
	Uranium-233/234	5.6E-02	1.1E-02
	Uranium-235	2.6E-03	2.5E-03
	Uranium-238	1.6E-02	5.7E-03
	Plutonium-238	-1.9E-03	2.7E-03
	Plutonium-239/240	-1.9E-03	1.9E-03
	Plutonium-241	-1.4E+00	2.8E-01
	Strontium-90	5.4E-04	1.4E-02
	Polonium-210	-8.7E-04	2.7E-02
HS-LGS Surface Water Laguna Grande de la Sol	Potassium-40	1.1E+03	1.3E+02
	Cobalt-60	2.5E-01	3.2E-01
	Cesium-137	6.6E-02	2.1E-01
	Lead-210	7.5E+00	4.0E+00
	Radium-226	3.1E-01	1.3E-02
	Radium-228	2.0E-01	5.6E-02
	Actinium-228	-3.3E-01	9.7E-01
	Americium-241	6.8E-02	3.2E-02
	Thorium-228	1.3E-02	5.8E-03
	Thorium-230	7.4E-02	1.3E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-LGS Surface Water Laguna Grande de la Sol (continued)	Thorium-232	-1.1E-03	2.1E-03
	Uranium-233/234	2.1E+00	6.3E-01
	Uranium-235	2.1E+00	6.3E-01
	Uranium-238	2.7E+00	6.8E-01
	Plutonium-238	9.4E-04	1.8E-03
	Plutonium-239/240	3.8E-03	5.2E-03
	Plutonium-241	-2.3E+00	5.3E-01
	Strontium-90	-2.6E-01	4.7E-01
	Polonium-210	1.4E-01	1.2E-01
HS-LBL Surface Water Lake Brantley	Potassium-40	1.6E+00	2.8E+00
	Cobalt-60	2.3E-02	1.3E-01
	Cesium-137	1.1E-02	1.2E-01
	Lead-210	6.7E+00	2.2E+00
	Radium-226	5.1E-03	1.8E-03
	Radium-228	7.1E-02	3.9E-02
	Actinium-228	1.1E+00	8.1E-01
	Americium-241	2.9E-02	9.7E-03
	Thorium-228	6.2E-03	3.7E-03
	Thorium-230	6.6E-02	1.1E-02
	Thorium-232	0.0E+00	1.7E-03
	Uranium-233/234	1.1E-01	1.5E-02
	Uranium-235	1.9E-03	4.2E-03
	Uranium-238	5.5E-02	1.1E-02
	Plutonium-238	-1.4E-03	2.8E-03
	Plutonium-239/240	1.9E-03	2.7E-03
	Plutonium-241	-1.2E+00	2.6E-01
	Strontium-90	1.4E-02	1.3E-02
	Polonium-210	0.0E+00	3.5E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-SEW Surface Water Sewage Lagoon	Potassium-40	2.2E+00	2.9E+00
	Cobalt-60	1.6E-02	1.3E-01
	Cesium-137	-1.7E-02	1.1E-01
	Lead-210	2.0E-01	3.2E+00
	Radium-226	4.6E-03	2.2E-03
	Radium-228	1.8E-02	6.9E-02
	Actinium-228	2.3E-01	4.8E-01
	Americium-241	3.1E-02	8.6E-03
	Thorium-228	-1.6E-03	2.7E-03
	Thorium-230	6.2E-02	1.1E-02
	Thorium-232	2.1E-03	2.0E-03
	Uranium-233/234	2.3E-02	7.2E-03
	Uranium-235	5.6E-04	2.4E-03
	Uranium-238	4.9E-03	4.2E-03
	Plutonium-238	2.2E-03	5.9E-03
	Plutonium-239/240	1.5E-03	4.1E-03
	Plutonium-241	-1.6E+00	4.0E-01
	Strontium-90	2.3E-03	1.6E-02
	Polonium-210	3.9E-04	3.3E-02
HS-TUT Surface Water Tut Tank	Potassium-40	9.1E+00	2.4E+00
	Cobalt-60	-1.1E-01	1.5E-01
	Cesium-137	1.4E-02	1.2E-01
	Lead-210	9.1E+00	2.3E+00
	Radium-226	9.3E-03	2.4E-03
	Radium-228	1.0E-01	4.6E-02
	Actinium-228	2.3E-01	5.0E-01
	Americium-241	4.4E-02	1.8E-02
	Thorium-228	7.1E-03	5.3E-03
	Thorium-230	5.0E-02	1.2E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-TUT Surface Water Tut Tank (Continued)	Thorium-232	1.3E-03	3.1E-03
	Uranium-233/234	2.3E-02	7.1E-03
	Uranium-235	2.4E-03	3.3E-03
	Uranium-238	1.1E-02	4.9E-03
	Plutonium-238	7.2E-04	4.3E-03
	Plutonium-239/240	1.5E-03	2.8E-03
	Plutonium-241	-1.7E+00	4.1E-01
	Strontium-90	1.5E-02	1.7E-02
	Polonium-210	1.3E-03	2.9E-02
HS-PCN Surface Water Pierce Canyon	Potassium-40	8.2E+00	2.4E+00
	Cobalt-60	1.4E-01	1.3E-01
	Cesium-137	4.8E-02	1.3E-01
	Lead-210	7.5E-01	3.7E+00
	Radium-226	4.5E-03	1.9E-03
	Radium-228	8.0E-03	4.9E-02
	Actinium-228	2.6E-01	5.0E-01
	Americium-241	3.1E-02	1.1E-02
	Thorium-228	4.2E-03	2.8E-03
	Thorium-230	7.7E-02	1.2E-02
	Thorium-232	-1.4E-03	2.1E-03
	Uranium-233/234	1.2E-01	1.6E-02
	Uranium-235	6.3E-03	4.9E-03
	Uranium-238	5.6E-02	1.1E-02
	Plutonium-238	4.4E-04	2.9E-03
	Plutonium-239/240	8.9E-04	1.7E-03
	Plutonium-241	-8.3E-01	2.4E-01
	Strontium-90	-1.1E-02	2.8E-02
	Polonium-210	1.1E-03	4.1E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
AS-PCN Surface Water Pierce Canyon	Potassium-40	1.1E-01	2.9E+00
	Cobalt-60	1.0E-01	1.3E-01
	Cesium-137	-4.4E-02	1.2E-01
	Lead-210	8.1E+00	2.3E+00
	Radium-226	3.1E-03	1.6E-03
	Radium-228	2.8E-02	4.5E-02
	Actinium-228	4.2E-01	5.2E-01
	Americium-241	1.6E-02	6.7E-03
	Thorium-228	2.3E-03	5.5E-03
	Thorium-230	5.6E-02	1.6E-02
	Thorium-232	0.0E+00	3.2E-03
	Uranium-233/234	1.2E-01	1.5E-02
	Uranium-235	7.1E-03	4.6E-03
	Uranium-238	5.0E-02	1.0E-02
	Plutonium-238	8.7E-04	2.4E-03
	Plutonium-239/240	1.3E-03	1.9E-03
	Plutonium-241	-7.4E-01	2.5E-01
	Strontium-90	-4.2E-03	1.3E-02
	Polonium-210	4.6E-04	3.7E-02
HS-COY Surface Water Coyote Tank Blind Duplicate sample of Upper Pecos River	Potassium-40	2.8E-01	2.8E+00
	Cobalt-60	-2.4E-02	1.4E-01
	Cesium-137	-7.7E-02	1.2E-01
	Lead-210	2.1E-01	3.4E+00
	Radium-226	3.4E-03	1.7E-03
	Radium-228	3.9E-02	4.4E-02
	Actinium-228	2.4E-01	4.5E-01
	Americium-241	2.2E-02	7.4E-03
	Thorium-228	9.3E-04	2.6E-03
	Thorium-230	2.4E-02	6.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HS-COY Surface Water Coyote Tank Blind Duplicate sample of Upper Pecos River (continued)	Thorium-232	4.7E-04	9.1E-04
	Uranium-233/234	1.9E-01	1.8E-02
	Uranium-235	7.0E-03	4.1E-03
	Uranium-238	7.3E-02	1.1E-02
	Plutonium-238	0.0E+00	2.1E-03
	Plutonium-239/240	2.1E-03	2.1E-03
	Plutonium-241	-9.2E-01	3.0E-01
	Strontium-90	7.2E-03	1.2E-02
	Polonium-210	2.0E-03	4.7E-02
HS-COW Surface Water Coyote Well blind blank Deionized water	Potassium-40	8.1E+00	2.5E+00
	Cobalt-60	4.8E-02	1.6E-01
	Cesium-137	1.0E-01	1.1E-01
	Lead-210	5.6E-01	3.3E+00
	Radium-226	1.6E-03	1.3E-03
	Radium-228	3.7E-02	3.6E-02
	Actinium-228	2.3E-01	5.1E-01
	Americium-241	2.5E-02	8.4E-03
	Thorium-228	-4.4E-04	1.9E-03
	Thorium-230	4.8E-02	9.1E-03
	Thorium-232	4.4E-04	1.5E-03
	Uranium-233/234	9.5E-03	4.7E-03
	Uranium-235	6.2E-04	2.1E-03
	Uranium-238	2.0E-03	2.4E-03
	Plutonium-238	0.0E+00	1.4E-03
	Plutonium-239/240	1.0E-03	2.4E-03
	Plutonium-241	-6.8E-01	2.9E-01
	Strontium-90	-4.0E-03	1.5E-02
	Polonium-210	-1.1E-03	3.1E-02

APPENDIX A4

BOTTOM SEDIMENTS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-BRA Bottom Sediment Brantley Lake	Potassium-40	2.6E-01	4.7E-02
	Cobalt-60	-5.0E-04	7.8E-04
	Cesium-137	-4.0E-04	8.0E-04
	Lead-210	3.2E-03	1.2E-02
	Radium-226	1.5E-02	1.7E-02
	Radium-228	1.4E-02	3.7E-03
	Americium-241	8.7E-03	2.1E-03
	Thorium-228	1.6E-02	2.6E-03
	Thorium-230	2.6E-02	3.3E-03
	Thorium-232	1.7E-02	2.7E-03
	Uranium-233/234	1.9E-02	2.8E-03
	Uranium-235	1.1E-03	8.9E-04
	Uranium-238	1.9E-02	2.8E-03
	Plutonium-238	1.0E-04	4.4E-04
	Plutonium-239/240	1.0E-04	3.4E-04
	Plutonium-241	-1.9E-01	8.5E-02
	Strontium-90	-1.4E-04	1.3E-03
	Polonium-210	6.4E-03	8.9E-03
HB-CBD Bottom Sediment Carlsbad	Potassium-40	3.6E-01	6.8E-02
	Cobalt-60	6.8E-04	1.3E-03
	Cesium-137	7.1E-03	3.4E-03
	Lead-210	6.4E-02	2.4E-02
	Radium-226	4.9E-02	3.4E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-CBD Bottom Sediment Carlsbad (continued)	Radium-228	2.4E-02	6.1E-03
	Americium-241	7.2E-03	2.1E-03
	Thorium-228	2.6E-02	4.8E-03
	Thorium-230	3.2E-02	5.4E-03
	Thorium-232	2.4E-02	4.6E-03
	Uranium-233/234	4.9E-02	4.6E-03
	Uranium-235	2.7E-03	1.3E-03
	Uranium-238	3.3E-02	3.8E-03
	Plutonium-238	1.4E-04	2.8E-04
	Plutonium-239/240	5.8E-04	5.6E-04
	Plutonium-241	-3.8E-01	1.2E-01
	Strontium-90	-2.4E-04	1.9E-03
	Polonium-210	4.9E-02	1.0E-02
HB-HIL Bottom Sediment Hill Tank	Potassium-40	8.4E-01	1.4E-01
	Cobalt-60	-4.5E-04	1.1E-03
	Cesium-137	1.2E-02	3.7E-03
	Lead-210	5.9E-02	2.2E-02
	Radium-226	4.1E-02	3.1E-02
	Radium-228	4.0E-02	7.5E-03
	Americium-241	1.0E-02	2.3E-03
	Thorium-228	3.4E-02	9.4E-03
	Thorium-230	5.1E-02	1.1E-02
	Thorium-232	3.7E-02	9.4E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-HIL Bottom Sediment Hill Tank (continued)	Uranium-233/234	2.5E-02	3.1E-03
	Uranium-235	1.7E-03	9.3E-04
	Uranium-238	2.4E-02	3.0E-03
	Plutonium-238	4.2E-04	5.0E-04
	Plutonium-239/240	6.3E-04	5.8E-04
	Plutonium-241	-2.1E-01	8.7E-02
	Strontium-90	2.5E-03	1.9E-03
	Polonium-210	5.7E-02	1.2E-02
HB-IDN Bottom Sediment Indian Tank	Potassium-40	6.2E-01	1.1E-01
	Cobalt-60	-3.2E-04	1.2E-03
	Cesium-137	1.5E-02	4.5E-03
	Radium-226	3.3E-02	2.8E-02
	Radium-228	3.8E-02	7.1E-03
	Lead-210	5.8E-02	2.2E-02
	Americium-241	7.3E-03	2.1E-03
	Thorium-228	4.6E-02	1.4E-03
	Thorium-230	5.2E-02	1.5E-02
	Thorium-232	2.7E-02	1.2E-03
	Uranium-233/234	2.7E-02	3.1E-03
	Uranium-235	2.1E-03	9.9E-04
	Uranium-238	2.8E-02	3.1E-03
	Plutonium-238	0.0E+00	2.8E-04
	Plutonium-239/240	4.1E-04	4.0E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-IDN Bottom Sediment Indian Tank (continued)	Plutonium-241	-2.3E-01	8.5E-02
	Strontium-90	3.4E-03	1.9E-03
	Polonium-210	4.4E-02	1.1E-02
HB-LGS Bottom Sediment Laguna Grande de la Sol	Potassium-40	3.3E-01	6.2E-02
	Cobalt-60	4.3E-04	1.0E-03
	Cesium-137	2.9E-03	1.5E-03
	Lead-210	1.3E-02	1.7E-02
	Radium-226	3.9E-02	2.7E-02
	Radium-228	1.3E-02	1.0E-02
	Americium-241	1.2E-02	3.4E-03
	Thorium-228	1.0E-02	2.7E-03
	Thorium-230	2.6E-02	4.4E-03
	Thorium-232	3.0E-03	1.9E-03
	Uranium-233/234	7.5E-02	5.7E-03
	Uranium-235	3.6E-03	1.5E-03
	Uranium-238	3.9E-02	4.2E-03
	Plutonium-238	-1.0E-04	2.0E-04
	Plutonium-239/240	6.3E-04	5.0E-04
	Plutonium-241	-2.3E-01	8.8E-02
	Strontium-90	-1.1E-03	2.4E-03
	Polonium-210	1.4E-02	1.0E-02
HB-NOY Bottom Sediment Noya Tank	Potassium-40	6.2E-01	1.1E-01
	Cobalt-60	-3.2E-04	9.1E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-NOY Bottom Sediment Noya Tank (continued)	Cesium-137	4.2E-03	1.9E-03
	Lead-210	1.7E-02	1.7E-02
	Radium-226	2.8E-02	2.3E-02
	Radium-228	2.2E-02	5.1E-03
	Americium-241	1.1E-02	2.5E-03
	Thorium-228	2.4E-02	4.9E-03
	Thorium-230	3.5E-02	5.8E-03
	Thorium-232	2.2E-02	4.5E-03
	Uranium-233/234	1.8E-02	2.5E-03
	Uranium-235	1.4E-03	7.6E-04
	Uranium-238	1.9E-02	2.5E-03
	Plutonium-239/240	-1.3E-04	2.5E-04
	Plutonium-238	2.5E-04	6.1E-04
	Plutonium-241	-2.9E-01	1.1E-01
	Strontium-90	-2.4E-04	1.5E-03
	Polonium-210	2.4E-02	1.1E-02
HB-PCN Bottom Sediment Pierce Canyon	Potassium-40	1.5E-01	3.1E-02
	Cobalt-60	6.5E-04	7.3E-04
	Cesium-137	-5.1E-04	8.2E-04
	Lead-210	1.2E-02	1.1E-02
	Radium-226	4.8E-02	2.4E-02
	Radium-228	1.2E-02	5.8E-03
	Americium-241	1.4E-02	2.7E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-PCN Bottom Sediment Pierce Canyon (continued)	Thorium-228	9.0E-03	2.2E-03
	Thorium-230	3.9E-02	4.4E-03
	Thorium-232	7.3E-03	2.0E-03
	Uranium-233/234	1.2E-01	6.7E-03
	Uranium-235	7.5E-03	1.9E-03
	Uranium-238	1.3E-01	6.9E-03
	Plutonium-238	0.0E+00	2.8E-04
	Plutonium-239/240	1.1E-03	6.6E-04
	Plutonium-241	-2.2E-01	8.2E-02
	Strontium-90	-1.6E-03	1.2E-03
	Polonium-210	1.4E-02	9.7E-03
HB-RED Bottom Sediment Red Tank	Potassium-40	4.0E-01	7.2E-02
	Cobalt-60	5.1E-04	9.2E-04
	Cesium-137	7.3E-03	3.0E-03
	Lead-210	3.0E-02	1.6E-02
	Radium-226	4.2E-02	2.6E-02
	Radium-228	2.3E-02	5.7E-03
	Americium-241	1.1E-02	2.4E-03
	Thorium-228	2.2E-02	4.6E-03
	Thorium-230	3.0E-02	5.3E-03
	Thorium-232	1.7E-02	4.1E-03
	Uranium-233/234	3.1E-02	8.3E-03
	Uranium-235	5.9E-04	3.1E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-RED Bottom Sediment Red Tank (continued)	Uranium-238	3.0E-02	7.5E-03
	Plutonium-238	-9.7E-05	1.9E-04
	Plutonium-239/240	1.9E-04	2.7E-04
	Plutonium-241	-2.1E-01	7.8E-02
	Strontium-90	-6.8E-04	1.2E-03
	Polonium-210	2.2E-02	9.5E-03
HB-TUT Bottom Sediment Tut Tank	Potassium-40	7.0E-01	1.2E-01
	Cobalt-60	-5.0E-04	9.8E-04
	Cesium-137	9.4E-04	1.6E-03
	Lead-210	2.5E-02	1.7E-02
	Radium-226	3.0E-02	2.5E-02
	Radium-228	3.0E-02	6.4E-03
	Americium-241	1.1E-02	2.7E-03
	Thorium-228	4.5E-02	1.2E-03
	Thorium-230	4.3E-02	1.1E-03
	Thorium-232	4.5E-02	1.1E-02
	Uranium-233/234	2.8E-02	3.2E-03
	Uranium-235	2.2E-03	9.9E-04
	Uranium-238	2.5E-02	3.0E-03
	Plutonium-238	0.0E+00	0.0E+00
	Plutonium-239/240	4.2E-04	4.1E-04
	Plutonium-241	-1.3E-01	9.0E-02
	Strontium-90	2.6E-03	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
HB-TUT Bottom Sediment Tut Tank (continued)	Polonium-210	3.1E-02	1.2E-02
HB-UPR Bottom Sediment Upper Pecos River	Potassium-40	1.7E-01	3.2E-02
	Cobalt-60	6.7E-05	6.8E-04
	Cesium-137	3.3E-05	6.7E-04
	Lead-210	1.6E-03	1.0E-02
	Radium-226	8.3E-03	1.3E-02
	Radium-228	4.4E-03	4.1E-03
	Americium-241	8.5E-03	2.1E-03
	Thorium-228	8.4E-03	1.8E-03
	Thorium-230	2.4E-02	3.0E-03
	Thorium-232	9.1E-03	1.9E-03
	Uranium-233/234	9.9E-03	2.0E-03
	Uranium-235	4.8E-04	7.5E-04
	Uranium-238	7.9E-03	1.7E-03
	Plutonium-238	-9.9E-05	1.9E-04
	Plutonium-239/240	7.9E-04	5.5E-04
	Plutonium-241	-2.2E-01	7.7E-02
	Strontium-90	-2.1E-04	1.3E-03
	Polonium-210	4.7E-03	1.0E-02

APPENDIX A5

GROUNDWATER

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H05B Groundwater Round 9	Potassium-40	3.7E+01	7.7E+00
	Cobalt-60	5.3E-02	2.0E-01
	Cesium-137	-1.2E-01	1.7E-01
	Lead-210	1.2E+00	4.5E+00
	Radium-226	1.5E+01	9.5E+00
	Radium-228	1.7E+00	1.7E+00
	Americium-241	3.8E-03	3.5E-03
	Thorium-228	3.8E-01	2.7E-02
	Thorium-230	6.7E-02	1.2E-02
	Thorium-232	0.0E+00	1.4E-03
	Uranium-233/234	1.1E-01	1.4E-02
	Uranium-235	3.8E-03	3.8E-03
	Uranium-238	7.0E-03	3.6E-03
	Plutonium-238	5.9E-03	3.6E-03
	Plutonium-239/240	1.8E-03	3.0E-03
	Plutonium-241	-1.9E-01	4.3E-01
	Strontium-90	-5.1E-02	2.4E-02
	Polonium-210	6.1E-02	4.8E-02
H02C Groundwater Round 6	Potassium-40	3.3E+00	3.1E+00
	Cobalt-60	9.5E-02	1.7E-01
	Cesium-137	8.1E-02	1.6E-01
	Lead-210	9.3E-01	3.9E+00
	Radium-226	3.3E+00	5.1E+00
	Radium-228	4.2E-01	6.8E-01
	Americium-241	1.4E-02	7.0E-03
	Thorium-228	2.3E-02	7.2E-03
	Thorium-230	3.6E-02	8.4E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H02C Groundwater Round 6 (continued)	Thorium-232	1.4E-03	2.5E-03
	Uranium-233/234	3.6E-01	5.2E-02
	Uranium-235	6.3E-03	9.1E-03
	Uranium-238	4.1E-02	2.0E-02
	Plutonium-238	1.4E-03	4.5E-03
	Plutonium-239/240	0.0E+00	2.8E-03
	Plutonium-241	-2.4E-01	5.6E-01
	Strontium-90	6.6E-02	1.3E-01
	Polonium-210	9.6E-03	4.8E-02
H09B Groundwater Round 5	Potassium-40	2.6E+00	2.5E+00
	Cobalt-60	-1.2E-01	1.7E-01
	Cesium-137	8.2E-02	1.5E-01
	Lead-210	5.5E-01	3.9E+00
	Radium-226	3.8E+00	4.9E+00
	Radium-228	8.3E-01	8.6E-01
	Americium-241	2.3E-02	8.4E-03
	Thorium-228	9.6E-03	4.5E-03
	Thorium-230	5.8E-02	1.1E-02
	Thorium-232	5.1E-04	9.9E-04
	Uranium-233/234	7.5E-01	3.9E-02
	Uranium-235	2.4E-02	7.9E-03
	Uranium-238	4.1E-01	2.9E-02
	Plutonium-238	4.3E-03	3.6E-03
	Plutonium-239/240	1.2E-03	1.7E-03
	Plutonium-241	1.7E+00	5.1E-01
	Strontium-90	-9.3E-03	2.2E-02
	Polonium-210	6.0E-03	7.3E-02
H3B3 Groundwater Round 9	Potassium-40	1.2E+01	4.2E+00
	Cobalt-60	3.4E-02	1.9E-01

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H3B3 Groundwater Round 9 (continued)	Cesium-137	-2.9E-02	1.6E-01
	Lead-210	2.3E+00	4.0E+00
	Radium-226	7.4E+00	6.1E+00
	Radium-228	1.3E+00	1.5E+00
	Americium-241	3.6E-03	3.7E-03
	Thorium-228	1.3E-01	1.6E-02
	Thorium-230	4.4E-02	9.0E-03
	Thorium-232	-9.6E-04	2.3E-03
	Uranium-233/234	4.8E-01	3.1E-02
	Uranium-235	9.8E-03	5.4E-03
	Uranium-238	6.3E-02	1.1E-02
	Plutonium-238	9.1E-03	5.1E-03
	Plutonium-239/240	-5.1E-04	1.0E-03
	Plutonium-241	9.6E-03	3.9E-01
	Strontium-90	-2.2E-02	3.0E-02
	Polonium-210	1.4E-02	3.5E-02
H11B Groundwater Round 8	Potassium-40	1.8E+01	5.5E+00
	Cobalt-60	-6.5E-02	1.7E-01
	Cesium-137	-4.6E-02	1.6E-01
	Lead-210	1.7E+00	4.1E+00
	Radium-226	7.0E+00	5.9E+00
	Radium-228	9.9E-01	1.1E+00
	Americium-241	8.9E-03	4.8E-03
	Thorium-228	7.1E-02	1.3E-02
	Thorium-230	5.2E-02	1.1E-02
	Thorium-232	-5.4E-04	1.8E-03
	Uranium-233/234	2.5E-01	2.3E-02
	Uranium-235	7.7E-03	5.6E-03
	Uranium-238	3.8E-02	9.5E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H11B Groundwater Round 8 (continued)	Plutonium-238	2.0E-03	3.4E-03
	Plutonium-239/240	4.6E-03	3.4E-03
	Plutonium-241	3.3E+00	6.1E-01
	Strontium-90	9.8E-03	1.4E-02
	Polonium-210	3.5E-02	5.2E-02
H14C Groundwater Round 7	Potassium-40	1.1E+01	4.0E+00
	Cobalt-60	1.4E-01	2.0E-01
	Cesium-137	-4.0E-03	2.0E-01
	Lead-210	1.2E+01	3.3E+00
	Radium-226	9.5E+00	7.6E+00
	Radium-228	6.9E-01	9.2E-01
	Americium-241	1.5E-02	5.8E-03
	Thorium-228	5.6E-02	1.1E-02
	Thorium-230	2.9E-02	8.3E-03
	Thorium-232	1.0E-03	2.0E-03
	Uranium-233/234	3.2E-01	3.1E-02
	Uranium-235	7.1E-03	6.0E-03
	Uranium-238	4.9E-02	1.2E-02
	Plutonium-238	4.6E-03	4.2E-03
	Plutonium-239/240	5.7E-04	1.9E-03
	Plutonium-241	7.0E-01	4.7E-01
	Strontium-90	5.4E-03	9.5E-03
	Polonium-210	7.9E-03	3.5E-02
H04B Groundwater Round 9	Potassium-40	7.1E+00	3.5E+00
	Cobalt-60	8.2E-02	1.7E-01
	Cesium-137	-1.3E-01	1.6E-01
	Lead-210	8.9E-01	4.0E+00
	Radium-226	3.3E+00	4.2E+00
	Radium-228	5.4E-01	7.3E-01

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H04B Groundwater Round 9 (continued)	Americium-241	1.3E-02	5.4E-03
	Thorium-228	6.7E-03	4.6E-03
	Thorium-230	3.9E-02	9.7E-03
	Thorium-232	-6.1E-04	1.2E-03
	Uranium-233/234	5.7E-01	3.6E-02
	Uranium-235	1.6E-02	7.2E-03
	Uranium-238	1.0E-01	1.5E-02
	Plutonium-238	-3.3E-03	4.6E-03
	Plutonium-239/240	-1.6E-03	5.6E-03
	Plutonium-241	-1.3E-01	1.2E+00
	Strontium-90	1.1E-01	5.9E-02
	Polonium-210	7.8E-03	3.6E-02
H06B Groundwater Round 9	Potassium-40	1.1E+01	4.1E+00
	Cobalt-60	-7.8E-02	1.9E-01
	Cesium-137	-2.0E-02	1.5E-01
	Lead-210	3.1E+00	3.7E+00
	Radium-226	7.3E+00	4.8E+00
	Radium-228	8.7E-01	8.8E-01
	Americium-241	8.3E-03	4.9E-03
	Thorium-228	4.2E-02	1.4E-02
	Thorium-230	2.5E-02	1.4E-02
	Thorium-232	2.2E-03	5.3E-03
	Uranium-233/234	2.9E-01	2.5E-02
	Uranium-235	1.4E-02	7.0E-03
	Uranium-238	7.7E-02	1.3E-02
	Plutonium-238	8.9E-03	6.6E-03
	Plutonium-239/240	2.5E-03	5.0E-03
	Plutonium-241	-1.4E+00	9.5E-01
	Strontium-90	-2.7E-02	1.6E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/L	95% CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
H06B Groundwater Round 9 (continued)	Polonium-210	7.3E-03	3.6E-02
WIPP 19 Groundwater Round 9	Potassium-40	1.4E+01	5.0E+00
	Cobalt-60	4.5E-02	1.9E-01
	Cesium-137	9.0E-02	1.7E-01
	Lead-210	3.8E+00	4.5E+00
	Radium-226	8.7E+00	6.9E+00
	Radium-228	1.2E+00	1.3E+00
	Americium-241	8.4E-03	5.5E-03
	Thorium-228	2.8E-01	2.6E-02
	Thorium-230	6.3E-02	1.3E-02
	Thorium-232	-1.3E-03	1.8E-03
	Uranium-233/234	5.5E-01	5.4E-02
	Uranium-235	1.3E-02	9.2E-03
	Uranium-238	9.4E-02	2.3E-02
	Plutonium-238	4.3E-03	4.9E-03
	Plutonium-239/240	7.2E-04	3.2E-03
	Plutonium-241	-6.6E-01	5.4E-01
	Strontium-90	-5.8E-03	2.3E-02
	Polonium-210	4.1E-02	7.0E-02

APPENDIX A6

BIOTICS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-CT1 Biotic Vegetation Control 1	Potassium-40	2.5E-01	6.5E-02
	Cobalt-60	2.2E-03	2.4E-03
	Cesium-137	-1.7E-03	2.0E-03
	Lead-210	1.1E-01	5.8E-02
	Radium-226	5.3E-03	6.0E-02
	Radium-228	5.7E-03	1.3E-02
	Actinium-228	5.7E-03	1.3E-02
	Americium-241	4.8E-03	1.4E-03
	Thorium-228	-8.9E-05	6.3E-04
	Thorium-230	8.9E-05	3.9E-04
	Thorium-232	2.7E-04	3.0E-04
	Uranium-233/234	2.9E-04	6.9E-04
	Uranium-235	0.0E+00	4.7E-04
	Uranium-238	2.9E-04	5.1E-04
	Plutonium-238	-1.9E-04	4.6E-04
	Plutonium-239/240	-9.5E-05	4.2E-04
	Plutonium-241	-7.9E-02	4.7E-02
	Strontium-90	4.7E-03	1.1E-03
	Polonium-210	1.7E-02	3.3E-03
BV-CT2 Biotic Vegetation Control 2	Potassium-40	2.9E-01	5.3E-02
	Cobalt-60	7.4E-04	1.2E-03
	Cesium-137	4.6e-04	1.1E-03
	Lead-210	7.2E-02	3.3E-02
	Radium-226	3.9E-02	2.6E-02
	Radium-228	7.8E-03	6.3E-03
	Actinium-228	7.8E-03	6.3E-03
	Americium-241	6.7E-03	1.9E-03
	Thorium-228	8.6E-04	6.7E-04
	Thorium-230	1.7E-03	7.9E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-CT2 Biotic Vegetation Control 2 (continued)	Thorium-232	0.0E+00	2.6E-04
	Uranium-233/234	5.7E-04	6.5E-04
	Uranium-235	2.4E-04	3.3E-04
	Uranium-238	8.6E-04	6.2E-04
	Plutonium-238	2.9E-04	3.3E-04
	Plutonium-239/240	9.6E-05	5.0E-04
	Plutonium-241	-9.2E-02	4.8E-02
	Strontium-90	7.1E-03	1.2E-03
	Polonium-210	1.2E-02	2.0E-03
BV-SE1 Biotic Vegetation South East 1	Potassium-40	2.3E-01	5.7E-02
	Cobalt-60	2.5E-03	1.8E-03
	Cesium-137	1.1E-04	1.7E-03
	Lead-210	9.8E-02	5.2E-02
	Radium-226	3.9E-02	3.5E-02
	Radium-228	7.0E-03	1.0E-02
	Actinium-228	7.0E-03	1.0E-02
	Americium-241	6.1E-03	1.6E-03
	Thorium-228	1.1E-03	7.4E-04
	Thorium-230	1.3E-03	6.9E-04
	Thorium-232	8.5E-04	6.7E-04
	Uranium-233/234	4.8E-04	5.0E-04
	Uranium-235	3.6E-04	4.0E-04
	Uranium-238	6.7E-04	7.8E-04
	Plutonium-238	0.0E+00	3.7E-04
	Plutonium-239/240	-9.4E-05	3.2E-04
	Plutonium-241	-5.6E-02	4.8E-02
	Strontium-90	5.3E-03	1.2E-03
	Polonium-210	2.1E-02	2.3E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-NW1 Biotic Vegetation North West 1	Potassium-40	3.2E-01	5.8E-02
	Cobalt-60	2.0E-04	1.3E-03
	Cesium-137	8.3E-04	1.1E-03
	Lead-210	5.9E-02	3.7E-02
	Radium-226	3.8E-02	4.5E-02
	Radium-228	8.9E-03	1.1E-02
	Actinium-228	8.9E-03	1.1E-02
	Americium-241	7.1E-03	1.8E-03
	Thorium-228	9.4E-04	8.3E-04
	Thorium-230	3.4E-03	1.2E-03
	Thorium-232	5.7E-04	5.8E-04
	Uranium-233/234	1.8E-03	9.3E-04
	Uranium-235	2.3E-04	6.5E-04
	Uranium-238	9.5E-04	6.4E-04
	Plutonium-238	3.9E-05	3.8E-04
	Plutonium-239/240	9.7E-05	3.3E-04
	Plutonium-241	-8.3E-02	4.7E-02
	Strontium-90	9.0E-03	1.2E-03
	Polonium-210	1.7E-02	2.2E-03
BV-NW2 Biotic Vegetation North West 2	Potassium-40	3.3e-01	6.0E-02
	Cobalt-60	-5.2E-04	1.4E-03
	Cesium-137	1.1E-03	1.4E-03
	Lead-210	9.0E-02	4.7E-02
	Radium-226	1.6E-02	4.6E-02
	Radium-228	5.0E-03	7.2E-03
	Actinium-228	8.0E-03	7.2E-03
	Americium-241	6.0E-03	1.6E-03
	Thorium-228	6.4E-04	9.0E-04
	Thorium-230	6.2E-03	1.6E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-NW2 Biotic Vegetation North West 2 (continued)	Thorium-232	9.1E-04	6.2E-04
	Uranium-233/234	3.7E-04	5.2E-04
	Uranium-235	0.0E+00	4.5E-04
	Uranium-238	4.7E-04	4.1E-04
	Plutonium-238	-9.5E-05	3.2E-04
	Plutonium-239/240	0.0E+00	2.6E-04
	Plutonium-241	-6.5E-02	4.8E-02
	Strontium-90	8.6E-03	1.1E-03
	Polonium-210	2.0E-02	2.1E-03
BV-WE1 Biotic Vegetation WIPP East 1	Potassium-40	2.5E-01	4.4E-02
	Cobalt-60	-3.4E-05	1.1E-03
	Cesium-137	5.2E-04	9.1E-04
	Lead-210	3.8E-02	2.8E-02
	Radium-226	1.1E-02	2.9E-02
	Radium-228	3.3E-03	5.5E-03
	Actinium-228	3.3E-03	5.5E-03
	Americium-241	7.0E-03	1.6E-03
	Thorium-228	9.3E-05	7.0E-04
	Thorium-230	1.0E-02	1.9E-03
	Thorium-232	5.6E-04	5.8E-04
	Uranium-233/234	9.3E-05	6.6E-04
	Uranium-235	2.3E-04	6.4E-04
	Uranium-238	3.7E-04	5.8E-04
	Plutonium-238	-1.8E-04	2.5E-04
	Plutonium-239/240	9.1E-05	3.1E-04
	Plutonium-241	-1.7E-02	4.6E-02
	Strontium-90	6.8E-03	1.1E-03
	Polonium-210	2.1E-02	2.1E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BV-SE2 Biotic Vegetation South East 2	Potassium-40	3.2E-01	6.4E-02
	Cobalt-60	-1.1E-03	1.9E-03
	Cesium-137	1.4E-03	1.7E-03
	Lead-210	9.9E-02	5.0E-02
	Radium-226	2.2E-02	4.6E-02
	Radium-228	8.5E-03	1.2E-02
	Actinium-228	8.5E-03	1.2E-02
	Americium-241	6.4E-03	1.6E-03
	Thorium-228	9.9E-04	8.4E-04
	Thorium-230	2.9E-03	1.1E-03
	Thorium-232	6.3E-04	5.3E-04
	Uranium-233/234	5.0E-04	6.5E-04
	Uranium-235	6.2E-04	5.4E-04
	Uranium-238	3.0E-04	6.5E-04
	Plutonium-238	9.7E-05	3.3E-04
	Plutonium-239/240	4.8E-04	4.2E-04
	Plutonium-241	-8.7E-02	4.8E-02
	Strontium-90	7.6E-03	1.3E-03
	Polonium-210	1.2E-02	2.8E-03
BQ-SAB Biotic Quail Secured Area Boundary	Potassium-40	8.4E-02	3.0E-02
	Cobalt-60	8.1E-04	8.4E-04
	Cesium-137	6.2E-04	9.2E-04
	Lead-210	3.7E-02	1.1E-02
	Radium-226	8.9E-03	1.9E-02
	Radium-228	2.5E-03	3.3E-03
	Americium-241	4.9E-04	3.0E-04
	Thorium-228	3.0E-05	1.6E-04
	Thorium-230	2.9E-03	6.0E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BQ-SAB Biotic Quail Secured Area Boundary (continued)	Thorium-232	9.0E-05	1.3E-04
	Uranium-233/234	1.5E-03	4.5E-04
	Uranium-235	8.4E-05	1.2E-04
	Uranium-238	2.4E-04	2.4E-04
	Plutonium-238	3.6E-05	1.6E-04
	Plutonium-239/240	-3.6E-05	1.6E-04
	Plutonium-241	1.6E-02	3.1E-02
	Strontium-90	1.7E-03	8.7E-04
	Polonium-210	6.0E-04	1.9E-03
BF-BRA Biotic Fish Brantley Lake	Potassium-40	1.1E-01	3.6E-02
	Cobalt-60	4.6E-04	9.5E-04
	Cesium-137	6.9E-04	9.5E-04
	Lead-210	3.6E-03	1.7E-02
	Radium-226	1.9E-02	1.4E-02
	Radium-228	1.3E-03	4.3E-03
	Americium-241	2.3E-04	1.0E-03
	Thorium-228	6.0E-05	1.4E-04
	Thorium-230	4.2E-03	7.0E-04
	Thorium-232	3.0E-05	1.0E-04
	Uranium-233/234	1.6E-03	4.8E-04
	Uranium-235	2.0E-04	2.3E-04
	Uranium-238	6.4E-04	3.1E-04
	Plutonium-238	1.8E-04	1.7E-04
	Plutonium-239/240	-8.8E-05	1.2E-04
	Plutonium-241	2.4E-02	3.8E-02
	Strontium-90	3.6E-04	6.1E-04
	Polonium-210	3.0E-04	1.7E-03
BF-PEC Biotic Fish Pecos River	Potassium-40	9.5E-02	3.1E-02
	Cobalt-60	-7.7E-05	7.7E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BF-PEC Biotic Fish Pecos River (continued)	Cesium-137	-2.0E-04	8.1E-04
	Lead-210	1.3E-02	1.5E-02
	Radium-226	1.9E-02	1.2E-02
	Radium-228	2.1E-03	2.9E-03
	Americium-241	-6.8E-03	3.0E-02
	Thorium-228	-3.5E-05	2.4E-04
	Thorium-230	2.2E-03	5.5E-04
	Thorium-232	1.0E-04	1.2E-04
	Uranium-233/234	2.2E-03	8.1E-04
	Uranium-235	2.5E-04	2.2E-04
	Uranium-238	1.2E-03	4.7E-04
	Plutonium-238	-1.2E-04	1.3E-04
	Plutonium-239/240	7.8E-05	1.5E-04
	Plutonium-241	-1.4E-02	3.1E-02
	Strontium-90	1.1E-04	6.4E-04
	Polonium-210	1.2E-04	1.8E-03
BR-SAR Biotic Rabbit South Access Road	Potassium-40	1.3E-01	4.4E-02
	Cobalt-60	6.0E-04	1.1E-03
	Cesium-137	8.9E-04	1.1E-03
	Lead-210	5.7E-04	1.8E-02
	Radium-226	1.2E-02	2.4E-02
	Radium-228	4.5E-03	4.2E-03
	Americium-241	3.4E-04	2.7E-04
	Thorium-228	-3.4E-05	6.7E-05
	Thorium-230	2.4E-03	5.8E-04
	Thorium-232	1.0E-04	1.5E-04
	Uranium-233/234	1.4E-04	6.5E-05
	Uranium-235	2.1E-05	3.1E-05
	Uranium-238	4.5E-05	3.8E-05

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BR-SAR Biotic Rabbit South Access Road (continued)	Plutonium-238	2.3E-04	2.0E-04
	Plutonium-239/240	0.0E+00	0.0E+00
	Plutonium-241	-1.2E-02	0.0E+00
	Strontium-90	-7.7E-06	6.2E-04
	Polonium-210	-4.9E-05	1.8E-03
BD-SAR Biotic Deer South Access Road Muscle	Potassium-40	9.5E-02	3.2E-02
	Cobalt-60	7.3E-04	8.4E-04
	Cesium-137	-5.8E-05	8.2E-04
	Lead-210	1.4E-03	1.3E-02
	Radium-226	2.2E-02	1.3E-02
	Radium-228	4.0E-03	2.9E-03
	Americium-241	0.0E+00	5.1E-04
	Thorium-228	1.1E-04	5.0E-04
	Thorium-230	1.1E-02	2.3E-03
	Thorium-232	1.1E-04	3.8E-04
	Uranium-233/234	5.4E-03	1.6E-03
	Uranium-235	3.7E-04	5.4E-04
	Uranium-238	1.9E-03	8.9E-04
	Plutonium-238	3.0E-04	4.3E-04
	Plutonium-239/240	2.0E-04	3.9E-04
	Plutonium-241	2.6E-02	8.3E-02
	Strontium-90	-6.6E-04	6.1E-04
	Polonium-210	1.5E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Liver	Potassium-40	7.1E-02	3.1E-02
	Cobalt-60	2.6E-04	8.9E-04
	Cesium-137	-9.7E-04	1.1E-03
	Lead-210	4.6E-02	1.2E-02
	Radium-226	4.7E-03	2.0E-02
	Radium-228	3.9E-03	3.8E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-SAR Biotic Deer South Access Road Liver (continued)	Americium-241	1.5E-03	5.6E-04
	Thorium-228	4.0E-04	2.9E-04
	Thorium-230	4.6E-03	8.9E-04
	Thorium-232	4.4E-05	1.5E-04
	Uranium-233/234	3.0E-03	7.3E-04
	Uranium-235	-5.1E-05	3.8E-04
	Uranium-238	1.3E-03	5.4E-04
	Plutonium-238	8.5E-05	1.2E-04
	Plutonium-239/240	8.5E-05	1.7E-04
	Plutonium-241	-1.7E-02	3.6E-02
	Strontium-90	1.2E-04	5.3E-04
	Polonium-210	3.4E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Heart	Potassium-40	8.5E-02	3.1E-02
	Cobalt-60	1.3E-03	1.7E-03
	Cesium-137	-1.1E-04	9.6E-04
	Lead-210	8.8E-03	1.6E-02
	Radium-226	6.0E-03	1.9E-02
	Radium-228	3.0E-03	3.5E-03
	Americium-241	1.2E-03	7.0E-04
	Thorium-228	0.0E+00	6.1E-04
	Thorium-230	1.3E-02	2.3E-03
	Thorium-232	0.0E+00	2.8E-04
	Uranium-233/234	2.8E-03	8.7E-04
	Uranium-235	3.6E-04	4.2E-04
	Uranium-238	3.5E-04	3.9E-04
	Plutonium-238	2.4E-04	2.4E-04
	Plutonium-239/240	1.2E-04	1.7E-04
	Plutonium-241	2.0E-02	5.4E-02

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-SAR Biotic Deer South Access Road Heart (continued)	Strontium-90	4.8E-04	7.4E-04
	Polonium-210	2.1E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Muscle	Potassium-40	8.5E-02	2.9E-02
	Cobalt-60	-2.5E-04	6.8E-04
	Cesium-137	1.8E-04	7.9E-04
	Lead-210	1.2E-03	1.2E-02
	Radium-226	1.2e-02	1.0E-02
	Radium-228	3.9E-03	2.7E-03
	Americium-241	1.4E-03	6.3E-04
	Thorium-228	0.0E+00	2.4E-04
	Thorium-230	4.5E-03	9.4E-04
	Thorium-232	9.9E-05	1.9E-04
	Uranium-233/234	2.0E-03	6.9E-04
	Uranium-235	6.0E-05	2.6E-04
	Uranium-238	2.4E-04	3.2E-04
	Plutonium-238	8.7E-05	2.1E-04
	Plutonium-239/240	4.4E-05	8.6E-05
	Plutonium-241	-5.6E-04	3.7E-02
	Strontium-90	-2.5E-04	5.0E-04
	Polonium-210	1.2E-04	1.8E-03
BD-SAR Biotic Deer South Access Road Kidney	Potassium-40	4.0E-02	3.1E-02
	Cobalt-60	1.8E-03	1.4E-03
	Cesium-137	-1.7E-04	1.3E-03
	Lead-210	4.8E-02	1.4E-02
	Radium-226	1.9E-02	3.1E-02
	Radium-228	3.6E-03	4.8E-03
	Americium-241	1.2E-03	7.3E-04

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-SAR Biotic Deer South Access Road Kidney (continued)	Thorium-228	4.5E-04	2.9E-04
	Thorium-230	2.9E-03	6.9E-04
	Thorium-232	8.2E-05	2.5E-04
	Uranium-233/234	1.6E-03	6.9E-04
	Uranium-235	2.1E-04	2.4E-04
	Uranium-238	6.2E-04	4.3E-04
	Plutonium-238	2.1E-04	2.5E-04
	Plutonium-239/240	0.0E+00	1.4E-04
	Plutonium-241	2.1E-02	4.5E-02
	Strontium-90	-3.8E-04	4.6E-04
	Polonium-210	2.0E-03	1.9E-03
BD-SAR Biotic Deer South Access Road Liver	Potassium-40	8.4E-02	2.8E-02
	Cobalt-60	-4.6E-05	7.0E-04
	Cesium-137	-5.2E-04	8.0E-04
	Lead-210	2.9E-02	9.0E-03
	Radium-226	3.5E-04	1.6E-02
	Radium-228	4.6E-03	4.3E-03
	Americium-241	1.0E-03	5.5E-04
	Thorium-228	1.2E-03	5.4E-04
	Thorium-230	4.7E-03	1.0E-03
	Thorium-232	0.0E+00	2.3E-04
	Uranium-233/234	1.4E-03	7.0E-04
	Uranium-235	7.1E-05	3.1E-04
	Uranium-238	4.0E-04	3.7E-04
	Plutonium-238	4.4E-04	3.7E-04
	Plutonium-239/240	6.3E-05	1.2E-04
	Plutonium-241	-2.3E-02	5.3E-02
	Strontium-90	-3.3E-04	6.1E-04
	Polonium-210	5.5E-04	1.9E-03

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULT/UNIT Bq/g	95 % CONFIDENCE LEVEL AT TWO STANDARD DEVIATIONS
BD-NAR Biotic Deer North Access Road Muscle	Potassium-40	7.7E-02	2.5E-02
	Cobalt-60	3.6E-04	5.9E-04
	Cesium-137	3.9E-04	6.9E-04
	Lead-210	2.5E-02	7.2E-03
	Radium-226	8.4E-05	1.2E-02
	Radium-228	2.1E-03	2.2E-03
	Americium-241	7.9E-04	3.7E-04
	Thorium-228	9.3E-05	1.8E-04
	Thorium-230	3.7E-03	8.3E-04
	Thorium-232	0.0E+00	2.8E-04
	Uranium-233/234	1.7E-03	5.5E-04
	Uranium-235	1.9E-04	1.9E-04
	Uranium-238	8.3E-04	3.6E-04
	Plutonium-238	7.7E-05	1.9E-04
	Plutonium-239/240	-7.7E-05	1.1E-04
	Plutonium-241	-1.6E-02	3.2E-02
	Strontium-90	8.4E-04	6.7E-04
	Polonium-210	8.8E-05	1.9E-03

APPENDIX B

1994

NONRADIOLOGICAL

SOIL ANALYSIS

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW1 Terrestrial Surface Non-Radiological North West 1	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	6	mg/kg
	pH	7.5	pH
	Calcium, total	9.0	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	2.2	mg/L
	Sodium, total	3.2	mg/L
	Sodium Absorption Ratio	0.25	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	7	mg/kg
	pH	7.3	pH
	Calcium, total	11	mg/L
	Potassium, total	17	mg/L
	Magnesium, total	2.4	mg/L
	Sodium, total	3.4	mg/L
	Sodium Absorption Ratio	0.24	meq/L
	Saturation Percent	17	% mg/L
	Conductivity	0.14	mmhos/cm
	Chloride	7	mg/kg
	pH	7.3	pH
	Calcium, total	58	mg/L
	Potassium, total	20	mg/L
	Magnesium, total	7.6	mg/L
	Sodium, total	9.0	mg/L
	Sodium Absorption Ratio	0.30	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.070	mmhos/cm
	Chloride	7	mg/kg
	pH	7.4	pH
	Calcium, total	6.3	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW1 Terrestrial Surface Non-Radiological North West 1 (continued)	Potassium, total	8.9	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	2.7	mg/L
	Sodium Absorption Ratio	0.26	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	6	mg/kg
	pH	7.5	pH
	Calcium, total	11	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	2.4	mg/L
	Sodium, total	1.8	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.088	mmhos/cm
	Chloride	6	mg/kg
	pH	7.5	pH
	Calcium, total	8.1	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	2.3	mg/L
	Sodium, total	2.0	mg/L
	Sodium Absorption Ratio	0.16	meq/L
TS-NW2 Terrestrial Surface Non-Radiological North West 2	Saturation Percent	20	% mg/L
	Conductivity	0.043	mmhos/cm
	Chloride	7	mg/kg
	pH	6.6	pH
	Calcium, total	3.4	mg/L
	Potassium, total	8.7	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.16	meq/L
	Saturation Percent	19	% mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW2 Terrestrial Surface Non-Radiological North West 2 (continued)	Conductivity	0.039	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	2.7	mg/L
	Potassium, total	6.1	mg/L
	Magnesium, total	1.7	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.12	meq/L
	Saturation Percent	21	% mg/L
	Conductivity	0.053	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	4.4	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	2.2	mg/L
	Sodium Absorption Ratio	0.24	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.047	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	4.6	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	2.3	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	16	% mg/L
	Conductivity	0.033	mmhos/cm
	Chloride	6	mg/kg
	pH	6.4	pH
	Calcium, total	< 2.5	mg/L
	Potassium, total	6.5	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-NW2 Terrestrial Surface Non-Radiological North West 2 (continued)	Magnesium, total	1.1	mg/L
	Sodium, total	2.4	mg/L
	Sodium Absorption Ratio	0.49	meq/L
	Saturation Percent	21	% mg/L
	Conductivity	0.047	mmhos/cm
	Chloride	6	mg/kg
	pH	6.5	pH
	Calcium, total	4.5	mg/L
	Potassium, total	8.2	mg/L
	Magnesium, total	1.3	mg/L
	Sodium, total	1.3	mg/L
	Sodium Absorption Ratio	0.14	meq/L
TS-SE1 Terrestrial Surface Non-Radiological South East 1	Saturation Percent	19	% mg/L
	Conductivity	0.12	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.4	pH
	Calcium, total	13	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	4.2	mg/L
	Sodium, total	1.3	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.071	mmhos/cm
	Chloride	8	mg/kg
	pH	7.7	pH
	Calcium, total	5.8	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	4.5	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.067	mmhos/cm

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-SE1 Terrestrial Surface Non-Radiological South East 1 (continued)	Chloride	7	mg/kg
	pH	6.5	pH
	Calcium, total	6.4	mg/L
	Potassium, total	17	mg/L
	Magnesium, total	2.9	mg/L
	Sodium, total	0.9	mg/L
	Sodium Absorption Ratio	0.07	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.11	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.6	pH
	Calcium, total	10	mg/L
	Potassium, total	11	mg/L
	Magnesium, total	2.7	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.10	mmhos/cm
	Chloride	9	mg/kg
	pH	7.3	pH
	Calcium, total	7.9	mg/L
	Potassium, total	17	mg/L
	Magnesium, total	2.4	mg/L
	Sodium, total	1.6	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	17	% mg/L
	Conductivity	0.12	mmhos/cm
	Chloride	31	mg/kg
	pH	7.5	pH
	Calcium, total	9.9	mg/L
	Potassium, total	15	mg/L
	Magnesium, total	3.4	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-SE1 Terrestrial Surface Non-Radiological South East 1 (continued)	Sodium, total	1.1	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
TS-SE2 Terrestrial Surface Non-Radiological South East 2	Saturation Percent	20	% mg/L
	Conductivity	0.055	mmhos/cm
	Chloride	8	mg/kg
	pH	6.9	pH
	Calcium, total	4.8	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	2.1	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.063	mmhos/cm
	Chloride	9	mg/kg
	pH	6.1	pH
	Calcium, total	11	mg/L
	Potassium, total	15	mg/L
	Magnesium, total	2.1	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.07	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.039	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.8	pH
	Calcium, total	2.8	mg/L
	Potassium, total	8.9	mg/L
	Magnesium, total	1.4	mg/L
	Sodium, total	2.0	mg/L
	Sodium Absorption Ratio	0.25	meq/L
	Saturation Percent	22	% mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-SE2 Terrestrial Surface Non-Radiological South East 2 (continued)	Conductivity	0.11	mmhos/cm
	Chloride	12	mg/kg
	pH	6.6	pH
	Calcium, total	14	mg/L
	Potassium, total	12	mg/L
	Magnesium, total	2.7	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.071	mmhos/cm
	Chloride	49	mg/kg
	pH	7.1	pH
	Calcium, total	5.9	mg/L
	Potassium, total	9.1	mg/L
	Magnesium, total	1.1	mg/L
	Sodium, total	1.6	mg/L
	Sodium Absorption Ratio	0.16	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.039	mmhos/cm
	Chloride	6	mg/kg
	pH	6.9	pH
	Calcium, total	2.6	mg/L
	Potassium, total	7.4	mg/L
	Magnesium, total	1.4	mg/L
	Sodium, total	0.9	mg/L
	Sodium Absorption Ratio	0.11	meq/L
TS-CT1 Terrestrial Surface Non-Radiological Control 1	Saturation Percent	19	% mg/L
	Conductivity	0.052	mmhos/cm
	Chloride	17	mg/kg
	pH	6.4	pH
	Calcium, total	3.0	mg/L
	Potassium, total	9.7	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT1 Terrestrial Surface Non-Radiological Control 1 (continued)	Magnesium, total	2.6	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.10	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.030	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.4	pH
	Calcium, total	2.6	mg/L
	Potassium, total	8.3	mg/L
	Magnesium, total	1.4	mg/L
	Sodium, total	0.9	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.046	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.4	pH
	Calcium, total	3.9	mg/L
	Potassium, total	13	mg/L
	Magnesium, total	1.8	mg/L
	Sodium, total	1.5	mg/L
	Sodium Absorption Ratio	0.16	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.038	mmhos/cm
	Chloride	< 6	mg/kg
	pH	6.3	pH
	Calcium, total	3.6	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	1.7	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	0.13	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.041	mmhos/cm

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT1 Terrestrial Surface Non-Radiological Control 1 (continued)	Chloride	< 6	mg/kg
	pH	6.5	pH
	Calcium, total	< 2.5	mg/L
	Potassium, total	7.9	mg/L
	Magnesium, total	1.0	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	0.26	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.052	mmhos/cm
	Chloride	7	mg/kg
	pH	6.5	pH
	Calcium, total	4.2	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	1.5	mg/L
	Sodium, total	1.4	mg/L
	Sodium Absorption Ratio	0.15	meq/L
TS-CT2 Terrestrial Surface Non-Radiological Control 2	Saturation Percent	17	% mg/L
	Conductivity	0.043	mmhos/cm
	Chloride	17	mg/kg
	pH	7.1	pH
	Calcium, total	3.0	mg/L
	Potassium, total	8.8	mg/L
	Magnesium, total	2.5	mg/L
	Sodium, total	0.7	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.032	mmhos/cm
	Chloride	11	mg/kg
	pH	7.3	pH
	Calcium, total	2.5	mg/L
	Potassium, total	8.5	mg/L
	Magnesium, total	1.9	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT2 Terrestrial Surface Non-Radiological Control 2 (continued)	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.041	mmhos/cm
	Chloride	8	mg/kg
	pH	7.2	pH
	Calcium, total	3.8	mg/L
	Potassium, total	8.0	mg/L
	Magnesium, total	2.0	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	22	% mg/L
	Conductivity	0.075	mmhos/cm
	Chloride	9	mg/kg
	pH	7.1	pH
	Calcium, total	9.5	mg/L
	Potassium, total	11	mg/L
	Magnesium, total	2.2	mg/L
	Sodium, total	0.7	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.045	mmhos/cm
	Chloride	9	mg/kg
	pH	6.8	pH
	Calcium, total	2.7	mg/L
	Potassium, total	8.5	mg/L
	Magnesium, total	0.7	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.056	mmhos/cm
	Chloride	11	mg/kg

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-CT2 Terrestrial Surface Non-Radiological Control 2 (continued)	pH	7.2	pH
	Calcium, total	5.0	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	2.3	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
TS-WE1 Terrestrial Surface Non-Radiological WIPP East 1	Saturation Percent	17	% mg/L
	Conductivity	0.056	mmhos/cm
	Chloride	8	mg/kg
	pH	7.4	pH
	Calcium, total	3.9	mg/L
	Potassium, total	7.9	mg/L
	Magnesium, total	2.1	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	0.12	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.060	mmhos/cm
	Chloride	8	mg/kg
	pH	7.2	pH
	Calcium, total	3.4	mg/L
	Potassium, total	6.1	mg/L
	Magnesium, total	1.2	mg/L
	Sodium, total	1.6	mg/L
	Sodium Absorption Ratio	0.19	meq/L
	Saturation Percent	19	% mg/L
	Conductivity	0.061	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.1	pH
	Calcium, total	3.6	mg/L
	Potassium, total	8.5	mg/L
	Magnesium, total	1.6	mg/L
	Sodium, total	1.3	mg/L

SAMPLE ANALYSIS BY LOCATION	PARAMETER	RESULTS	UNIT
TS-WE1 Terrestrial Surface Non-Radiological WIPP East 1 (continued)	Sodium Absorption Ratio	0.14	meq/L
	Saturation Percent	18	% mg/L
	Conductivity	0.049	mmhos/cm
	Chloride	< 6	mg/kg
	pH	7.2	pH
	Calcium, total	3.1	mg/L
	Potassium, total	7.0	mg/L
	Magnesium, total	2.0	mg/L
	Sodium, total	1.0	mg/L
	Sodium Absorption Ratio	0.11	meq/L
	Saturation Percent	21	% mg/L
	Conductivity	0.087	mmhos/cm
	Chloride	9	mg/kg
	pH	6.8	pH
	Calcium, total	9.3	mg/L
	Potassium, total	14	mg/L
	Magnesium, total	2.5	mg/L
	Sodium, total	1.2	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L
	Saturation Percent	20	% mg/L
	Conductivity	0.071	mmhos/cm
	Chloride	7	mg/kg
	pH	7.1	pH
	Calcium, total	6.8	mg/L
	Potassium, total	10	mg/L
	Magnesium, total	2.5	mg/L
	Sodium, total	0.8	mg/L
	Sodium Absorption Ratio	< 0.01	meq/L

APPENDIX D5
ENVIRONMENTAL MONITORING PLAN AT THE WASTE ISOLATION PILOT PLANT

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Waste Isolation Pilot Plant

Environmental Monitoring Plan

DOE/WIPP 96-2194

This document is issued by Westinghouse Electric Corporation, Waste Isolation Division, as the Management and Operating Contractor for the Department of Energy, Waste Isolation Pilot Plant, Carlsbad, New Mexico, 88221.

DOE CONTRACT NUMBER: DE-AC04-86AL31950

DOE/WIPP 96-2194

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TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

2.0 PROJECT DESCRIPTION 2-1

3.0 SITE CHARACTERISTICS 3-1
- 3.1 GEOGRAPHY 3-1
- 3.2 GEOLOGY 3-1
- 3.3 CLIMATOLOGY 3-1
- 3.4 HYDROLOGY 3-2
- 3.5 ECOLOGY 3-2
- 3.6 DEMOGRAPHY 3-3

4.0 DOSE CALCULATIONS 4-1

5.0 ENVIRONMENTAL MONITORING PROGRAM 5-1
- 5.1 GUIDELINES 5-1
- 5.2 SITE CHARACTERIZATION 5-3
  - 5.2.1 WIPP Biology Program 5-3
  - 5.2.2 United States Geological Survey (USGS) Studies 5-4
- 5.3 RADIOLOGICAL ENVIRONMENTAL MONITORING 5-4
  - 5.3.1 Effluent Monitoring - Liquid Releases 5-4
  - 5.3.2 Effluent Monitoring - Airborne Emissions 5-5
  - 5.3.3 External Radiation 5-6
  - 5.3.4 Airborne Particulates 5-6
  - 5.3.5 BIOTICS 5-8
  - 5.3.6 SOIL SAMPLING 5-9
  - 5.3.7 SURFACE WATER/DRINKING WATER 5-9
  - 5.3.8 GROUNDWATER 5-9
  - 5.3.9 SEDIMENT SAMPLING 5-10
- 5.4 NONRADIOLOGICAL ENVIRONMENTAL MONITORING 5-10
  - 5.4.1 Meteorological Monitoring 5-11
  - 5.4.2 Volatile Organic Compound Monitoring Program 5-11
  - 5.4.2.1 VOC Monitoring Plan 5-12
  - 5.4.3 Groundwater Surveillance 5-12
  - 5.4.4 Ecological Monitoring Plot Selection 5-12
  - 5.4.5 Aerial Photography 5-13
  - 5.4.6 Wildlife Ecology 5-13

6.0 SAMPLE HANDLING AND LABORATORY PROCEDURES 6-1
- 6.1 SAMPLE HANDLING 6-1
- 6.2 RADIOLOGICAL ENVIRONMENTAL SURVEILLANCE 6-2
- 6.3 NONRADIOLOGICAL ENVIRONMENTAL MONITORING 6-3

7.0 DATA ANALYSES 7-1
7.1 ACCURACY 7-1
7.2 TEMPORAL AND SPATIAL ANALYSIS 7-2
7.3 DISTRIBUTIONS AND DESCRIPTIVE STATISTICS 7-3
7.4 DATA ANOMALIES 7-3
7.5 COMPARISONS AND REPORTING 7-4

8.0 QUALITY ASSURANCE 8-1
8.1 INTRODUCTION 8-1
8.2 GOAL 8-1
8.3 PROGRAM ELEMENTS/CRITERIA 8-3
8.3.1 Program 8-3
8.3.2 Personnel Training and Qualification 8-4
8.3.3 Quality Improvement 8-4
8.3.4 Documents and Records 8-4
8.3.5 Work Processes 8-4
8.3.6 Design 8-6
8.3.7 Procurement 8-6
8.3.8 Inspection and Acceptance Testing 8-7
8.3.9 Management Assessment 8-7
8.3.10 Independent Assessment 8-7

9.0 REQUIRED RECORDS AND REPORTS 9-1
9.1 GENERAL INFORMATION AND PURPOSE 9-1
9.2 RECORD KEEPING 9-1
9.3 REPORTING 9-1

10.0 REFERENCES 10-1

LIST OF TABLES

TABLE NO.	TITLE	
5-1	EMP SAMPLING SCHEDULE	5-15
5-2	EMP ANALYTICAL ARRAY	5-16
8-1	10 CFR 830.120 CROSS REFERENCE TO ASME NQA-1 AND EPA QAMS-005/80	8-2

LIST OF FIGURES

FIGURE NO.	TITLE	
3-1	LOCATION OF THE WIPP SITE	3-4
3-2	PLAT OF WIPP SITE	3-5
3-3	GENERALIZED STRATIGRAPHY OF THE WIPP SITE	3-6
5-1	AIR SAMPLING SITES	5-18
5-2	VEGETATION SAMPLING SITES	5-19
5-3	SOIL SAMPLING SITES	5-20
5-4	SURFACE WATER, DRINKING WATER SAMPLING SITES	5-21
5-5	GROUNDWATER LEVEL SURVEILLANCE WELLS	5-22
5-6	LOCATION OF THE NEW WATER QUALITY SAMPLING WELLS	5-23
5-7	SEDIMENT SAMPLING SITES	5-24
5-8	CATCHMENT BASINS AND METEOROLOGICAL MONITORING SITES	5-25
5-9	LOCATIONS OF ECOLOGICAL MONITORING SITES	5-26

LIST OF ACRONYMS

AEC	Atomic Energy Commission
AIBS	American Institute of Biological Scientists
ANSI	American National Standards Institute
SER	Site Environmental Report
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
CAM	Continuous Air Monitor
CAO	Carlsbad Area Office
CAP88-PC	Clean Air Act Associated Package, 1988
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CH	Contact-Handled
CMS	Central Monitoring System
DOE	Department of Energy
DOE/AL	DOE Albuquerque Operations Office
DOT	Department of Transportation
EC	Electrical Conductivity
EDE	Effective Dose Equivalent
EEG	Environmental Evaluation Group
EMP	Environmental Monitoring Plan
EPA	Environmental Protection Agency
FAS	Fixed Air Sampler

LIST OF ACRONYMS
(CONTINUED)

FEIS	Final Environmental Impact Statement
HEPA	High Efficiency Particulate Air (filter)
ICRP	International Commission on Radiological Protection
LD	Limit of Detection
LoVol	Low Volume Air Sampler
LWA	Land Withdrawal Act
NCR	Nonconformance Report
NCRP	National Commission on Radiation Protection and Measurements
NES	Nonradiological Environmental Surveillance
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
NMD	No-Migration Determination
NMED	New Mexico Environment Department
NMVP	No-Migration Variance Petition
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OEMP	Operational Environmental Monitoring Plan
PDR	Program Deficiency Report
QA/QC	Quality Assurance/Quality Control
RBP	Radiological Baseline Program
RCA	Request for Corrective Action
RCRA	Resource Conservation and Recovery Act

LIST OF ACRONYMS
(CONTINUED)

RES	Radiological Environmental Surveillance
RH	Remote-Handled
SAR	Safety Analysis Report
SEIS	Final Supplement Environmental Impact Statement
SES	Storage Exhaust Shaft
SNL	Sandia National Laboratories
SOP	Standard Operating Procedure
STAR	Stability and Array File
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TLD	Thermoluminescent Dosimeter
TRU	Transuranic
TRUPACT	Transuranic Package Transporters
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
USBM	United States Bureau of Mines
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WHB	Waste Handling Building

LIST OF ACRONYMS
(CONTINUED)

WID	Westinghouse, Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WQSP	Water Quality Sampling Program

PREFACE

DOE Order 5400.1 (1990) requires each DOE site to prepare an Environmental Monitoring Plan (EMP). This document is to be reviewed annually and updated every three years. This is the second update of the EMP.

This EMP will be reviewed annually and will document any proposed changes in the environmental monitoring program. Changes to the environmental monitoring program may be necessary to allow the use of advanced technology and new data collection techniques.

The fundamental purpose of this document is to describe the programs established to ensure that there are no detrimental effects on the environment as a result of routine WIPP activities.

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1.0 INTRODUCTION

U.S. Department of Energy (DOE) Order 5400.1, General Environmental Protection Program Requirements (DOE, 1990a), requires each DOE facility to prepare an Environmental Monitoring Plan (EMP). This document is prepared for the Waste Isolation Pilot Plant (WIPP) in accordance with the guidance contained in DOE Order 5400.1 (DOE, 1990a); DOE Order 5400.5, Radiation Protection of the Public and Environment; and the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T, 1991). (Note: Draft 10 CFR 834, Radiation Protection of the Public and Environment is expected to be finalized in 1996 and will replace DOE Order 5400.5). The WIPP project is operated by Westinghouse Electric Corporation, Waste Isolation Division (WID), for the DOE.

This plan defines the extent and scope of the WIPP effluent and environmental monitoring programs during the facility's preoperational and operational life. This document also discusses the WIPP's quality assurance/quality control programs as they relate to environmental monitoring.

This plan provides a comprehensive description of environmental activities at WIPP including:

- A summary of environmental programs including the status of environmental permits and monitoring activities (Section 1.0);
- A description of the WIPP project and its mission (Section 2.0);
- A description of the local environment including demographics (Section 3.0);
- An overview of the methodology used to assess radiological consequences to the public including brief discussions of potential exposure pathways, routine and accidental releases, and their consequences (Section 4.0);
- A summary of preoperational environmental monitoring and assessment activities (Section 5.0); and
- Responses to the requirements described in the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T).

This document extensively references DOE Orders and other federal and state regulations affecting environmental monitoring programs at the site. WIPP procedure manuals, which implement the requirements of this program plan, are also referenced.

The DOE regulates its own activities for radiation protection of the public under the authority of the Atomic Energy Act of 1954, as amended. The effluent and environmental monitoring activities prescribed by DOE Order 5400.5 and the DOE/EH-0173T guidance manual are designed to ensure that DOE facilities collect the information required to estimate potential and actual radiation doses to the surrounding population. Effluent and environmental monitoring also provide the data necessary to demonstrate compliance with applicable environmental protection regulations.

Other federal agencies, such as the U.S. Environmental Protection Agency (EPA), are empowered through specific legislation to regulate certain aspects of DOE activities potentially affecting public health and safety or the environment. Presidential Executive Order 12088, *Federal Compliance with Pollution Control Standards*, requires the heads of executive agencies to ensure that all federal facilities and activities comply with applicable pollution control standards and to take all necessary actions for the prevention, control, and abatement of environmental pollution.

Beyond statutory requirements, the DOE has established a general environmental protection policy. The "Environmental Policy Statement (issued by then Secretary Herrington on January 8, 1986, and extended on January 7, 1987) describes the DOE's commitment to national environmental protection goals by conducting operations "in an environmentally safe and sound manner . . . in compliance with the letter and spirit of applicable environmental statutes, regulations, and standards" (DOE, 1986a). This Environmental Policy Statement also states the DOE's commitment to "good environmental management in all of its programs and at all of its facilities in order to correct existing environmental problems, to minimize risks to the environment or public health, and to anticipate and address potential environmental problems before they pose a threat to the quality of the environment or public welfare." Additionally, "it is DOE's policy that efforts to meet environmental obligations be carried out consistently across all operations and among all field organizations and programs" (DOE, 1986a).

The WIPP complies with the terms of the Agreement for Consultation and Cooperation established in 1981 with the State of New Mexico. This agreement, required by the federal legislation which authorized the WIPP project (Public Law 96-164, 1980), specifies that DOE notify the State of New Mexico prior to commencement of key events. The Supplemental Stipulated Agreement requires DOE to provide the State with sufficient information to conduct an independent review of WIPP activities.

The 1992 WIPP Land Withdrawal Act (LWA), Public Law 102-579, requires the DOE to prepare and implement a Land Management Plan and Memorandum of Understanding with the Bureau of Land Management (BLM). The primary objectives of the Land Management Plan are to identify resource values, promote multiple-use management, and identify long term goals for the management of WIPP lands through the decommissioning phase.

Environmental activities at the WIPP project generally fall into three categories: (1) the performance of analyses and preparation of documents to address DOE requirements, as well as applicable regulations of the EPA and other federal and state agencies; (2) the conduct of environmental studies to monitor site impacts; and (3) the implementation of measures to mitigate adverse impacts.

A number of provisions taken to mitigate potential environmental impacts appear in Statements of Work issued to all contractors involved in the construction of the WIPP facility. These provisions are listed below:

- Protection of environmental resources including the avoidance of unnecessary damage to vegetation, wildlife, and soil by controlling traffic, minimizing disturbance zones, and cleaning up spills.

- Protection of air resources including the control of hydrocarbon emissions by using proper fuels, the suppression of dust by spraying with water, and the monitoring and control of noise.

- Protection of water resources including the use of retention ponds for controlling suspended materials, solutes, and other pollutants.

- Preservation and recovery of historical, archaeological, and cultural resources including the interruption of construction activities as necessary to investigate and mitigate impacts to historical or archaeological resources.

- Post-construction cleanup including the removal of temporary construction facilities, haul roads, stockpiles, and work areas, as well as the restoration of all damaged landscape features outside the limits of approved work areas.

WIPP must also comply with specified permitting and approval requirements of several federal and state regulating agencies. A database is maintained of all required permits, notices, and approvals which apply to the WIPP project. This database enables environmental personnel to anticipate commitments such as renewal dates, fee payments, and reclamation requirements. This database is updated and published annually in the WIPP Site Environmental Report (SER).

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2.0 PROJECT DESCRIPTION

The purpose of WIPP is to provide for disposal of transuranic waste by establishing an effective system for management of transuranic waste from generation to disposal. This program only applies to transuranic (TRU) waste generated by the defense activities of the U.S. Government.

The preoperational radiological and ecological environmental monitoring programs were detailed in earlier documents entitled: *Radiological Baseline Program for the Waste Isolation Pilot Plant* (Reith and Daer, 1985) and *Ecological Monitoring Program for the Waste Isolation Pilot Plant, Semi-annual Report* (Reith et al., 1985). A summary of those programs is presented in Section 5.0 of this document. The environmental monitoring program continues the established preoperational environmental monitoring efforts as appropriate and adds monitoring of the airborne and liquid effluent discharges. Details regarding the design and operation of the WIPP facility are in the Safety Analysis Report (SAR) (DOE/WIPP-95-2065 REV.0, 1995).

Both contact handled (CH) and remote handled (RH) waste will be received and disposed of at the WIPP facility. CH waste consists of TRU waste that has a relatively low surface dose rate and therefore lends itself to direct handling. RH waste is TRU waste that, due to higher levels of penetrating radiation, must be shielded and handled remotely. Waste will be classed as CH or RH based on whether surface dose rates are less than or greater than 200 mrem/hr, respectively. TRU waste is radioactive waste that, without regard to source or form, is contaminated with alpha-emitting TRU radionuclides having atomic numbers larger than 92 and half-lives longer than 20 years in concentrations greater than 100 nanocuries per gram of waste. The CH and RH waste contain both alpha and beta-gamma emitting nuclides. Isotopes of plutonium, americium, and curium will be the predominant radionuclides contaminating the TRU waste. The waste will be in a variety of forms such as concrete stabilized sludges, decommissioned machine tools, glove boxes, etc. All wastes received by the WIPP will be restricted to those that meet specific Waste Acceptance Criteria (WAC Rev. 5) which prohibit pressurized gases and explosives, and limits free liquids to less than one percent of the volume of each container. General criteria defining the various categories of radioactive waste, including TRU waste, appear in DOE Order 5820.2A and DOE/AL Order 5820.2. A portion of the waste that will be emplaced will also be contaminated with hazardous materials. The hazardous waste component is subject to regulation by the NMED under the Resource Conservation and Recovery Act (RCRA), and consists largely of toxicity characteristic metals, halogenated organic compounds, and nonhalogenated organic compounds.

Waste will be delivered to the WIPP Waste Handling Building (WHB) via semi-trailer trucks. CH wastes will arrive in shipping packages known as TRUPACT IIs (TRansUranic PACkage Transporters). TRUPACT IIs are durable, Type B, Nuclear Regulatory Commission (NRC) certified transport containers, designed to accommodate both waste boxes and drums. The DOE has received a certificate of compliance from the NRC for use of the TRUPACT II. Remote-handled transuranic (RH TRU) wastes will be packaged in waste canisters and shipped to WIPP in special transportation casks. The remote-handled casks are awaiting NRC approval.

The disposal rooms prepared for the waste have been excavated from the Salado Formation, a thick sequence of salt beds deposited 250 million years ago (Permian age). The disposal horizon is located at a depth of 655 meters (2,150 feet). Once waste containers are removed from the TRUPACT II, they are secured to a transport pallet and then within the WHB placed on the waste-handling hoist, and lowered to the disposal horizon. Waste containers will then be removed from the hoist and emplaced within the disposal rooms. Eventually, specially designed seals and closure systems will be placed in the excavated shafts and in the drifts. Geologic pressures and the plasticity of the salt will result in the excavation's gradual closure due to creep. This closure will encapsulate and isolate any waste within the Salado formation.

The underground area is ventilated by air entering via the Salt Handling, Air Intake, and Waste Handling Shafts and exiting through the Exhaust Shaft. In the event of an accident involving waste in the underground, air from the Exhaust Shaft will be directed, at a reduced flow rate, through the Exhaust Filter Building containing banks of high efficiency particulate air (HEPA) filters in order to remove potentially contaminated particulates. Exhaust ventilation from the WHB is continuously HEPA filtered and is not expected to represent a significant release point. Effluent monitoring is discussed in Chapter 5.0.

3.0 SITE CHARACTERISTICS

3.1 GEOGRAPHY

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 3-1) within the Pecos Valley section of the southern Great Plains physiographic province (Powers et al., 1978). The site is 42 km (26 miles) east of Carlsbad in an area known as Los Medaños (the dunes). Los Medaños is a relatively flat, sparsely inhabited plateau with little surface water.

The WIPP site (Figure 3-2) consists of 16 sections of federal land in Township 22 South, Range 31 East. The 16 sections of federal land were withdrawn from the application of public land laws by the WIPP Land Withdrawal Act (LWA), Public Law 102-579, that was signed on October 30, 1992. The LWA transferred the responsibility for the administration of the 16 sections from the Department of Interior, Bureau of Land Management, to the Department of Energy. This law specified that mining and drilling for purposes other than support of the WIPP project are restricted within this 16 section area with the exception of Section 31. Oil and gas activities are restricted in Section 31 from the surface down to 6,000 feet.

3.2 GEOLOGY

Los Medaños soils are sandy and well drained with a well developed caliche layer occurring below one meter. There are no integrated natural surface drainage features at the site. Scattered throughout the local area are numerous livestock watering ponds (tanks) and seasonally wet, shallow lakes (playas) which are located approximately seven miles southwest of the site. Geologically, the site is located in the northern portion of the Delaware Basin, one of the western--most sedimentary basins known collectively as the Permian Basin. Approximately 3,960 meters (13,000 feet) of strata are present in the Delaware Basin (Bachman, 1984) including hundreds of meters of evaporite sequences composed in part of halite, anhydrite, and gypsum. Figure 3-3 illustrates the local stratigraphy.

3.3 CLIMATOLOGY

Regional climate is semi-arid with generally warm temperatures. Approximately 31 centimeters (12 inches), is the average annual precipitation amount. About half of the precipitation is received from June through September in the form of high intensity-short duration thunderstorms. Daytime summer temperatures consistently exceed 32°C (90°F) and often rise above 38°C (100°F). Winter temperatures often rise as high as 21°C (70°F) during the afternoon. Night time lows during winter average near -5°C (23°F), occasionally dipping below -10°C (14°F). Prevailing winds are from the southeast; however, strong winds are common and can blow from any direction creating potentially violent windstorms which carry large volumes of dust and sand. The wind test data have remained essentially the same from year to year. Detailed compilations of climatic data have appeared in the Ecological Monitoring Reports (Fischer et al., 1985; 1987) and in the Annual Site Environmental Reports for calendar years 1988, 1989, 1990, 1991, 1992, 1993, 1994, and 1995 (DOE/WIPP 89-005, DOE/WIPP 90-003, DOE/WIPP 91-008, DOE/WIPP 92-007, DOE/WIPP 93-017, DOE/WIPP 94/2033, DOE/WIPP 95-2094 and DOE/WIPP 96-2182, respectively). Additional climatic information appears in the Final Environmental Impact Statement (FEIS) (DOE, 1980), Final Supplement Environmental Impact Statement (SEIS) (DOE, 1990d), and the SAR (DOE, 1995).

3.4 HYDROLOGY

Surface water is absent at the WIPP site. The nearest large surface water body, Laguna Grande de la Sal, is located approximately 13 kilometers (8 miles) west-southwest of the WIPP site in Nash Draw where shallow brine ponds occur. The Pecos River is located 22.4 kilometers (14 miles) southwest of the WIPP site.

Several water-bearing zones have been studied near the WIPP. The most significant are the Culebra and Magenta Members of the Rustler Formation, which consist primarily of fractured dolomite. These dolomite units produce brackish to saline water. Another saline water-bearing zone identified is the Rustler-Salado contact, which contains very little water at the WIPP site.
It was exposed during shaft construction and produced only a small amount of brine seepage. Other water bearing zones that have been evaluated as part of site characterization include the Dewey Lake Redbeds and the overlying Triassic Dockum Group, the Bell Canyon and Castile Formations.

The Dewey Lake Formation, which contains limited amounts of potable water, is comprised of alternating thin, even beds of siltstone and mudstone with lenticular interbeds of fine-grained sandstone. Exploratory drilling during site hydrogeologic evaluation did not identify a continuous zone of saturation within the Dewey Lake. The few Dewey Lake wells yielding water for domestic and stock purposes are believed to be completed in the thin, discontinuous lenticular sands where favorable groundwater recharge occurs (Mercer, 1983). A more complete discussion of both the regional and site-specific groundwater hydrology is contained in the WIPP SAR.

3.5 ECOLOGY

The biota of Los Medaños represent a transition between the northern Chihuahuan Desert and the southern Great Plains. The soils at the site include sandy surface soils with wind-blown particles, a thin soil crust, and a layer of moist subsoil. These sandy soils form stabilized coppice dunes interspersed with swales.

Shrubs and grasses are the most prominent components of the local flora. The development of specific plant communities is dependent on such factors as the infiltration rate of the surface soil, depth to a restrictive layer (e.g., caliche), and the extent to which the surface soil has been reworked by wind or water erosion. The area is dominated by the shinnery oak, mesquite, sand sage, and perennial grasses. Typical grassland and shrubland species dominate the fauna of the area. The primary mammals found at the site include the lagomorphs (rabbits and hares), desert mule deer, desert dwelling rodent species, and carnivore species such as the coyote, gray fox, badger, and striped skunk.

A large variety of bird species are also found in the region. The following avian species are present in greatest densities: scaled quail, mourning dove, mocking bird, loggerhead shrike, pyrrhuloxia, black-throated sparrow, western meadowlark, the lark bunting, vesper sparrow, Cassin's sparrow, and the white-crowned sparrow. The Harris hawk, the Chihuahuan raven, Swainson's hawk, the Northern Harrier, and the American kestrel are also found at the site.

There have been 29 species of amphibians and reptiles observed in the site vicinity. Characteristic reptiles in the region include the western box turtle, side-blotched lizard, western whiptail, bullsnake, and prairie rattlesnake. The representative amphibians are the tiger salamander, green toad, and plain's spadefoot.

A brief summary of the ecological baseline surveys appears in Appendix H of the FEIS (DOE, 1980). If there are any changes observed in the area ecology they will be noted in the WIPP SERs.

3.6 DEMOGRAPHY

There are 26 permanent residents at various locations within 10 miles of the WIPP site. Most of the population within 50 miles of the WIPP site is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal and Artesia, New Mexico. The nearest community is the village of Loving, New Mexico, 18 miles west-southwest of the center of the WIPP site. The population of Loving decreased from an estimated 1,600 in 1980 to 1,243 in 1990, the year of the latest census. The nearest major population center is the city of Carlsbad, New Mexico, 26 miles west of the WIPP site. The population of Carlsbad has increased from an estimated 28,600 in 1980 to an estimated 29,500 in 1990. The population within 10 miles of the WIPP site is associated with ranching, oil/gas well activities, and potash mining. These levels fluctuate depending on the manpower needs of these businesses.

The nearest residents to the site include eight individuals living at the Mills Ranch, 5.8 km (3.5 miles) south-southwest of the center of the site, and two individuals living at the Smith Ranch, 10 km (6 miles) west-northwest of the center of the site (DOE/WIPP 93-017). Both neighboring ranches have been and will continue to be monitored as part of WIPP's environmental surveillance program. Detailed demographic summaries and projections are in the WIPP SEIS (DOE, 1990d) and WIPP SAR (DOE, 1995).

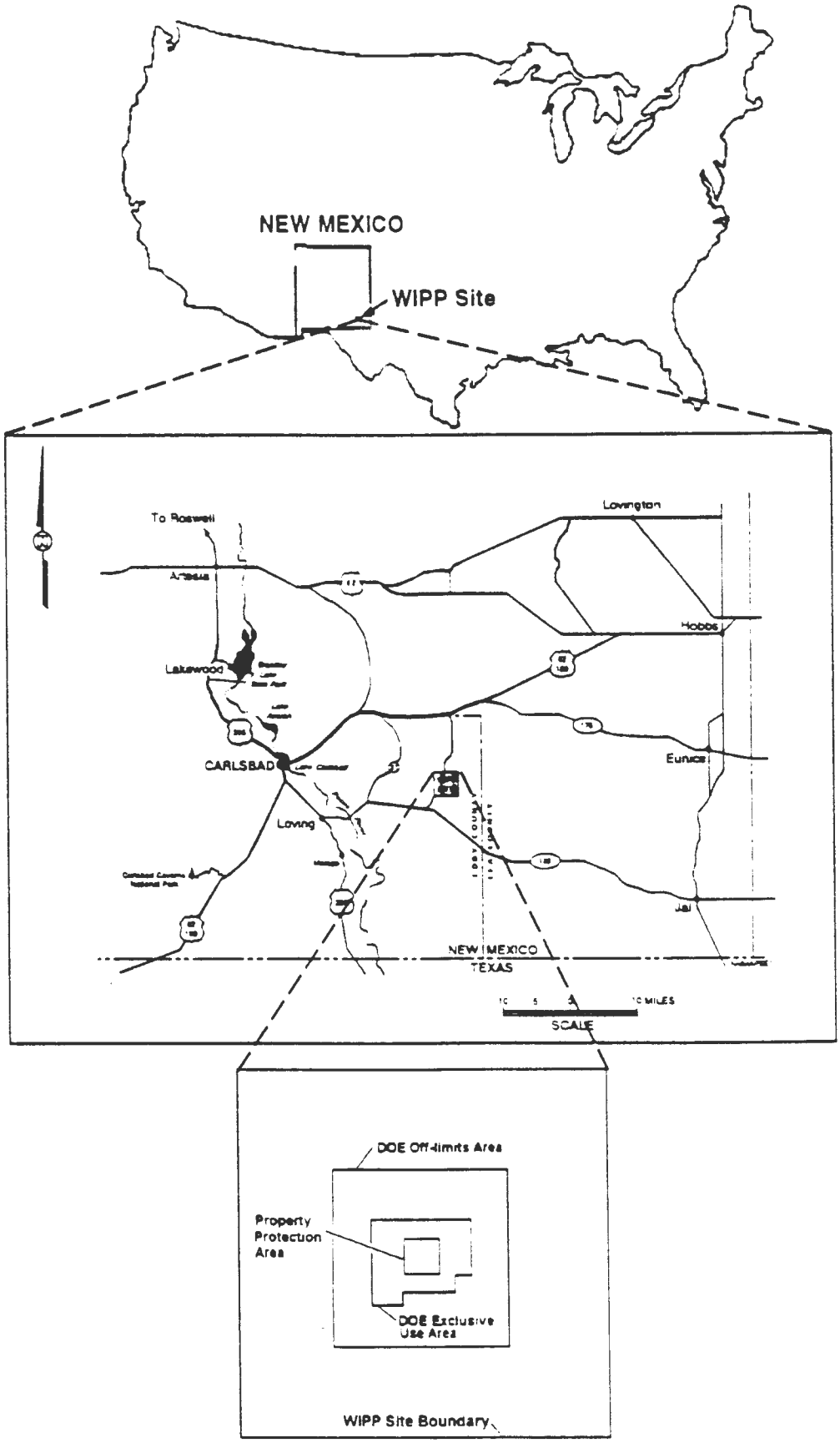


Figure 3-1 Location of the WIPP Site

896B:1806g

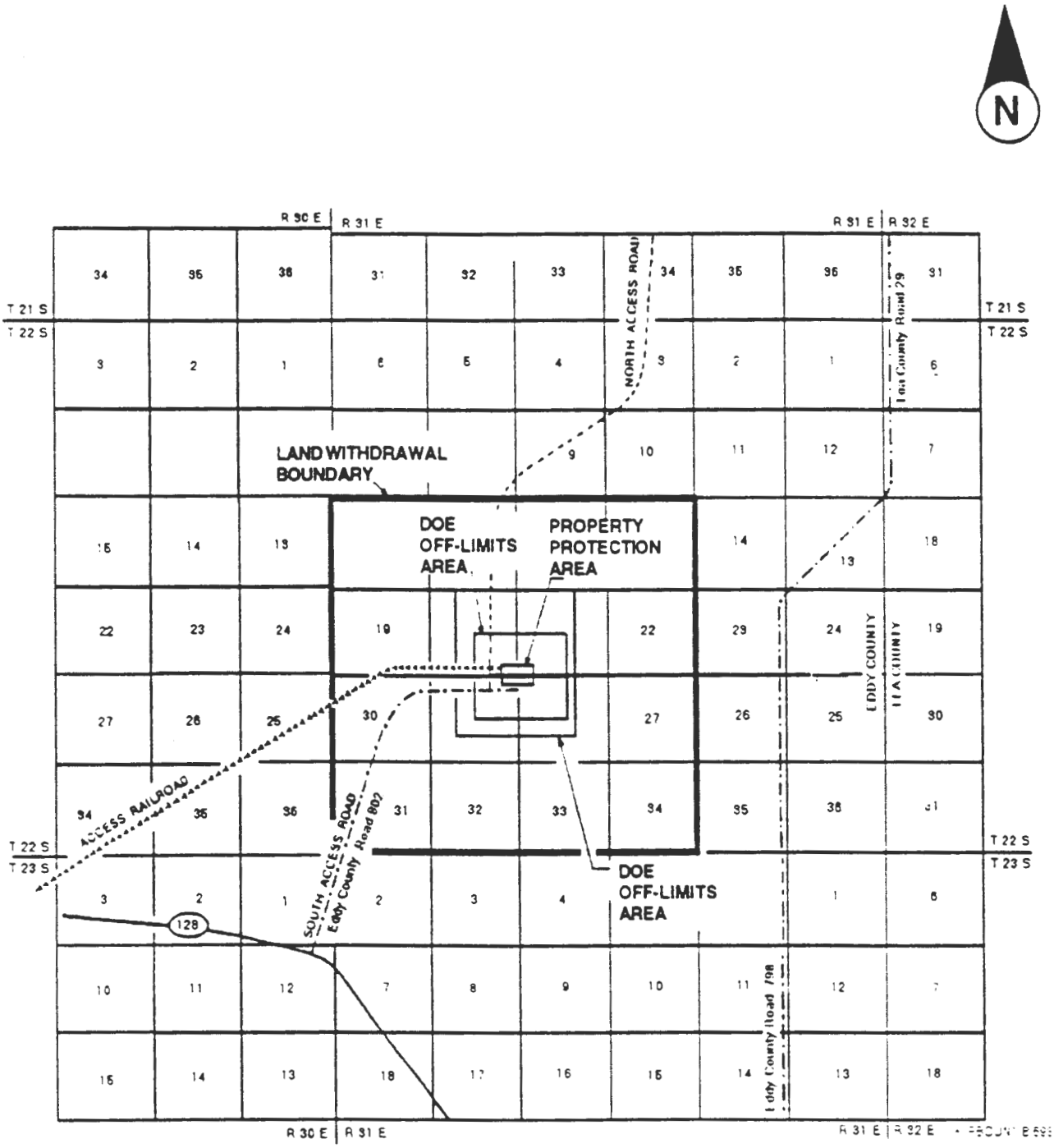
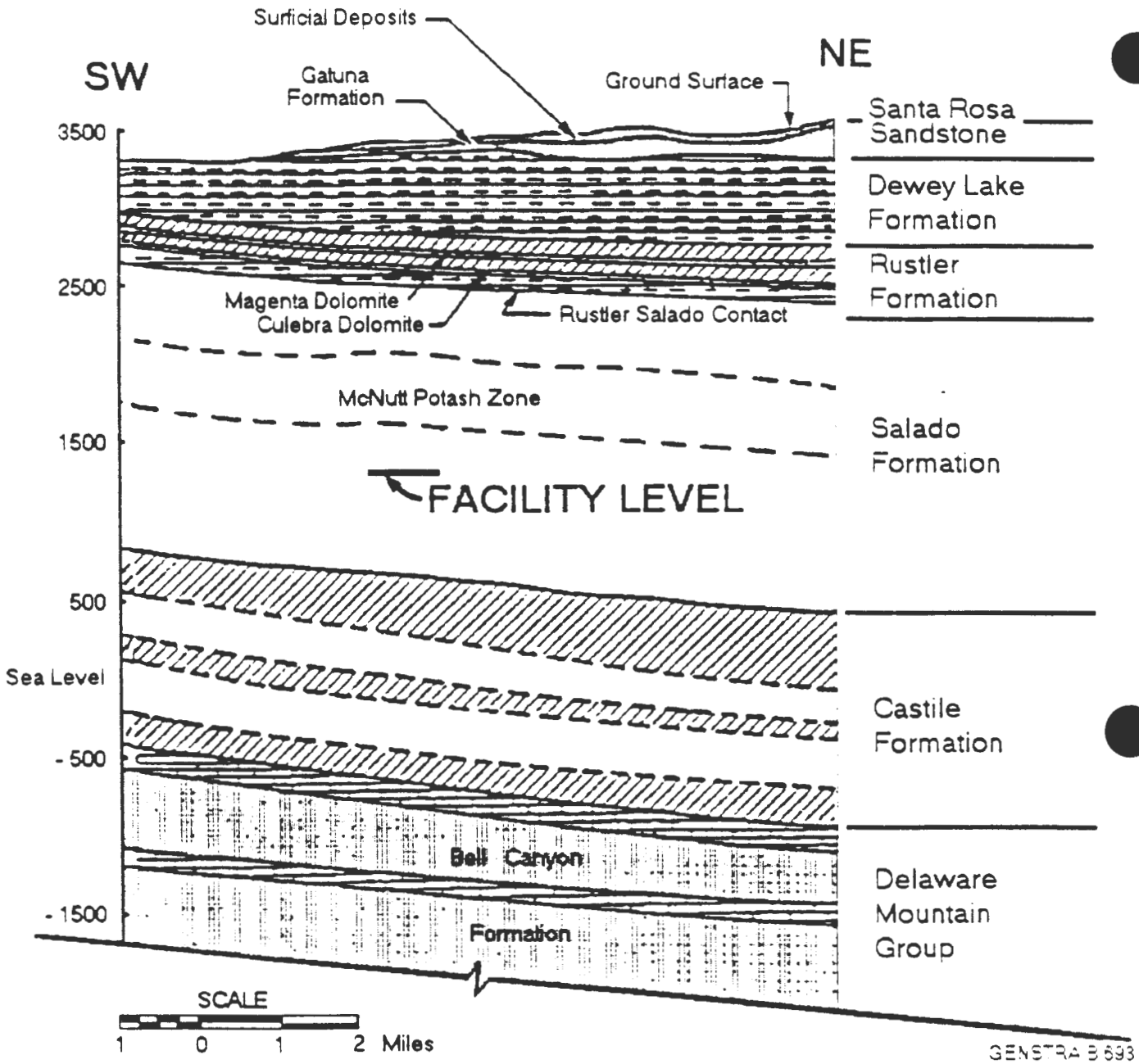


Figure 3-2 Plat of WIPP Site



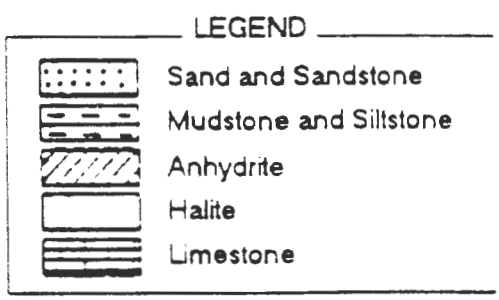


Figure 3-3 Generalized Stratigraphy of the WIPP Site

4.0 DOSE CALCULATIONS

This section is typically written to discuss dose calculations involving on and off site dose assessment. As stated in sections *7.1.4.1 On-Site Dose Assessment* and *7.1.4.2 Off-site Dose Assessment* of the WIPP Safety Analysis Report (DOE/WIPP-95-2065 Rev. 0); "Therefore, WIPP normal operations do not involve or entail any planned or expected releases of airborne radioactive materials."

Due to the current interpretation of requirements affecting dose calculations with respect to WIPP activities, this updated Environmental Monitoring Plan has all calculations and associated discussions relating to radiological dose assessment removed to comply with the current version of the WIPP SAR.

Nonradiological consequences to members of the public associated with potential airborne chemical releases from the WIPP facility during normal operations are expected to be *de minimus*. This expectation is based on (1) extensive site exposure measurements and calculations which indicate that employee exposures are being maintained well below Occupational Safety and Health Administration Permissible Exposure Limits (as stipulated in 29 CFR 1910.1000), (2) all chemicals used on site must receive approval prior to purchase, with approval based on the minimization of personnel exposure and environmental impact, and (3) the site Nonradiological Environmental Program which has been monitoring for nonradiological emissions from the time of the site's inception with no indication of environmental impact.

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5.0 ENVIRONMENTAL MONITORING PROGRAM

As required by DOE Order 5400.1, each facility is required to perform a "preoperational study to begin not less than one year, and preferably two years before start-up to evaluate seasonal changes." The DOE WIPP is complying with this requirement by compiling preoperational radiological and non-radiological environmental data. The environmental data is published annually in the Site Environmental Report.

An analysis of the historical preoperational data is contained in the following documents: 1) *Statistical Summary of the Radiological Baseline for the WIPP*, (DOE/WIPP 92-037), 2) *Summary of the Salt Impact Studies at the WIPP, 1984 to 1990*, (DOE/WIPP 92-038), 3) *A Study of Disturbed Land Reclamation Techniques for the WIPP*, (DOE/WIPP 92-039), and 4) *Background Water Quality Characterization Report for the WIPP*, (DOE/WIPP 92-013).

The environmental sampling programs used to establish the preoperational study were originally defined in Chapter 5 of the OEMP (DOE/WIPP 88-025). The OEMP was updated in 1994 into the WIPP Environmental Monitoring Plan (EMP) (DOE/WIPP 94-024). This is an update of the 1994 EMP. This plan describes the current environmental monitoring efforts at the WIPP as the project moves from the predisposal phase into the disposal phase. An additional change in this updated EMP is the inclusion of *7.1.4.1 On-Site Dose Assessment* and *7.1.4.2 Off-site Dose Assessment* of the *WIPP Safety Analysis Report (DOE/WIPP-95-2065 Rev. 0)*, that states, "Therefore, WIPP normal operations do not involve or entail any planned or expected releases of airborne radioactive materials." With the inclusion of this referenced document, the environmental monitoring data being collected is being compiled to broaden the radiological baseline in the WIPP vicinity and could be used as a confirmatory tool used to quantify unplanned radiological occurrences.

The Westinghouse, Waste Isolation Division (WID) Environmental Monitoring Section at the WIPP is administered by the Environment, Safety, & Health Department to ensure compliance with pertinent environmental regulations as required by DOE Order 5400.1. DOE Order 5400.1 states that environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on-site and off-site. An environmental surveillance program shall be undertaken at DOE sites to determine the need for a permanent surveillance program. In addition, environmental surveillance programs and components should be determined on a site-specific basis by the field organization. These programs should not be considered static but flexible to allow for samples of opportunity and conversely, not to collect samples if circumstances warrant cancellation of a sampling activity. Programs should reflect facility characteristics; applicable regulations; hazard potential; quantities and concentrations of materials released; the extent and use of affected air, land, biotics, and water; and specific local public interest or concern (DOE, 1990a).

5.1 GUIDELINES

Under the Atomic Energy Act of 1954, as amended, the DOE is obligated to regulate its own activities so as to provide radiation protection for both workers and the public. Presidential Executive Order 12088, *Federal Compliance with Pollution Control Standards*, further requires the heads of executive agencies to ensure that all Federal facilities and activities comply with applicable pollution control standards and to take all actions necessary for the prevention, control, and abatement of environmental pollution.

It is the policy of the DOE to conduct effluent monitoring and environmental surveillance programs that are appropriate for determining adequate protection of the public and the environment during DOE operations and to assure that operations are in compliance with DOE and other applicable Federal, State, and local radiation standards and requirements. It is also DOE policy that departmental monitoring and surveillance programs be capable of detecting and quantifying unplanned releases, while meeting high standards of quality and credibility. It is DOE's objective

that all DOE operations properly and accurately measure radionuclides in effluent streams and in the ambient environmental media.

A Guide for Environmental Radiological Surveillance at DOE Installations, (DOE/EP-0023) (Corley et al., 1981) states that the factors which should be considered in determining the relative level of environmental surveillance required at a facility include:

(1) the potential hazard of the materials released, considering both expected quantities and relative radiotoxicities;

(2) the extent to which facility operations are routine and unchanging;

(3) the need for supplementing and complementing effluent monitoring;

(4) the size and distribution of the exposed population;

(5) the cost-effectiveness of increments to the environmental surveillance program; and

(6) the availability of measurement techniques which will provide sufficiently sensitive comparisons with applicable standard and background measurements.

The above guidance, the risk analysis in the WIPP SAR, and the dose criteria in DOE Order 5400.5 indicate that operational dose estimates for the WIPP are significantly below dose criteria. However, the purpose of the WIPP is to demonstrate that the long-term disposal of TRU waste in bedded salt can be accomplished safely, and that the natural environment will not be significantly impacted as a result of the construction and operation of the disposal facility. The WIPP EMP encompasses a comprehensive set of parameters that detect environmental impacts. As required in DOE Order 5400.1, the EMP is reviewed annually and updated every three years. The EMP scope and intensity is adjusted in response to changing facility processes, environmental parameters, and program results.

Parameters measured include environmental radiation analysis of air, surface and groundwater, sediments, soils, and biotics, the status of the local biological community, and groundwater quality measurements. Nonradiological portions of the program focus on the immediate area surrounding the site, whereas radiological surveillance generally covers a broader geographical area including nearby ranches, villages, and cities. Environmental monitoring will continue at the site during project operations and through decommissioning and beyond for 2-5 years in accordance with the *Agreement for Consultation and Cooperation between the Department of Energy and the State of New Mexico*.

The goal of the environmental monitoring program is to determine if the local ecosystem has been impacted during the predisposal and disposal phases of the WIPP, and if so, to evaluate their severity, geographic extent, and environmental significance. Tables 5-1 and 5-2 summarize the EMP sampling schedule and analytical array. These tables list the sample types, number of sampling stations, approximate sampling schedule and the environmental/ecological parameters monitored or analyzed. It is important to emphasize the need for flexibility in the design and implementation of the EMP. Additional or different types of samples will be collected and analyzed as necessary to investigate and explain trends or anomalies that may have a bearing on the WIPP's environmental impacts. Baseline conditions were initially characterized by the Radiological Baseline Program (RBP) and summarized in the Statistical Summary of the Radiological Baseline for the WIPP (DOE/WIPP 92-037). The RBP will continue until first waste receipt at which point it will become an operational monitoring program. Environmental and ecological sampling during operations will be adjusted to fit the needs of the project.

As recommended in DOE/EH-0173T, the EMP provides the guidance for monitoring levels of naturally occurring radionuclides, those associated with world-wide fallout, and those expected in the WIPP wastes. The geographic scope of radiological sampling is based on projections of potential release pathways for the types of radionuclides in the WIPP wastes. Also, the surrounding population centers are monitored even though release scenarios involving radiation doses to residents of those population centers are improbable. Ecological sampling activities may be performed at the permanent ecological monitoring plots. These sampling locations are unchanged from those reported in the OEMP.

Sampling and related activities (sample logging, packaging, and shipping) are conducted in accordance with the procedures and instructions described in the WIPP Procedures. Standard sampling practices and techniques are used (see Section 6.0). Samples sent off site are analyzed by a commercial laboratory.

Sample splits are made available to the Environmental Evaluation Group (EEG) and the NMED. The EEG has developed and implemented an environmental monitoring program at WIPP which provides independent verification of the WIPP's environmental monitoring results. The EEG environmental surveillance program has provided independent data verification for the WIPP Project during the preoperational phase to date. Historically, NMED oversight at the WIPP has included independent verification of environmental sampling, effluent and spill sampling, oversight of cleanup and environmental restoration activities, data validation/verification, and comprehensive program evaluations.

The Carlsbad Environmental Monitoring and Research Center, operated by New Mexico State University, is a research organization which also conducts independent environmental monitoring in the WIPP vicinity. The Center currently operates one underground and two surface aerosol monitoring sites at the WIPP. Studies are now being conducted to determine the size distribution for atmospheric aerosols as well as their chemical and radionuclide composition. The results of these studies will provide the basis for identifying the various sources of atmospheric aerosols (e.g., oil and gas, potash mining, soil, and WIPP).

Quality assurance/quality control has been established within the framework of the overall WID Quality Assurance Manual (WP 13-1) and is described in Section 8 of this EMP. When the WIPP data are received, they are evaluated and presented in the WIPP Site Environmental Report.

5.2 SITE CHARACTERIZATION

Characterization studies were initiated to begin evaluating the adequacy of the site as a long-term repository and to obtain information necessary for modeling. These earlier studies have influenced the current WIPP environmental monitoring efforts described below.

5.2.1 WIPP Biology Program

The WIPP Biology Program (Best and Neuhauser, 1980) began in August 1975 with baseline studies of climate, soils, vegetation, arthropods, and vertebrates. The program was expanded in late 1977 to include studies of floristics, primary productivity, plant succession, microbial biogeochemistry, and the aquatic ecosystem of the lower Pecos River. The major objectives were: 1) to acquire baseline data on the WIPP environment, including information for environmental documentation; 2) to provide data useful in the determination of possible radionuclide pathways between the WIPP facility and humans; and 3) to aid in the establishment of a long-term ecological monitoring program.

In 1980, the program was re-oriented to emphasize studies that would help predict specific environmental impacts associated with construction and operations. Soils were experimentally

treated with salt, and plants were trampled and grazed in order to make quantitative predictions of the effects of these potential impacts. The effects of salt on population of arthropods and decomposition of leaf litter were also studied because of the relatively high sensitivity of these ecosystem components and processes as possible indicators of chemical impacts.

5.2.2 United States Geological Survey (USGS) Studies

Oak Ridge National Laboratory (ORNL) and the USGS jointly selected the northern portion of the Delaware Basin as a general location for waste disposal in early 1972. Following the initial site selection the USGS began regional geologic investigations. Their research documented naturally occurring radionuclide levels in subsurface water of the three major members of the Rustler Formation. Data on gross alpha/beta, radium, and uranium levels in each member from a total of 20 well locations were obtained (USGS, 1983). Also, the USGS maintains a routine surface sampling program on the Pecos River (USGS, 1978-1984). Summaries of the USGS mineral, petroleum, and geohydrology studies are presented in the WIPP FEIS (DOE, 1980).

Additionally, Columbia University personnel under Nuclear Regulatory Commission (NRC) contract performed a study of radionuclide mobility in the highly saline groundwater of the Delaware Basin, which is the area underlying the WIPP (Simpson et al., 1985). This study documented radium, uranium, thorium, and plutonium levels in groundwater and surface waters of the Delaware Basin. A summary of the data from the Columbia University study is presented in Bradshaw and Louderbough (1987).

5.3 RADIOLOGICAL ENVIRONMENTAL MONITORING

The operational environmental surveillance program will be continued, with some modifications of the preoperational program and parameters monitored during the RBP and Ecological Monitoring Program. Each sampling subprogram of the EMP is described below.

5.3.1 Effluent Monitoring - Liquid Releases

DOE Order 5400.5 is the DOE driver that sets dose limits and requires monitoring of liquid effluent streams. The *Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T) is the guidance document that sets the standard for meeting the requirements of DOE order 5400.5. Liquid effluent monitoring is necessary to quantify radionuclides released to the environment and to alert operators of process inconsistences and malfunctions of emission controls.

The only credible source of waste-generated liquid contamination at the WIPP is the Waste Handling Building (WHB). There is no direct connection between the WHB and the sewage treatment system; therefore, there is no direct pathway for radioactive or hazardous contaminants associated with the TRU wastes to enter the WIPP sewage treatment system. There is a sump in the WHB that collects liquids from throughout the WHB. Should there ever be any liquid accumulation in the sump as a result of a waste package release or subsequent fire-suppression water collection, the water in the sump will be sampled and analyzed for contamination as shown in Table 5-2. The following would then be performed in order to assure proper management of the waste:

- If the fire water is radioactive, it will be assumed to be TRU mixed waste and will be managed as derived waste. Solidification will occur as the water is transferred to the derived waste drum. Characterization will be in accordance with the WIPP Resource, Conservation, and Recovery Act Part B Permit Application.

- If the fire water is nonradioactive, a determination will be made if the water is hazardous waste. The determination will include sampling and analysis. Any waste determined to be nonradioactive hazardous waste will be managed in accordance with WIPP facility procedures for such waste.

- If the fire water is nonhazardous, as described in the New Mexico Environment Department (NMED) Discharge Plan for the WIPP (DP-831), it will be discharged to the WIPP facility sewage lagoon.

If the sump contents are radioactive or hazardous, or both, the WIPP will remove and solidify the contents of the sump.

The WIPP sewage treatment system is a zero discharge facility made up of parallel synthetically lined settling and polishing cells that gravity flows treated effluent into a chlorination system, and then flows through lined evaporation ponds. The berm that surrounds the sewage lagoon is designed to eliminate storm water inflows and potential discharges. The facility is designed to contain a 100 year/24 hour storm event. The facility is designed to accommodate normal sewage effluent and to provide for disposal of nonhazardous waters. Brine waters discharged into the sewage evaporation basin result from observation well pumping around the WIPP site.

Although the sewage treatment facility is a zero discharge facility, when it was expanded in 1993 the NMED required that a Discharge Plan be prepared which would stipulate monitoring requirements for water quality, and effluent volume.

WIPP procedure WP 02-EM1001, *Sewage Discharge Monitoring* incorporates the requirements of the Discharge Plan. Sewage system effluent water samples are collected quarterly from the primary settling ponds and evaporation ponds. Samples are analyzed for Nitrates (NO_3), Total Kjeldahl Nitrogen (TKN), Total Dissolved Solids (TDS), and Radium 226 and 228.

The WIPP also conducts oversight sampling twice annually for ammonia, total metals, dissolved metals, chemical oxygen demand, cyanide, total organic compounds, oil/grease, phenols, pesticides, semi-volatiles, volatiles, pH, hexavalent chromium, total suspended solids, and total dissolved solids.

The level of sludges accumulating in the sewage system are monitored by WID operations as part of routine maintenance. If sludges accumulate in the sewage lagoon to a level that could impact facility storage capacity, representative samples of the solids will be collected and analyzed for the parameters defined in 40 CFR 503, *Standards for the use or Disposal of Sewage Sludge*. Based on the analytical results, the sludge will be managed and disposed in accordance with 40 CFR Part 503.

The drinking water supplied to the WIPP is also sampled annually to monitor differences between the influent and effluent.

5.3.2 Effluent Monitoring - Airborne Emissions

Airborne effluent monitoring is especially important to the WIPP EMP. There are two potential sources of contaminated airborne emissions from the WIPP operations: releases generated above ground in WHB operations, and those generated underground that are released through the Exhaust Shaft (Figure 5-1). As recommended by DOE/EH-0173T both potential sources are sampled as appropriate.

Two effluent monitoring stations, A and B, sample exhaust from the underground operations. Sample extraction probes sample the unfiltered exhaust stream in the Exhaust Shaft (Station A), the filtered exhaust down stream of the Exhaust Filter Building (Station B), and the filtered exhaust of

the Waste Handling Building (Station C). The filtered exhaust passes through HEPA filter banks prior to reaching the sample extraction probes at Stations B and C.

Because significant concentrations of salt dust are potentially present in the airstream at Station A, standard isokinetic sampling probes have been demonstrated to be ineffective. Therefore, an anisokinetic, shrouded probe system has been designed, developed and tested specifically for use at the WIPP. The Station A sampling array is composed of the anisokinetic shrouded probe, a flow controlling device, and a sample-collection filter. Station B, in the Exhaust Filter Building, is configured similarly. The exhaust air from the WHB (Station C) is continuously routed through two stages of HEPA filters. After the air is filtered, it is sampled with an isokinetic sampling array connected to a flow-control and sampling system.

After Transuranic waste is received at the WIPP, filters (samples) from the fixed air samplers (FAS) systems at Stations A, B, and C will be collected (at two cubic feet per minute) each working day, and counted for gross alpha and gross beta activity. Selected effluent air samples will be analyzed for specific radionuclides (Table 5-2) on site or at an off-site lab if significant gross alpha or beta activity is indicated.

Gross alpha and beta counting are performed with gas-flow proportional counters. If a sample is counted and activity is recorded equal to, or less than 2.0 E^{-13} μCi/ml alpha, or 2.0 E^{-10} μCi/ml beta, (one-tenth of the Derived Air Concentration) then no action is required.

5.3.3 External Radiation

Continuous Exposure Rate Measurements

An assessment of the capabilities of the Reuter-Stokes with regard to the gamma source term of the WIPP bound transuranic waste indicates that such a dose-rate instrument would be ineffective for detecting a radiological release. The likelihood of detecting a release with the transuranic alpha emitters from air samples far exceeds the real-time dose rate capability of the Reuter-Stokes. Therefore, the decision was made to discontinue the Reuter-Stokes monitoring program.

5.3.4 Airborne Particulates

The WIPP SEIS identifies the atmospheric pathway as the most credible exposure pathway to the public from the WIPP. Therefore, airborne particulate sampling for alpha-emitting radionuclides is emphasized in the EMP. Air sampling results are used to trend environmental radiological levels and determine if there has been a deviation from established background radiological levels. The inhalation of airborne radionuclides, either directly from the source (facility) or from resuspension following deposition, may result in their uptake from the lung or the gastro-intestinal tract. Intake and subsequent distribution in the human body depends on the particle size and the chemical state of the radionuclide. DOE/EH-0173T and DOE/EP-0023 provide guidance on deployment, operations, and program management of an airborne particulate monitoring program.

DOE/EH-0173T recommends that:

> "Air sampling locations should be selected to represent radionuclide concentrations breathed by the population surrounding the nuclear facility. Selection of background sampling and measurement locations for air must be made with special care. For measurements to be compared with the effects of airborne releases, a minimum distance of 15 to 20 km from the larger sites and 10 to 15 km from the smaller sites in the least prevalent wind direction is suggested for background sampling.

> Off-site air samplers should be employed at each DOE site having potential airborne releases that could result in an annual effective dose equivalent greater than 1 mrem to the maximally exposed individual. Sample locations should include the following: a background or control location; locations of maximum predicted ground-level concentration from stack (or vent) releases, averaged over a period of 1 year where members of the public reside or abide; and locations in the nearest community within a 15-km radius of the site.
>
> The exact number of samplers will be determined by meteorology, demography, and the magnitude of projected doses to the surrounding population. Unless documented site-specific evidence exists to justify otherwise, the sample(s) at each air sampling station should be collected at a height of 2 m above ground level (approximately the height of inhalation for adults), in a location free from unusual localized effects or other conditions (e.g., in proximity to a large building, vehicular traffic, or trees) that could result in artificially high or low concentrations. Locations should be selected to avoid areas where large-particle (nonrespirable) fugitive dusts can dominate the sample (Ludwig 1976)."

A method similar to that developed (Waite 1973b) and evaluated by Waite (1973a) was used to determine the number of air sampling stations and their placement. Waite's method entails examining demographic and meteorologic data for the site to determine the distance to local population centers, their population, and the wind frequency distribution and weighing factors that are scaled to equal the desired number of sampling locations.

Low volume fixed air samplers (Lo-Vols) operating at two cubic feet per minute (0.056 cubic meters) are used to collect airborne particulates. As recommended in DOE/EH-0173T, the sample inlet probes are located approximately 2 meters (6.5 feet) above ground level in sites free from unusual micrometeorological or other conditions (e.g., proximity of large buildings, vehicular traffic) that could result in air concentration measurements that are artificially high or low. the inlets are configured to provide a minimum of 270 degree sample radius.

The current Lo-Vol sampling array (Figure 5-1) consists of seven sampling stations, the locations of which are based primarily on meteorological and demographic considerations and the need to provide as much continuity as possible between baseline and operational data. Lo-Vol samplers are at Carlsbad, Smith Ranch, Mills Ranch, WIPP South, WIPP East, and the WIPP Far Field sites. The original WIPP northwest location was discontinued due to its location being in a high vehicular traffic area. This location received heavy filter loading from dusts being resuspended by the traffic. One quality control sampler is rotated every quarter to a different sampling location to provide added assurance that the air samplers are operating consistently. As recommended in DOE/EH-0173T, a sampling station was added to incorporate a control site in the predominant upwind direction of the WIPP (the southeast control sampling location is approximately 12 miles southeast of the WIPP).

Lo-Vol filters are exchanged weekly, and after a 12-hour desiccation period, the loaded filters are weighed to calculate total suspended particulates. The filters are then transmitted to the WIPP radiochemistry counting laboratory and individually counted for gross alpha and beta activity. The filters are counted on a gas flow proportional counter with detection limits capable of ensuring compliance with regulatory standards. Quarterly composites of filters from each location undergo specific radionuclide analysis in accordance with Table 5-2.

Modifications have been proposed to the airborne emissions monitoring program. These changes would incorporate the use of continuous high volume (approximately 40 cubic feet per minute) air samplers around the WIPP site, and an increase in the number of sampling locations. Any changes implemented into the WIPP environmental air sampling program will be approved by the Carlsbad Area Office and discussed in the next updated EMP.

5.3.5 BIOTICS

Vegetation

Collection and analysis of vegetation samples serves three useful purposes: evaluating the potential radiation doses received by people consuming such vegetation; predicting the possible concentrations in meat, eggs, and milk from animals consuming contaminated forage (and resultant radiation doses to consumers of the animal products); and monitoring trends in environmental contamination and possible long term accumulation of radionuclides.

EMP vegetation samples are collected from the permanent locations where air samples and soil samples are collected (Figure 5-2). With multiple media samples collected at the same location, it provides for a broad environmental evaluation of a location with multi environmental media. In addition, if vegetable gardens are grown at the Smith and/or Mills Ranches, a leafy vegetable sample may be collected annually, and analyzed as specified in Table 5-2. Each sample will be collected as specified in the Environmental Procedures Manual (WP 02-3). Sufficient material will be collected to meet the needs of the analytical laboratory.

Beef/Deer

The WIPP SEIS indicates beef is not a significant pathway at the WIPP facility. Samples of tissues are not ideal indicator materials because of the time delay for transfer of radionuclides from the point of release through vegetation to muscle tissue. Therefore, frequent sampling of meat is normally required only when it is necessary to evaluate the radiation doses received via this foodstuff. With a few exceptions, radiation doses from ingestion of radionuclides are a measure of secondary importance.

Due to this secondary importance, the WIPP now only collects beef and deer samples on an as available basis. This is primarily through livestock and vehicle collisions on the roads in the WIPP vicinity. Therefore, the tissue and organ samples are collected only if they are easily attainable.

Quail, Rabbits, and Fish

As previously stated, muscle tissue is not a significant exposure pathway. However, DOE/EH-0173T indicates that game birds and mammals hunted locally should be sampled during the hunting season in the vicinity (within 25 km) of the site.

Rabbits and quail are collected annually on an "as available" basis. Quail are trapped at the facility, while rabbits are collected when found on roads in the WIPP site vicinity. A composite sample of muscle tissue from each type of animal is analyzed as shown in Table 5-2.

Fish are analyzed to quantify the dietary radionuclide intake by humans, and secondarily, as indicators of radioactivity in the ecosystem. Although aquatic foodstuffs are not considered a significant pathway from the WIPP operations, catfish are collected annually from the Pecos River near Carlsbad, Brantley Lake which is located on the Pecos River between Artesia and Carlsbad, New Mexico, and from a location noted as Pierce Canyon that is slightly down stream from Malaga, a small village south of Carlsbad.

The fish samples (tissue fillets) are removed from the carcass to approximate the activities of a sportsman (if fish are small they may be halved after the head and tail is removed). The fish samples are composited by location and analyzed for gross alpha and beta activity and the specific radionuclides indicated in Table 5-2. Catfish are appropriate for analysis in this program because they dwell and feed in bottom sediments where transuranic radionuclides may accumulate.

5.3.6 SOIL SAMPLING

EMP surface soil samples are collected annually from the six locations shown in Figure 5-3. Sampling sites are co-located at air particulate sampling locations and the vegetation sampling sites recommended in HASL-300 and DOE/EH-0173T. The frequency of sampling also follows the guidance contained in DOE/EH-0173T for obtaining long-term accumulation trends. Samples are currently being collected at depths of 0-2, 2-5, and 5-10 cm. However, this method is under review and may be modified. The soil samples are analyzed as indicated in Table 5-2.

5.3.7 SURFACE WATER/DRINKING WATER

Surface water is absent within the WIPP site. The EMP surface water samples are collected annually from the 14 locations in the WIPP vicinity specified in Figure 5-4. These locations comprise the major bodies of surface water in the WIPP vicinity and provide adequate data concerning the surface water pathway. Analyses are performed as specified in Table 5-2.

In addition to the regularly sampled surface water locations there will be additional "samples of opportunity" collected from the site run-off water catchment basins. Due to the varied precipitation events at the WIPP these samples will only be collected when there is adequate run-off available to be properly sampled. As standard for most of the surface water sampling sites, a sediment sample is also collected at the same location. Due to the construction of the basins it is not advisable to perforate the clay bottom to collect the sediment samples. Therefore, sediment samples will not be collected from these sites located directly south and west of the WIPP facility.

Drinking water is collected at the pumphouse from the WIPP supply system. This is the facility which receives/stores the fresh water that is supplied to the site. This water is sampled annually and analyzed for constituents in Table 5-2.

5.3.8 GROUNDWATER

DOE 5400.1 requires that groundwater that may potentially be affected by DOE operations be monitored to detect and document the effects of such operations on groundwater quality and quantity and to show compliance with applicable Federal and State laws and regulations. The groundwater monitoring programs should be conducted on-site and in the vicinity of DOE facilities to:

- Obtain data to determine baseline conditions of groundwater quality and quantity;
- Demonstrate compliance with and implementation of all applicable regulations and DOE Orders;
- Provide data for the early detection of groundwater pollution or contamination;
- Identify existing and potential groundwater contamination sources and to maintain surveillance of these sources; and
- Provide data upon which decisions can be made concerning land disposal practices and the management of groundwater resources.

The WIPP Groundwater Surveillance Program supports Performance Assessment and the EMP. The Groundwater Surveillance Program consists of two subprograms, the Groundwater Level Monitoring Program and the Water Quality Sampling Program (WQSP).

The Groundwater Level Monitoring Program consists of monthly collecting water level measurements from approximately 63 wells (Figure 5-5) in the vicinity of the WIPP. These measurements are tracked to determine if there is a change in the water levels over time and if so to determine the cause of the change.

For the WQSP, samples are collected from the wells noted on Figure 5-6. These samples taken are analyzed for chemical and physical parameters, as well as specific radionuclides as noted in Table 5-2. The protocols specified in the Groundwater Surveillance Program Plan and Procedures manual (WP 02-1) are followed in collecting groundwater samples.

In September and October 1994, six new wells (WQSP 1-6) were installed in the Culebra member of the Rustler formation and one new well (WQSP 6a) in the Dewey Lake for the purpose of water quality sampling. The new wells are constructed to EPA standards and have the potential to meet detection monitoring standards. Recommended EPA drilling methods were used to minimize the introduction of foreign materials into the well bore and prevent contamination of the aquifer. The addition of the new wells to the program is expected to improve the quality of the data collected and reduce the time and cost of sampling. The results of the first samples taken for the new well are reported in the 1995 WIPP Site Environmental Report.

5.3.9 SEDIMENT SAMPLING

Sediment samples are collected from 12 locations (Figure 5-7) annually in the vicinity of the WIPP site and analyzed for specific radionuclides noted in Table 5-2. On the Pecos River there are four locations located; at the upper Pecos near Artesia, New Mexico, Brantley Lake State Park, Lake Carlsbad recreational park, and Pierce Canyon. Eight dirt tanks (earthen catchment basins) are used by area ranchers to collect runoff water for livestock, these tanks are; Tut, Noya, Red, Indian, Lost, Bottom-of-the-Hill, Poker Trap, and Hill. Samples will be taken from the sewage lagoon outflow as soon as sediment build up is adequate for sampling purposes. There are no sediment samples collected from the WIPP water supply line. The analytical results for the sediment sample analysis are reported annually in the WIPP Site Environmental Report,

5.4 NONRADIOLOGICAL ENVIRONMENTAL MONITORING

Nonradiological environmental monitoring activities at the WIPP consist of a comprehensive set of sampling programs designed to detect and quantify impacts of construction and operational activities, and surface storage of salt on the local ecosystem. The requirements and objectives of both preoperational and operational nonradiological environmental monitoring are described in the WIPP FEIS (DOE, 1980). The ecological monitoring program functions as an "operational program" prior to and after commencement of waste emplacement, because it focuses on nonradiological effects which are ongoing.

Section 2.5 of Appendix J of the FEIS states:

> "The operational ecological monitoring program, building on the foundation established through preoperational ecological monitoring, will document the ecological effects of construction and operation . . . and will focus primarily on indicator organisms and selected abiotic parameters."

Primary guidance for ecological monitoring was derived from the WIPP FEIS and the American Institute of Biological Scientists (AIBS) evaluation of the WIPP Biology Program.

Projected construction impacts on the ecosystem include the deposition of fugitive dust generated by the handling of materials such as salt, caliche, and topsoil at the site, as well as noise and other unnatural conditions associated with human activities at the site. A detailed description of the

rationale for the ecological studies appears in the first semiannual Ecological Monitoring Program Report (Reith et al., 1985). Table 5-2 lists parameters which will be monitored by the EMP for evidence of possible site impacts. Results of these studies are published in the SER.

5.4.1 Meteorological Monitoring

The DOE/EH-0173T guidance manual lists guidance for each DOE site to establish a meteorological monitoring program appropriate for the activities at the site and the local topography and demography. Weather data must be monitored and recorded to supplement characterization of the local environment and facilitate the interpretation of data from other environmental monitoring activities at the WIPP.

Meteorological conditions were monitored by SNL at the WIPP from 1975 through 1980. Between 1984 and 1988, temperature, wind speed, and wind direction were continuously monitored from a 10-meter (33 feet) tower at the northwest corner of DOE Exclusive Use Area. Equipment to monitor precipitation and barometric pressure were added to this station during that period.

Use of the 10-meter (33 feet) tower as the primary meteorological monitoring station was discontinued in 1988, and the 10-meter station was relocated to the WIPP Far Field sampling location. The WIPP Far Field site is in the predominantly downwind direction from the WIPP exhaust releases and is the principal air quality sampling location for the EMP.

The primary meteorological monitoring station, is a 50-meter tower located northeast of the WIPP as shown in Figure 5-8. Temperature, wind speed, and wind direction are monitored at 2, 10, and 50 meters (16, 33, and 165 feet, respectively) barometric pressure, humidity, solar radiation, and precipitation are also monitored at this location. Dew point values are also calculated by the Central Monitoring System (CMS) from the temperature and humidity values and recorded for future reference. Measurements are recorded at the CMS, which tracks numerous real-time parameters on a centralized computer system.

A Quality Assurance Project Plan (QAPjP) is being developed for the collection of meteorological data use for regulatory purposes. The QAPjP will incorporate requirements of RCRA, Title 40 CFR 268.6, *EPA Guidance Manual for Petitioners*, EPA 530-R-92-023, and *On-Site Meteorological Program Guidance for Regulatory Modeling Applications*, EPA-450/4-87-13. This section of the EMP fulfills the requirement to have a meteorological monitoring plan as noted in DOE Order 5400.1.

5.4.2 Volatile Organic Compound Monitoring Program

The Volatile Organic Compound (VOC) Monitoring Program was established at the WIPP as required by the EPA. The requirements for the program published in the No-Migration Determination (NMD) issued by the EPA on November 14, 1990 (55 FR 47700). The DOE's 1993 decision to cancel the Bin-Scale and Alcove Test Phase activities resulted in amending the VOC Monitoring Programs objectives.

The DOE has collected airborne VOC data since 1990; these data will serve to characterize the background concentration levels for the WIPP. The VOC Monitoring Program will be in a state of transition until the requirements for a Disposal-Phase monitoring program have been established. Under the Baseline VOC Monitoring Program, the DOE will continue to collect background VOC data until the EPA issues an NMD for the Disposal Phase. The DOE anticipates that this NMD will be issued by June 1997 and will reflect the requirements for VOC Monitoring during disposal operations.

5.4.2.1. VOC Monitoring Plan

The Baseline VOC Monitoring Program measures VOC concentrations in the ambient air to determine the WIPP facility's background levels. This program will serve to differentiate between background VOCs from aboveground and underground sources and VOCs that will be released from TRU mixed waste during disposal operations. Monthly sampling is conducted at the following three stations:

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

Based on field and analytical VOC data collected under the Baseline VOC Monitoring Program, a Disposal-Phase monitoring plan was developed and submitted in the Final No-Migration Variance Petition (NMVP). In the NMVP, which is currently under review by the EPA, the DOE proposes a Confirmatory Monitoring Plan (CMP) for the Disposal Phase. The CMP describes a limited sampling and analysis program by which the DOE will confirm the accuracy of the compliance calculations presented in the NMVP. This program will involve the collection of air samples upstream and down stream of Panel 1 beginning just prior to waste emplacement and proceeding until at least six months following completion of panel closure. The DOE will continue monitoring until the criterion for terminating monitoring, as set forth in the CMP, are met.

5.4.3 Groundwater Surveillance

The objective of the WIPP groundwater monitoring program is to establish, by means of groundwater sampling and analysis events, an accurate and representative groundwater database that is scientifically defensible and supports regulatory compliance. This surveillance program will document the groundwater quality through time to determine if the water quality is changing. Collection of these samples will be from the wells noted in Figure .

General chemistry of the water is monitored utilizing standard wet chemistry analytical methods. These methods will analyze for standard primary constituents such as chlorides, magnesium, calcium and sulfates. In addition to the general chemistry analysis, background data on the 255 constituents listed in Appendix IX of 40 CFR 264 are also being monitored as a requirement of the WIPP RCRA Part B Permit Application.

Constituents listed in Appendix IX include, purgable volatile compounds, non-purgable volatile compounds, semi-volatile compounds, pesticides, polychlorinated biphenyls, herbicides, dioxins, and furans. A future determination will be made whether to continue to monitor all 255 constituents or target specific constituents during the operational phase of groundwater surveillance activities.

5.4.4 Ecological Monitoring Plot Selection

Sampling for the nonradiological environmental portions of the EMP focus on components of the ecosystem immediately surrounding the site and on the ecological parameters most likely to reflect the impact of construction and operational activities (see Section 3.5 for a discussion of the ecosystem at the WIPP). Sampling activities are performed at seven permanently marked ecological monitoring plots whose locations are unchanged from the original preoperational EMP. An identification sign located at the center of each plot serves as a permanent reference for the selection of sampling locations. Each plot is approximately 150 meters (492 feet) by 150 meters (492 feet), although the size of some plots are slightly restricted by roads and other barriers.

Ecological monitoring plots have been located with several criteria in mind:

- Some plots are in areas not directly disturbed by construction, but where the probability and extent of ecological impacts is greatest;
- Controls have been cited where potential impacts from the site are small or negligible; and
- Comparability among the plots has been maximized by situating them where soil, vegetation, and general appearance are judged to be as similar as possible.

Figure 5-9 illustrates the location of the permanent ecological monitoring plots. The plots likely to be impacted by site activities are Southeast 1 (SE1), Northwest 1 (NW1), and East 1 (E1). These three plots are adjacent to the two stockpiles where excavated salt is stored. NW1 is downwind from the facility and the active salt pile according to the prevailing winds, that blow from the southeast. Westerly winds tend to blow during the spring, and can be strong and persistent. During the spring westerlies, E1 is downwind of the site and the active storage pile. SE1 is adjacent to the smaller salt pile, but is outside the path of either primary or secondary wind directions.

Both SE1 and NW1 have counterparts (SE2 and NW2 respectively) located approximately 150 meters (492 feet) farther from the site and the salt piles to help determine the range of any ecological impacts. Finally, Control 1 (CT1) and Control 2 (CT2) are located more than two kilometers (1.2 miles) from the center of the WIPP activities. These are believed to be sufficiently distanced from the facility to minimize exposure, and be an effective "control" site to evaluate and compare ecological impacts.

5.4.5 Aerial Photography

Aerial photographs are utilized to document impacts of the WIPP activities on the local ecology. Removal of native habitat is due to construction of roads, parking lots, buildings, and salt storage piles. The extent of this habitat replacement is documented in aerial photographs. These photographs are typically taken annually.

Aerial photographs produce color stereo-pair photographs for stereoscopic examination as well as enlarged "spot photos" of the WIPP installation. The large-negative spot photographs are available for enlargements in both color and black and white, and can used for planimetric and/or other evaluations of the displacement of native habitat by WIPP activities. Project personnel and local emergency response agencies are also provided with spot photos for their own use. Selected key locations are temporarily flagged with conspicuous aerial markers to facilitate their recognition on the aerial photographs. Aerial photographic mission parameters may be altered as necessary to investigate areas of special interest.

5.4.6 Wildlife Ecology

Birds and mammals comprise the upper levels of the food chain in the natural ecosystem around the WIPP. These organisms may be impacted by noise and human presence as well as by changes in habitat structure due to salt impacts. Population densities are monitored annually to define normal cycles of abundance and to detect major changes in populations or communities which may be due to activities at the WIPP facility.

Wildlife within the WIPP Land Withdrawal Area are given consideration during planning stages of projects involving the disturbance or encroachment of wildlife habitat inside DOE lands by way of the WIPP Land Use Request process. Monitoring and research of specific wildlife populations occurs in accordance with applicable laws, agreements, and regulations subject to funding.

The WIPP conducts a number of general wildlife management activities. Each activity is mandated and/or supported by state and federal guidelines or by way of commitments created through interagency agreements (e.g., *Raptor Research and Monitoring Interagency Agreement*, and/or Memorandums of Understanding with other federal or state agencies).

Examination of wildlife species in the area reveals significant diversity and complexity. Management of indigenous wildlife incorporates the development of a logical sequence when programming activities. Solutions for problems (e.g., home-range, territoriality of desert mule deer) will serve the implementation of conservation and resource management objectives as they pertain to the management and operation of the WIPP site.

TABLE 5-1

EMP SAMPLING SCHEDULE

SAMPLE TYPE	NUMBER OF SAMPLING LOCATIONS	SAMPLING FREQUENCY
Liquid Influent	1	Annual
Liquid Effluent		
DP-831	1	Quarterly
WIPP Oversight	1	Biannual
Airborne Effluent	3	Continuous
Meteorology	2	Continuous
Air Particulate	7	Weekly
Game Birds	WIPP Vicinity	As Available
Rabbits	WIPP Vicinity	As Available
Beef/Deer	WIPP Vicinity	As Available
Fish	3	Annual
Vegetation	6	Annual
Soil	6	Annual
Surface Water*	14	Annual
Sediment	12	Annual
Groundwater	7 (others added as needed)	Annual
Aerial Photography	Site Wide	Annual
Volatile Organic Compound's	3	Monthly
* Site Run-off Catchment Basins	3	As Available

TABLE 5-2

EMP ANALYTICAL ARRAY

TYPE OF SAMPLE	ANALYSIS
Drinking Water	(1) Specific Radionuclides, Residual Chlorine, Choloforms, Nitrates, Elemental Lead
Liquid Influent	(1) Specific Radionuclides
Liquid Effluent	(1) Specific Radionuclides
- DP-831	(2) DP-831 Constituents
- WIPP Oversight	(3) WIPP Oversight Constituents
Airborne Effluent (Stations A, B, and C)	Gross α, Gross β, ^{238}Pu, ^{239}Pu, ^{241}Am
Meteorology	Temperature, Wind Speed, Wind Direction, Precipitation, Dew Point, Barometric Pressure, Solar Radiation
Aerial Photography	Documenting changes occurring to the land surface
Atmospheric Particulate	(1) Specific Radionuclides, gross α, gross β, and TSP
Beef	(1) Specific Radionuclides
Game Animals	(1) Specific Radionuclides
Vegetation	(1) Specific Radionuclides
Rabbits	(1) Specific Radionuclides
Beef/Deer	(1) Specific Radionuclides
Game Birds	(1) Specific Radionuclides
Fish	(1) Specific Radionuclides
Soil	(1) Specific Radionuclides
Surface Water	(1) Specific Radionuclides
Sediment	(1) Specific Radionuclides
Groundwater	(1) Specific Radionuclides, (4) Chemical Analysis, (5) Physical Properties, (6) TCLP Metals (7) 40 CFR 264, Appendix IX - analysis of groundwater samples

TABLE 5-2

EMP ANALYTICAL ARRAY
(continued)

TYPE OF SAMPLE	ANALYSIS
(1) Specific Radionuclides:	^{241}Am, ^{60}Co, ^{137}Cs, ^{40}K, ^{238}Pu, $^{239/240}Pu$, ^{90}Sr, and $U_{isotopic}$
(2) DP-831 Constituents:	NO_3, TKN, ^{226}Ra, ^{228}Ra, and TDS.
(3) WIPP Oversight Constituents:	COD, TOC, TSS, pH, oil/grease, metals, cyanide, phenols, volatiles, semi-volatiles, pesticides,

(4) Chemical Analysis: alkalinity, bromide, chloride, fluoride, iodide, nitrate, phenolics, phosphate, sulfate, total organic halogens, TOC, boron, calcium, iron, lithium magnesium, potassium, silica, sodium, carbon tetrachloride, methylene chloride, toluene, chlorobenezene, 1,1-dichloroethylane, 1,1-dichloroethylene, 1,1,1-trichloroethane, and 1,1,2,2-tetrachloroethane

(5) Physical Properties: pH, specific gravity, specific conductance, TDS, and TSS

(6) TCLP Metals

(7) 40 CFR 264, Appendix IX, analysis of groundwater samples

COD = Chemical Oxygen Demand
TDS = Total Dissolved Solids
TOC = Total Organic Compounds
TKN = Total Kjeldahl Nitrogen
TSP = Total Suspended Particulates
TSS = Total Suspended Solids

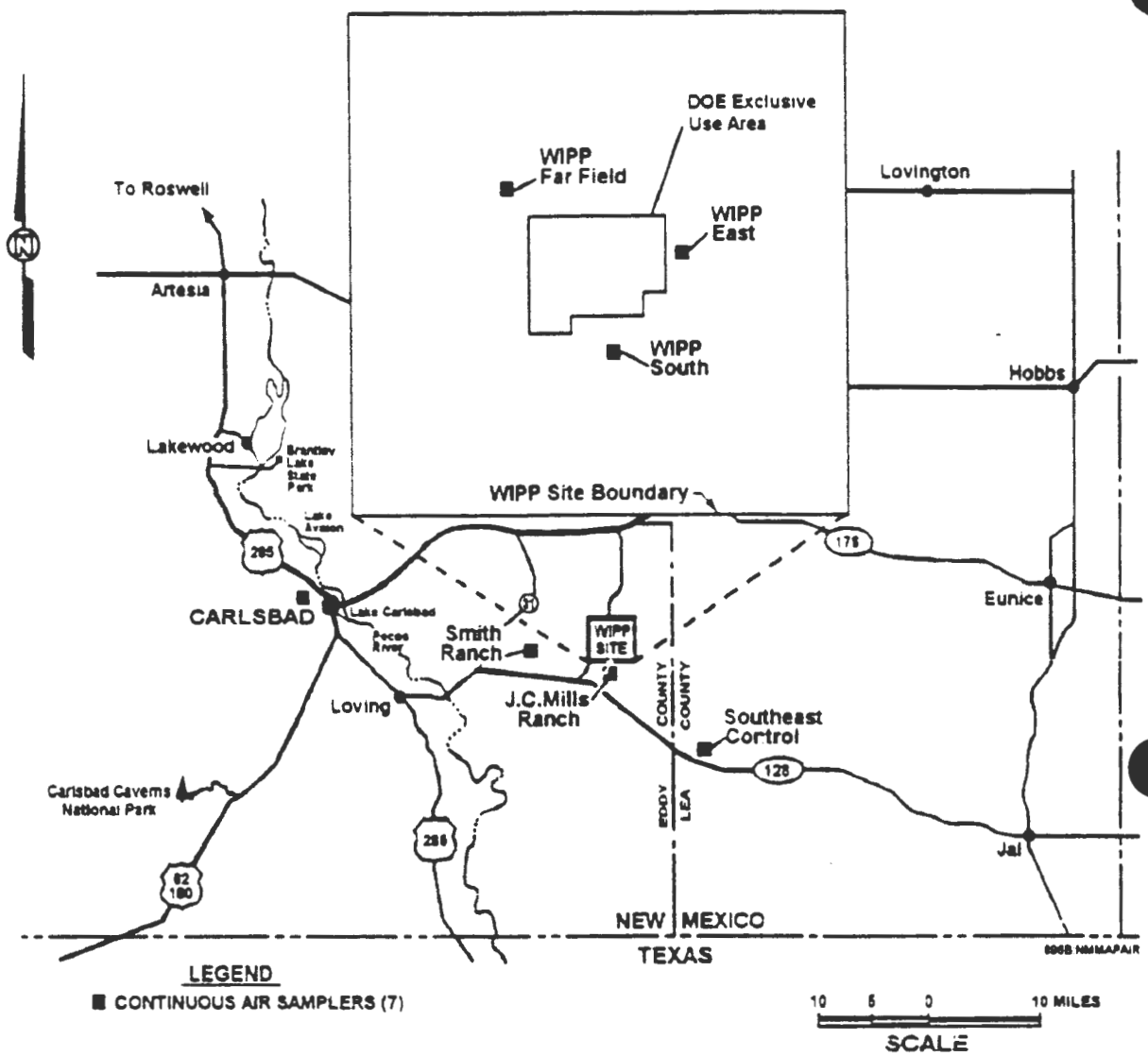

Figure 5-1 Air Sampling Sites

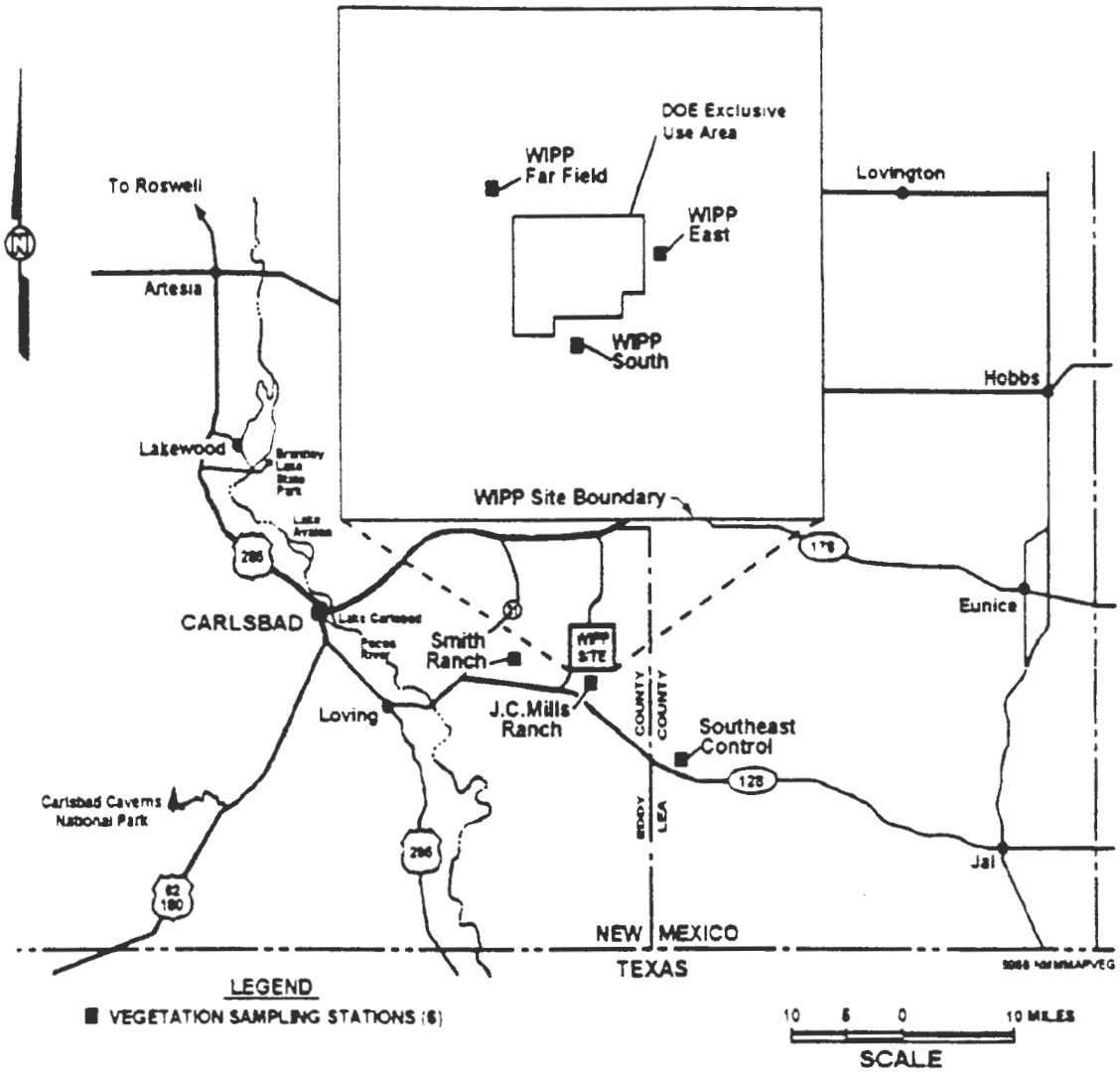

Figure 5-2 Vegetation Sampling Sites

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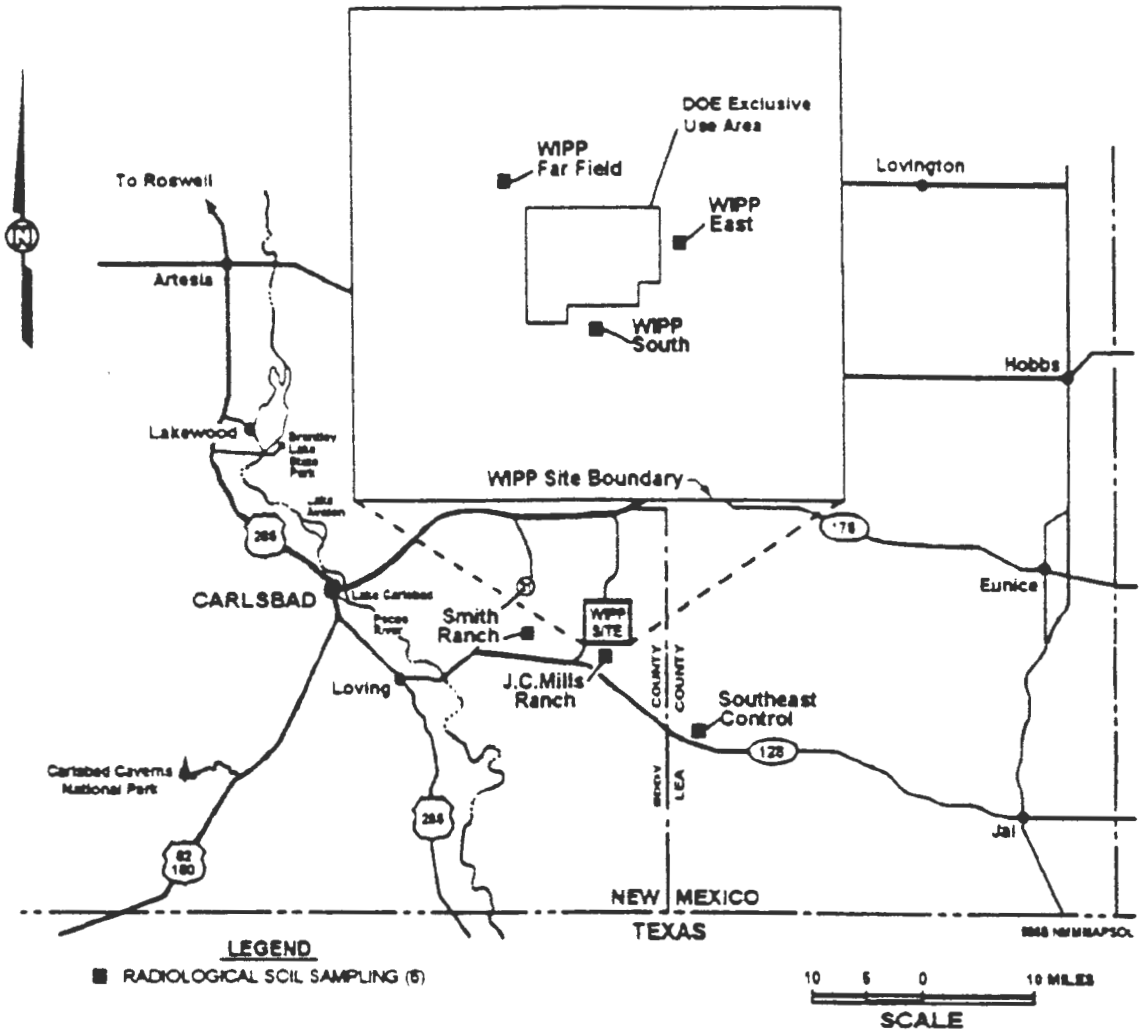

Figure 5-3 Soil Sampling Sites

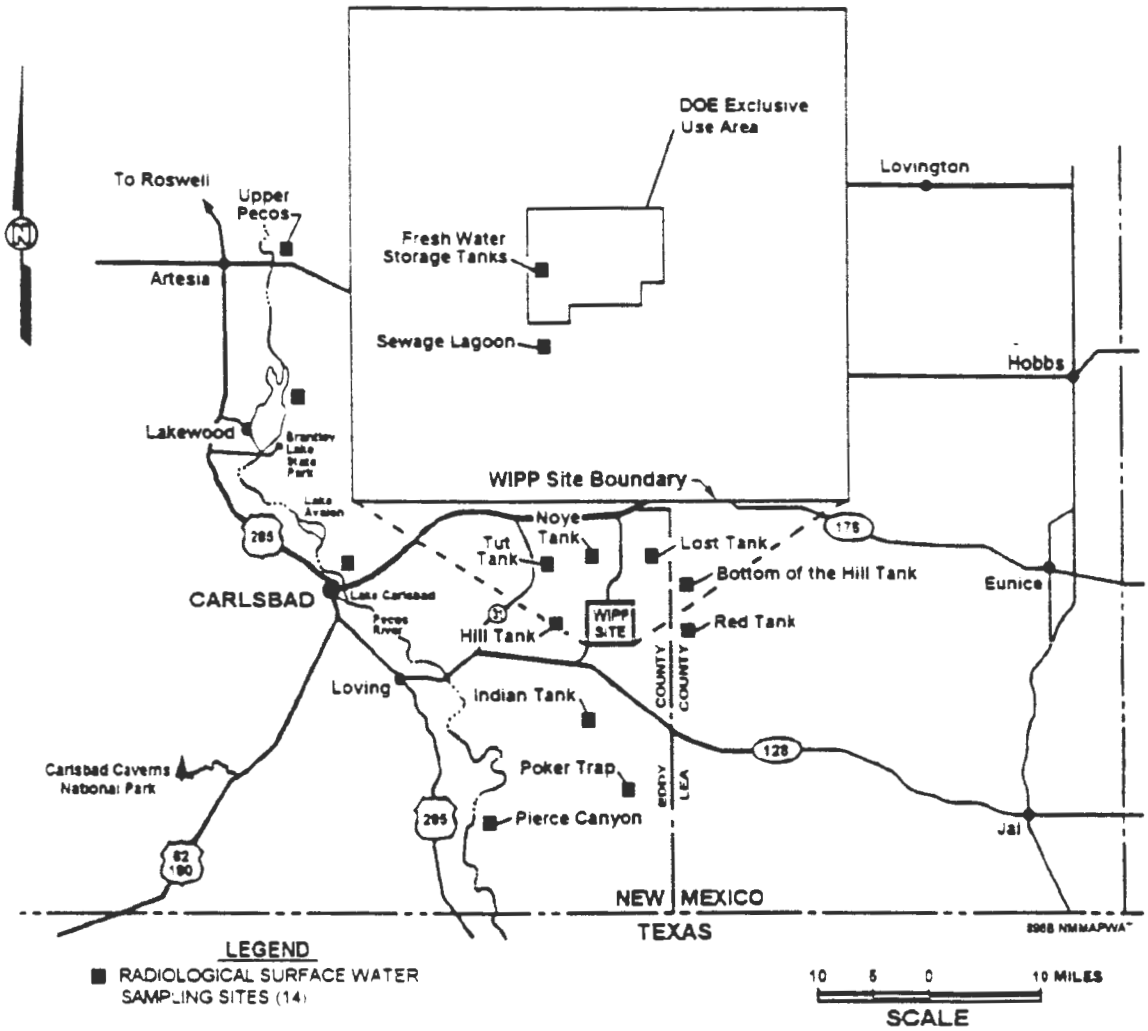

Figure 5-4 Surface Water / Drinking Water Sampling Sites

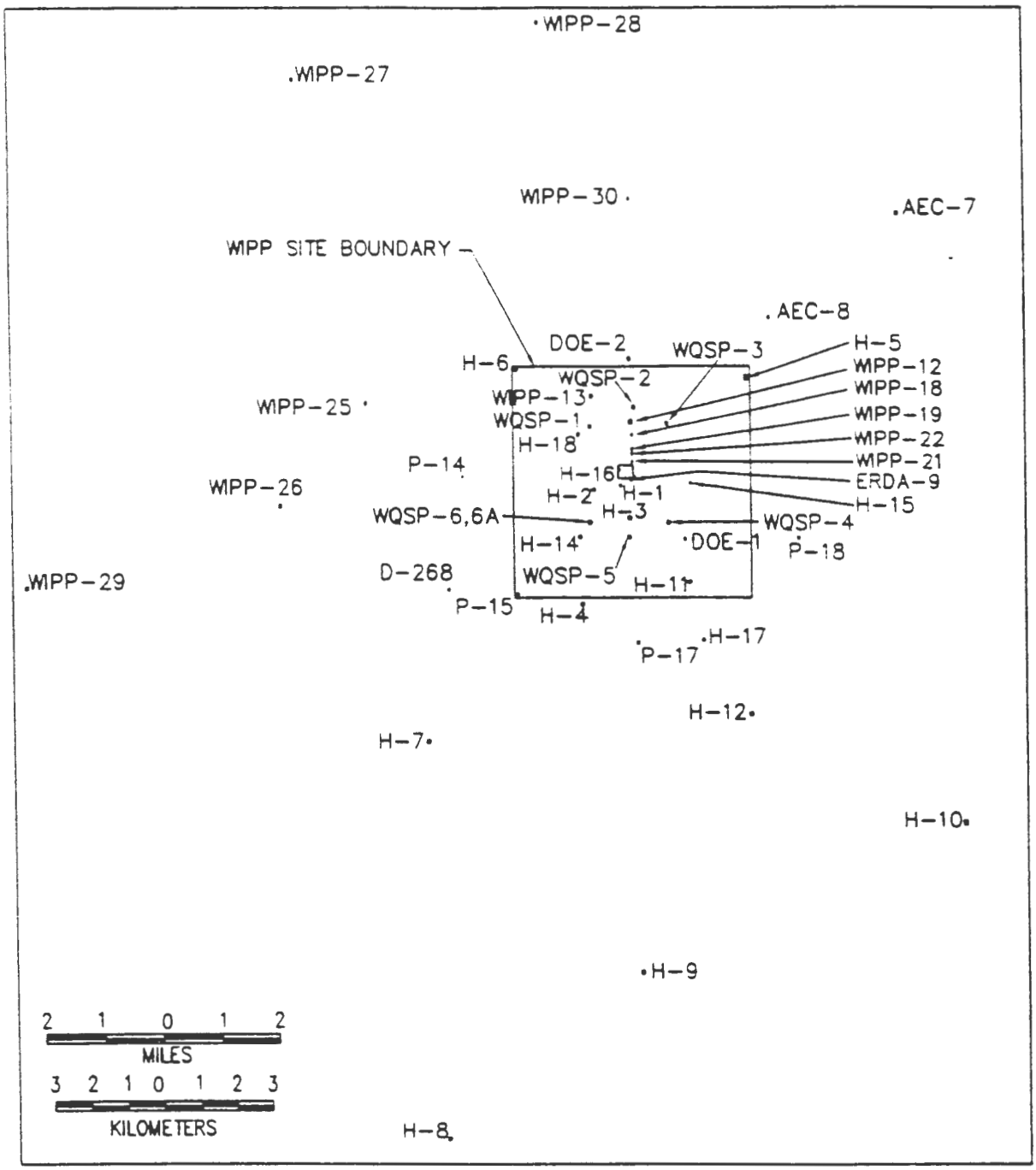

Figure 5-5 Groundwater Level Surveillance Wells

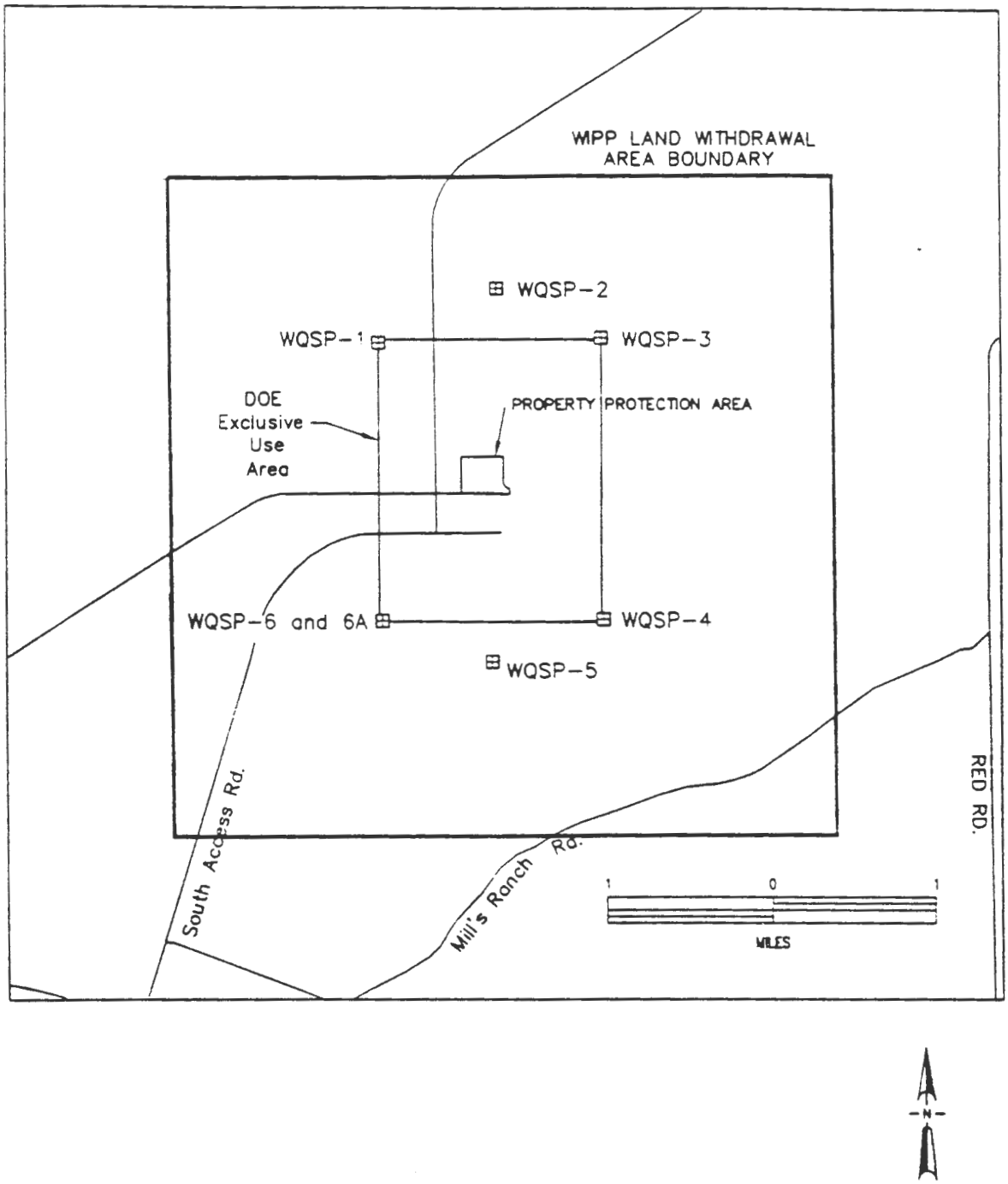

Figure 5-6 Location of the New Water Quality Sampling Wells

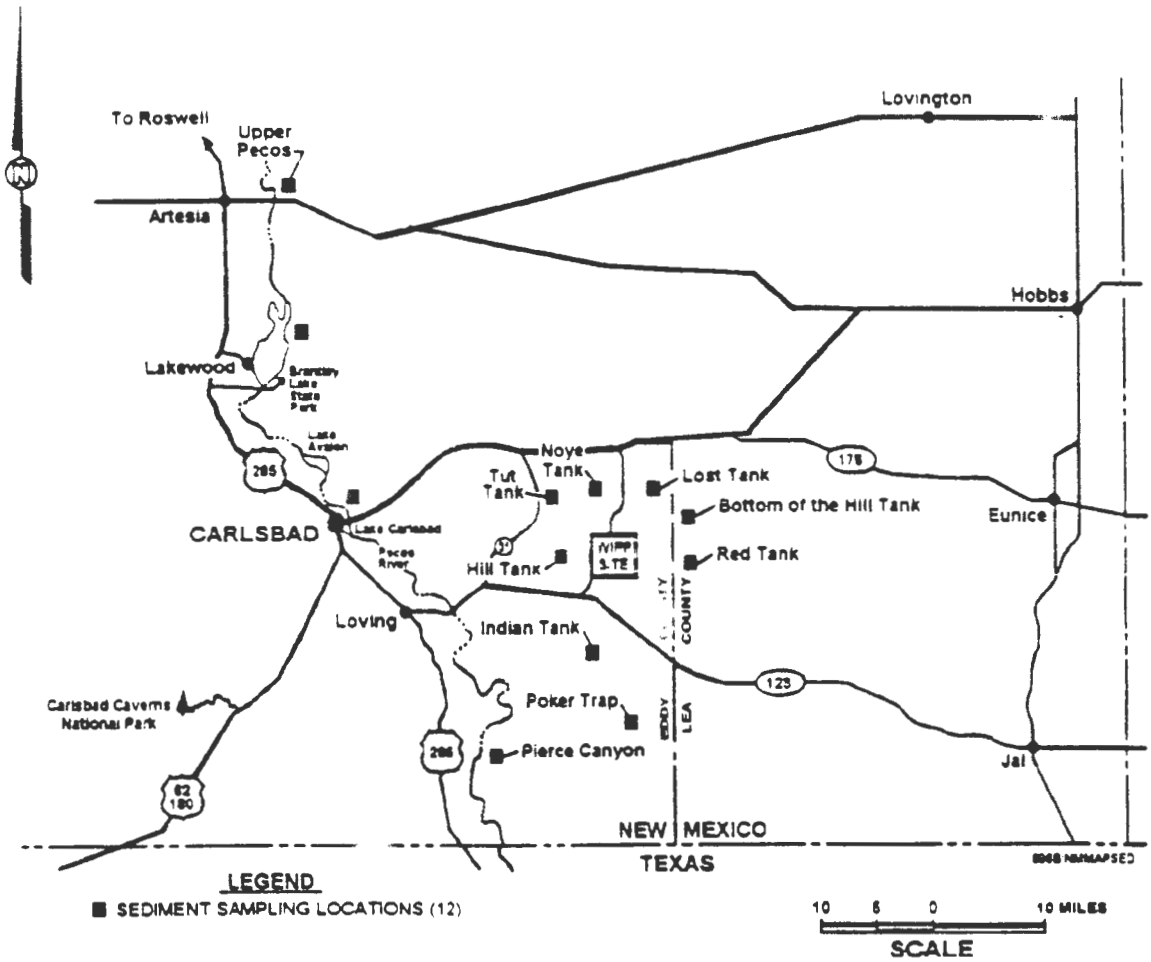

Figure 5-7 Sediment Sampling Sites

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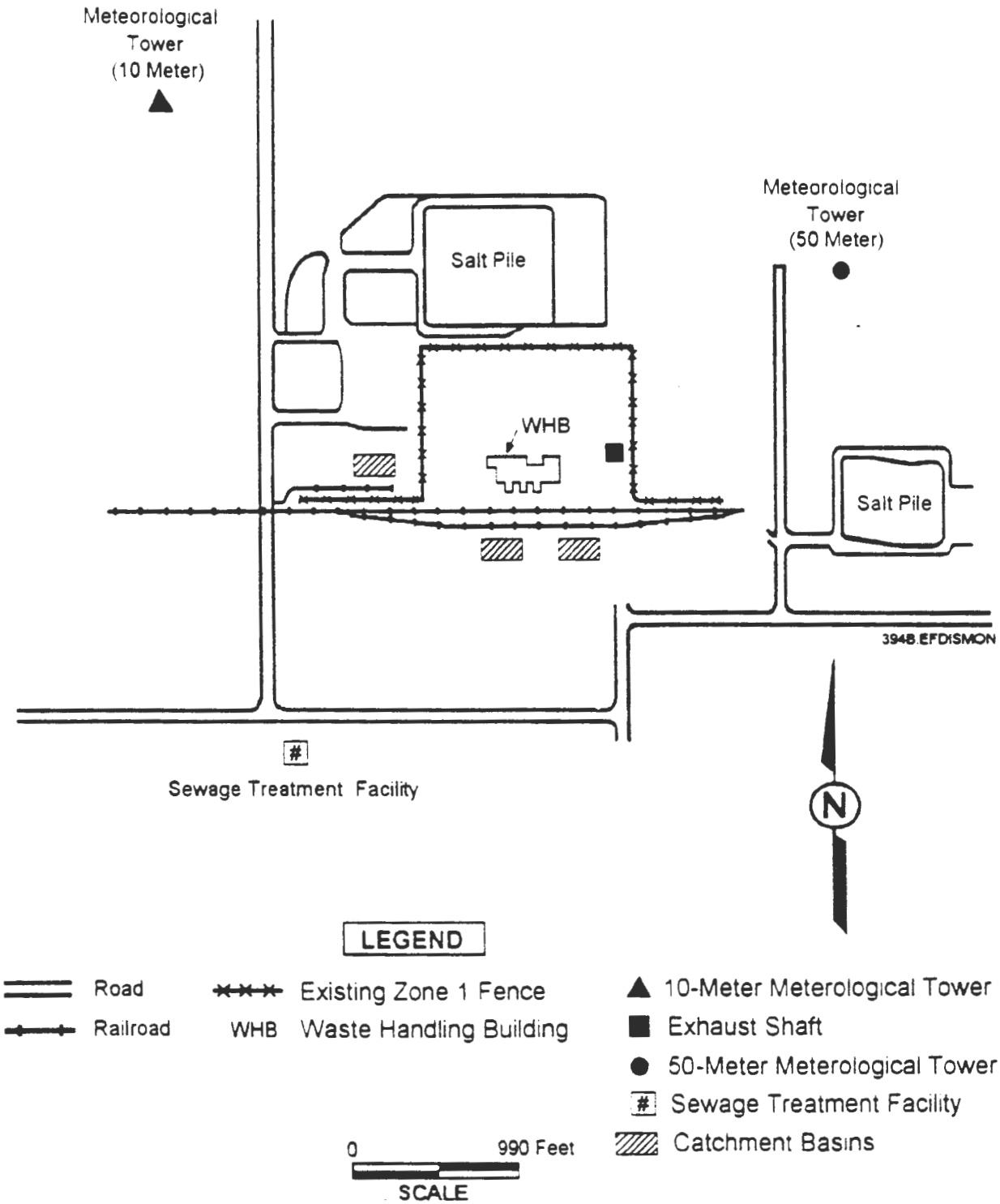

Figure 5-8 Catchment Basins and Meterological Monitoring Sites

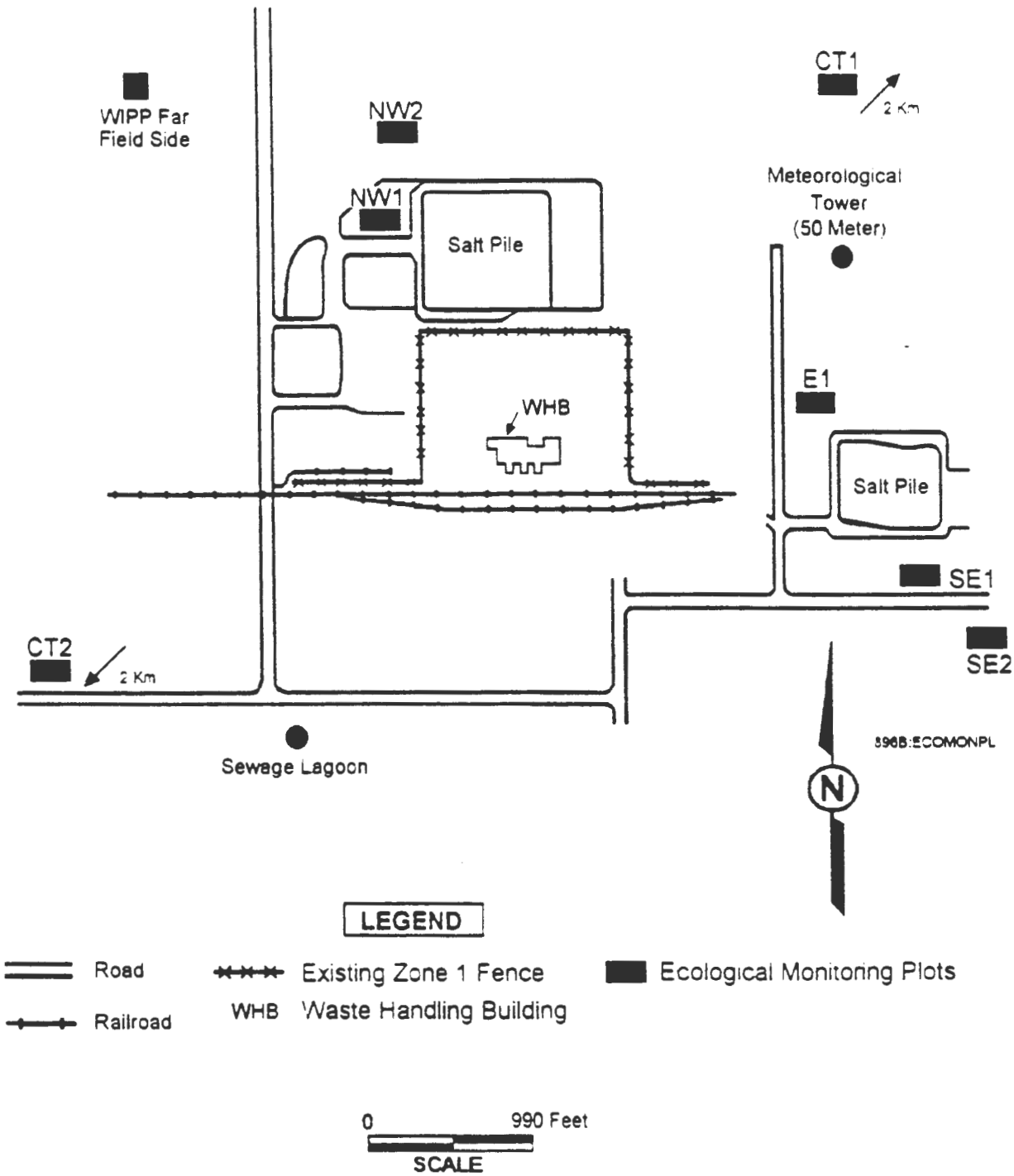

Figure 5-9 Locations of Ecological Monitoring Sites

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6.0 SAMPLE HANDLING AND LABORATORY PROCEDURES

Environmental sampling and analytical laboratory procedures used to obtain quality results for the WIPP are contained and/or described in the following documents:

- Environmental Procedures Manual (WP 02-3)
- Groundwater Monitoring Program Plan and Procedures Manual (WP 02-1)
- Radiological Control Manual (WP 12-5)
- WID Quality Assurance Program Description (WP 13-1)

The WIPP has analytical capabilities as well as subcontracted analytical support. Each laboratory is responsible for maintaining an approved quality assurance program for each program discussed in Chapter 5.

6.1 SAMPLE HANDLING

Sample Identification and Tracking

There is a sample identity code used to uniquely identify environmental samples collected. The code contains sample-specific information used to accurately identify sample type, sample location, date, and sequence of sampling event. A detailed description of the sample identification for radiological and nonradiological samples, calculations, computer inputs, and other applicable reviews are described in environmental sampling procedures. Field data sheets are also maintained in accordance with procedures. The sample tracking is performed from "cradle to grave".

Sampling Schedule

The sample type, location, and frequency of collection are noted in Table 5-1. The sampling schedule at the WIPP is characteristic of waste composition, climate, and demography.

Environmental Activity Levels

During operations, all TRU wastes will remain in sealed containers. Therefore, alpha emitting radionuclide levels in the environmental samples are expected to remain close to radiological background baseline. All environmental samples are collected in accordance with accepted practices and widely recognized methodologies and criteria for environmental monitoring (WP 02-3).

Packaging and Shipping of Samples Off-Site

Environmental samples sent off-site for analysis are packaged according to the specific sampling procedures (i.e., soil, water, vegetation, etc.) listed in the Environmental Procedures Manual (WP 02-3). The Environmental Monitoring procedures outline the chain-of-custody requirements that ensure the integrity of samples. The holding and turnaround times are established through the contract.

Quality Assurance

Contract laboratories are required to follow Quality Assurance/Quality Control (QA/QC) procedures. The quality of the data from analytical contract laboratories is verified by 1) participation in

interlaboratory cross-checks, 2) duplicate, and blank sample analysis, and 3) periodic comparison of results from sample splits that are provided to stakeholders. A comprehensive QA program has been implemented to ensure that the data collected are representative of actual concentrations in the environment. Each contract laboratory is responsible for maintaining an approved quality assurance program detailing the following:

1) routine calibration of instruments;

2) frequent source and background checks (as appropriate);

3) routine yield determinations of radiochemical procedures;

4) replicate/ duplicate analyses to check precision;

5) standard and spike analyses to check accuracy; and

6) verification of reagent expiration dates to ensure analytical accuracies.

The accuracy of radionuclide determination is ensured through the use of standards traceable to the National Institute of Standards and Technology, participation in the Environmental Protection Agency Cross-check Interlaboratory Comparison Program, the DOE/Environmental Measurements Laboratory cross-check program, and other interlaboratory analytical assessment programs, when available. The quality of the data is reviewed and validated for technical merit.

6.2 RADIOLOGICAL ENVIRONMENTAL SURVEILLANCE

A detailed explanation and justification of all radiological and non-radiological Environmental Surveillance is contained in Chapter 5 of this document.

Airborne Particulates

Continuous Low Volume air samplers are used at WIPP for particulate collection. These samplers have a regulated flow rate of 0.056 cubic meters per minute (two cubic feet per minute) of air through a 47-mm (1.9 inch) glass fiber filter. Filters are collected weekly and sent to the analytical laboratory in accordance with the Low-Volume Airborne Particulate Sampling Procedure. A gross alpha and gross beta count of each weekly filter is completed prior to compositing filters from each location for each sampling quarter. This analyses is conducted by the WIPP radiochemistry counting lab in accordance with approved operation and calibration procedures. Quarterly composite samples are also sent off site to a contract laboratory and analyzed using gamma spectrometry for representative gamma-emitting radionuclides typically present in the environment and those expected to occur in the waste received at WIPP. The contract laboratory also performs destructive chemical analysis for the specific alpha and beta activity.

Biotic Samples

Samples of native mammals, quail, fish, locally-produced beef, and vegetation are collected and prepared for radionuclide analyses as described in the Biotic Sampling Procedure. Analyses of all samples are performed by a laboratory in accordance with appropriate EPA and DOE approved methods.

Soil Sampling

Soil sampling procedures used at the WIPP are given in the Soil Sampling Procedure. Analyses of all samples are performed by a laboratory in accordance with appropriate EPA or DOE approved methods.

Surface Water and Sediments

Surface water and sediment samples for radionuclides are collected and handled according to Surface Water and Sediment Sampling Procedure. This procedure describes methods for collecting, preserving, and packaging representative water and sediment samples. Analyses of all samples are performed by a laboratory in accordance with appropriate EPA or DOE approved methods.

Groundwater

Groundwater sampling for radiological analyses is conducted according to the Groundwater Monitoring Program Plan and Procedures Manual. This sampling plan includes detailed procedures on collecting a representative sample by measurement of field parameters to determine a chemical steady-state with respect to those constituents. Included in this plan are the procedures associated with the pumping of groundwater, the serial sampling and analysis program, and the final sample collection and preparation for shipment to contract laboratories. Samples are analyzed by a laboratory in accordance with appropriate EPA or DOE approved methods.

6.3 NONRADIOLOGICAL ENVIRONMENTAL MONITORING

Groundwater

Groundwater sampling and handling procedures for nonradiological analyses are conducted in accordance with the Groundwater Monitoring Program Plan and Procedures manual (WP 02-1). Field parameters for nonradiological analyses include pH, EC, specific gravity, specific conductance, temperature, flow volumes and rates, chloride, calcium, magnesium, total sulfide as H_2S, alkalinity, and dissolved iron. Samples are also collected and sent to a contract laboratory for more extensive analyses performed in accordance with appropriate EPA methods.

VOC Monitoring

VOC sampling and analysis are performed at the WIPP facility using guidance in the EPA Compendium Method TO-14, *Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA Passivated Canister Sampling and Gas Chromatographic Analysis*, as a basis. The VOC samplers are operated by the WIPP facility personnel, and sample analyses are performed by a contract laboratory.

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7.0 DATA ANALYSES

This section describes the criteria and methods used for statistically analyzing data collected in the environmental monitoring program. The goal of statistical data analyses is to provide an objective and reliable means for interpreting data in relation to the objectives of the data collection program. For the program the principal goal is twofold: 1) to compile baseline data for historical comparison purposes, 2) to analyze for comparison to a data point or data set of equivalent data.

The data results of the sample media are graphed by analyte to evaluate analytical consistency. This initial data evaluation process provides a method of evaluating data consistency and trends. During this review should a discrepancy be noted, an in-depth evaluation can be performed to identify the source of the deviation, (i.e. statistical outlier or analytical technique).

Analyses are required for each parameter before statistically valid interpretation can be achieved. The type of analysis used varies among parameters due to the particular characteristics of parameters and the specific objectives of monitoring. Five general levels of data analyses are described here. Analyses at each of these levels is considered for each parameter. The levels are:

(1) Determination of accuracy for each point measurement by quantification and control of precision and bias;

(2) Evaluation of the effects of correlation on the expected value of the point measurement due to location and time of sampling;

(3) Identification of the appropriate model of variability (i.e., a probability density distribution) for each point measurement and the calculation of descriptive statistics based on the chosen model;

(4) Treatment of data anomalies; and

(5) Interpretation of data through statistically valid comparisons (tests) and trend analysis.

Each of these levels of data analyses are described below and with the requirements for application to the EMP.

7.1 ACCURACY

Accuracy is the closeness of a measurement to its actual, or true, value. Since the true value cannot be determined independently, accuracy cannot be absolutely determined. However, accuracy is controlled by two basic elements: bias (consistent over or underestimation of the true value) and precision, [concentration of repeated measurements around a central (expected) value]. Accuracy is maximized when bias is minimized and precision is maximized.

To some extent precision and bias are controlled by strict adherence to sample collection, handling, and measurement protocols. Environmental Monitoring procedures specify the protocols for those functions performed at the WIPP and quality control procedures establish control on precision and bias for contractors (see Section 8.0).

The remaining element of precision and bias is quantitatively estimated through periodic performance of the following measurements:

- measurement of duplicate samples;
- repeated measurement of the same sample;
- measurement of blank samples; and
- measurement of standard pseudo-samples (samples of an equivalent medium containing a known amount of the target species, i.e. spiked samples)

The measurement of duplicate samples is used for estimation of the amount of imprecision incurred through the entire process of sample collection, handling, and measurement. Repeated measurements are used to determine the amount of imprecision attributable to measurement. Blanks and pseudo-samples are used to evaluate bias incurred through measurement processes. Measurements of duplicate samples and repeated measurements have been performed. Results of the EPA cross-check Interlaboratory Comparison Program indicate that laboratories supporting the WIPP environmental monitoring program are within specified control limits. As required by DOE Order 5400.1, contract laboratories performing radiological analysis on WIPP samples, and the WIPP radiochemistry counting lab will participate in the DOE interlaboratory QA program coordinated by the DOE Environmental Measurements Laboratory of New York, New York.

The methods for satisfying these requirements will be dependent upon the sampling and measurement characteristics of each parameter. Generally, the following specifications will be followed:

- one duplicate sample is collected for each ten samples collected;
- one repeated measurement is made for each discrete set of samples analyzed, or for each tenth sample analyzed, whichever is more frequent;
- one blank sample is analyzed for each discrete set of samples analyzed (for radioactivity counts, the background count is not considered a blank); and
- measurements of pseudo-samples, (Note: until the WIPP has the capability to prepare or obtain "spiked samples", WIPP will rely on the contract laboratory's in-house spike sample and recovery process)

Variations from these specifications may be required due to peculiarities of the individual parameters, and is stated in the procedure for that parameter.

7.2 TEMPORAL AND SPATIAL ANALYSIS

Environmental parameters vary with space and time. The effect of one or both of these two factors on the expected value of a point measurement is statistically evaluated through spatial analysis and time series analysis; however, these methods often require extensive sampling efforts which are in excess of the practical requirements of the WIPP program. The application of these meth ds to a particular parameter must, therefore, be limited by consideration of its significance in the ..nal interpretation of the data.

In particular, spatial analysis has limited use in this program, although the effect of spatial correlation on the interpretation of the data is considered for each parameter. Spatial variability is accounted for by the use of predetermined key sampling locations. Data analysis is performed on a

location-specific basis, or data from different locations is combined only when the data are considered to be statistically homogeneous.

Time series analysis plays a more important role in data analysis for the EMP. Parameters are reported as time series, either in tabular form or plots. For key time series parameters, these plots are in the form of control charts on which control levels will be identified based on the preoperational data base, fixed standards, control location data bases, or other standards for comparison.

7.3 DISTRIBUTIONS AND DESCRIPTIVE STATISTICS

Descriptive statistics are calculated for each homogeneous data set. At a minimum, these include a central value and a standard deviation. The central value is the mean of the data. The standard deviation is calculated and used as a basis for the reported range in variation. Typically, plus or minus two standard deviations from the mean are plotted on the graphs. It is expected that 95 percent of the data will fall within the two standard deviation values. This provides for a 95 percent confidence level for the data.

7.4 DATA ANOMALIES

For many facilities data anomalies include data points reported as being below the minimum detectable concentration (MDC) or otherwise censored over a specific range of values, missing data points occurring randomly in the data set, and outliers which cannot be attributed to a known source of variation. This is somewhat misleading for radiological data from WIPP samples. Due to the low background concentrations within the geographical area of the WIPP, and to the fact that WIPP is not operational and considered a no-release facility, it is expected that a significant percentage of data will be below the analytical MDC. These values are not necessarily anomalies due to the rarity of measurable amounts of radioactivity in the WIPP vicinity.

Missing data points comprising less than 10 percent of the data set do not affect data analyses. Results based on data in which more than 10 percent is missing are identified as such at the time of reporting. Consideration of the potential effect of missing data must be made when the majority of the data are missing from a discrete time span.

An outlier is defined as any data point occurring in either extreme upper or lower range of the data distribution for which there is very low probability of occurrence, for normally distributed data. When no probability model is identified, outliers may only be found through visual inspection of the data. These occasionally occurring data values are withdrawn from data calculations and graphs. When a value of this type is removed it allows a better graphical presentation of quality data to maintain a reasonable scale on the graphs.

Data values below the MDC are not typically graphed or used in the standard deviation calculation. The mean is determined by dividing the sum of the data points above the MDC by the total number of data points (excluding blanks). There may not be a graph produced for every analyte corresponding to each matrix. Matrices with less than four data values at or above the MDC are typically not graphed. However, all data values are available for review relative to the matrix type and location.

If outside sources of variation are not identified to account for outliers in a data set, it is included in the data set and all subsequent analyses. If the inclusion of such outliers is found to affect the final results of the analyses significantly, both results (with and without outliers) are reported.

7.5 COMPARISONS AND REPORTING

Comparisons between data sets may be performed using standard statistical tests. The selection of the specific test is dependent upon the relative power of the test and the degree to which the underlying requirements of the test are met. In addition to tests comparing data from distinct locations and times, trend analyses may be performed on time series where sufficient data exist. A 95 percent confidence level will be used for the final interpretation of results.

Note: There has been no attempt in this section to define standard statistical terminology nor to reference common statistical formulae and derivations. Many satisfactory statistical texts and handbooks, in addition to those given in the reference, are available for this purpose.

8.0 QUALITY ASSURANCE

8.1 INTRODUCTION

This section defines the policies and procedures that have been implemented at the WIPP to provide confidence in the quality of the environmental data that are generated. Quality Assurance (QA) practices that cover monitoring activities at the WIPP are consistent with applicable elements of the 10-element format in ANSI/ASME NQA-I.

The WID Quality Assurance Program Description (QAPD), WP 13-1, defines QA requirements and responsibilities that apply to WID work. The format of Revision 16 of WP 13-1 is based on the QA criteria of 10 CFR 830.120. Because QA requirements of data collection for compliance with environmental regulations are less detailed than those usually applied to nuclear facilities, the WID QAPD also addresses EPA QA requirements extracted from the EPA's QAMS-005/80, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans*. For the WIPP project, these EPA QA requirements apply to Environmental Data Operations (EDOs); that is, compliance activities associated with collection and analysis of environmental samples, including data reduction, handling, reporting, and records management. Examples of EDOs at the WIPP include the monitoring programs for compliance with the No-Migration Variance, NESHAPS, and RCRA hazardous waste characterization. Table 8-1 demonstrates the relationship between QA requirements from 10 CFR 830.120, ASME NQA-1, and EPA QAMS-005/80.

8.2 GOAL

The Westinghouse Waste Isolation Division (WID) quality assurance policy sets a goal to perform all work in such manner that the required quality is attained or exceeded. To attain this goal the WID has developed and implemented a formal QA program that is tailored for activities associated with receipt of TRU waste, including operational safety, environmental compliance, and performance assessment.

TABLE 8-1

10 CFR 830.120 CROSS REFERENCE TO ASME NQA-1 AND EPA QAMS-005/80

	10 CFR 830.120	ASME NQA-1 BASIC REQUIREMENT	EPA QAMS-005/80 ELEMENT
MANAGEMENT	1. Program	1. Organization 2. Quality Assurance Program	3. Project Description 4. Project Organization & Responsibility 16. Quality Assurance Reports to Management
	2. Personnel Training and Qualification	2. Quality Assurance Program	3. Project Description 16. Quality Assurance Reports to Management
	3. Quality Improvement	15. Control of Nonconforming Items 16. Corrective Action	15. Corrective Action
	4. Documents and Records	6. Document Control 17. Quality Assurance Records	1. Title Page 2. Table of Contents
PERFORMANCE	5. Work Processes	5. Instructions, Procedures and Drawings 8. Identification and Control of Items 9. Control of Processes 12. Control of Measuring and Test Equipment 13. Handling, Storage and Shipping	6. Sampling Procedures 7. Sample Custody 8. Calibration 9. Analytical Procedures 13. Preventive Maintenance
	6. Design	3. Design Control	5. Data Quality Objectives 6. Sampling Procedures 10. Data Reduction 11. Internal Quality Control 14. Routine Procedures to Assess Data Quality
	7. Procurement	4. Procurement Document Control 7. Control of Purchased Items and Services	N/A
	8. Inspection and Acceptance Testing	10. Inspection 11. Test Control 12. Control of Measuring and Test Equipment 14. Inspection, Test and Operating Status	8. Calibration 13. Preventive Maintenance
ASSESS	9. Management Assessment	2. Quality Assurance Program	3. Project Description 12. Audits 14. Routine Procedures to Assess Data Quality 16. Quality Assurance Reports to Management
	10. Independent Assessment	18. Audits	14. Routine Procedures to Assess Data Quality

8.3 PROGRAM ELEMENTS/CRITERIA

The specific WIPP QA program elements/criteria that are applicable to the performance of the EMP are listed below by 10 CFR 830.120 criterion. These elements establish the applicable QA requirements that are required for compliance activities associated with the collection and analysis of environmental samples, including data reduction, handling, reporting, and records management.

8.3.1 Program

This element includes programmatic practices and procedures that include QA project plans for EDOs that consider and address the 16 essential elements described in Section 5 of the EPA QAMS-005/80. Project descriptions for specific EDOs are provided in project-specific QA project plans (QAPjPs). These project-specific QA project plans include explanations for exclusion of any of the 16 elements that would not be relevant to a specific project. The project descriptions include an experiment design description in sufficient detail for stand-alone review and approval of the plan. EDO project descriptions incorporate the following elements, as appropriate:

- Flow diagrams, tables, and charts;
- Dates anticipated for start and completion; and
- Intended end use of acquired data.

Each WIPP organization involved with activities and operations affecting environmental data quality will specify QA/QC responsibilities in departmental or project-specific QA project plans. The QA project plans include tables or charts showing the project organization and line authority. Key individuals, including the designated QA officer, who are responsible for ensuring the collection of valid data and the routine assessment of measurement systems for precision and accuracy, are listed.

Precision and accuracy of all environmental monitoring data are routinely assessed and reported. Project-specific QA project plans associated with EDOs provide the mechanism for periodic reports to the DOE WIPP project management on the performance of measurement systems and data quality. These reports include:

- Periodic assessment of measurement data accuracy, precision, and completeness;
- Results of performance audits;
- Results of system audits;
- Significant QA problems which if uncorrected could have a serious effect on the health and safety of WIPP workers and the public, seriously impact the operation of the WIPP, or have a noticeable adverse impact on the environment;
- Recommended corrective actions;
- Identification of individuals responsible for report preparation; and
- Provisions in the final report for a separate QA section that summarizes data quality information contained in the periodic reports.

8.3.2 Personnel Training and Qualification

The WIPP training program has been designed to ensure that personnel performing work are capable of performing their assigned task in a proficient manner. Personnel who perform work that requires special skills or abilities are required to meet the qualification requirements for that specific task unless directly supervised by a qualified person.

8.3.3 Quality Improvement

The quality improvement process has been established and implemented to improve quality and provide corrective action procedures. Corrective action procedures for activities associated with environmental data collection are identified in project-specific QA project plans. At a minimum, the following elements are addressed:

- Predetermined limits for data acceptability beyond which corrective action is required;
- Procedures for corrective action; and
- Identification of individuals responsible for initiating corrective action and individuals responsible for verifying and approving implementation of the corrective action.

Corrective action may be initiated through routine operations, performance audits, system audits, inter/intralaboratory comparison studies, or performance demonstrations conducted by DOE-CAO.

8.3.4 Documents and Records

Procedures are established that control the preparation, review, approval, issuance, use, and revision of documents that establish policies, prescribe work, specify requirements, establish design, or that are being used for the performance of quality-related activities. Each project-specific QA implementation plan for EDOs includes documentation of approval, in the form of a title page.

Procedures are also in place to ensure that records are specified, prepared, reviewed, approved, and maintained to accurately reflect completed work. This process is described in PR-15, Records management Plan. The WIPP record management program provides a project-wide records management system that coordinates the collection, maintenance, identification, and preservation of WIPP project records, in accordance with standards mandated by DOE Order 1324.5, *Records Management Program*.

8.3.5 Work Processes

Work is performed to established technical standards and administrative controls. For each major measurement parameter, the design of sampling methodology, equipment, and procedures are documented and approved. The following requirements for sample design are addressed in project-specific technical and/or QA plans, as applicable:

- Description of techniques or guidelines used to select sampling sites;
- Inclusion of specific sampling procedures to be used, either by reference in the case of approved standard operating procedures (SOPs), or in entirety if the procedures are nonstandard;

- Charts, flow diagrams, or tables delineating sampling program operations;
- A description of containers, procedures, reagents, etc., used for sample collection, preservation, transportation, and storage;
- Special conditions for the preparation of sampling equipment and containers to avoid sample contamination;
- Sample preservation methods and holding times;
- Time considerations for shipment of samples to the laboratory;
- Sample custody or chain-of-custody procedures; and
- Forms, notebooks, databases, and procedures to be used to document sample history, sampling conditions, and required analyses.

Samples collected for environmental compliance activities or for site validation are controlled by approved chain-of-custody procedures. The actual practices used are documented in project-specific QA implementation plans. The following sample custody procedures are specified in the QA project plan:

- For field sampling operations:
  - Documentation of procedures for preparation of reagents or supplies which become an integral part of the sample;
  - Procedures and forms for recording the exact location and specific considerations associated with sample acquisition;
  - Documentation of specific sample preservation methods; and
  - Sample labels containing all information necessary for effective sample tracking.
- For laboratory operations:
  - Identification of responsible party to act as sample custodian at the laboratory facility authorized to sign for incoming field samples, obtain documents of shipment, and verify the data entered onto the same custody records;
  - A laboratory sample custody log consisting of serially numbered standard lab-tracking report sheets; and
  - Specification of laboratory sample custody procedures for sample handling, storage, and dispersement for analysis.

Custody records are treated as permanent QA records by the recipient upon final transmission of the analytical data.

Calibration procedures and frequency for EDO activities are specified in project specific QA implementation plans. The plans include:

- A reference to the applicable SOP, or written description of the calibration procedures used for each major measurement parameter;
- Frequency of calibration; and
- Calibration standards to be used, as well as their sources and traceability.

Preventive maintenance of equipment used for collection and measurement of environmental data are identified in project specific QA implementation plans. The following types of preventive maintenance items are addressed:

- A schedule for preventive maintenance tasks; and
- A list of critical spare parts that should be available.

Procedures used for controlling the analysis of samples collected for EDO activities are specified in project-specific QA implementation or technical plans. For each measurement parameter the applicable procedure is either described in writing, or referenced as an SOP.

8.3.6 Design

Each major measurement parameter, the design of sampling methodology, equipment and procedures are documented and approved. The following requirements for sample design are addressed in project-specific plans and/or QA plans:

- Description of techniques or guidelines used to select sampling sites;
- Inclusion of specific sampling procedures to be used, either by reference in the case of approved SOPs, or in entirety if the procedures are nonstandard;
- Charts, flow diagrams, or tables delineating sampling program operations;
- Description of containers, procedures, reagents, etc., used for sample collection, preservation, transport, and storage;
- Special conditions for the preparation of sampling equipment and containers to avoid sample contamination;
- Sample preservation methods and holding times;
- Time considerations for shipment of samples to the laboratory;
- Sample custody or chain-of-custody procedures; and
- Forms, notebooks, databases, and procedures to be used to document sample history, sampling conditions, and required analyses.

8.3.7 Procurement

The control of procurement documents ensures that procured items and services meet established requirements and specifications. Basic procurement requirements include:

- Applicable design specifications and other order requirements are \or referenced in documents for procurement of items and services;

- That the supplier have a QA program consistent with applicable requirements; and
- That all procurement actions be performed in accordance with written procedures that describe the actions involved in the preparation, review, approval, control and changes of procurement documents.

8.3.8 Inspection and Acceptance Testing

Inspection and acceptance testing of specified items and processes are conducted using established acceptance and performance criteria.

Equipment used for inspections and tests are calibrated and maintained. Calibration procedures and frequency for EDO activities are specified in project specified QA implementation plans. These plans will include:

- A reference to the applicable SOP, or written descriptions of the calibration procedures used for each major measurement parameter;
- Frequency of calibration; and
- Calibration standards to be used, as well as their sources and traceability.

8.3.9 Management Assessment

Senior management assembles input from the following sources to form the basis of management assessment:

- Line management's self-assessment reports;
- Independent assessment reports; and
- Corrective action reports including conditions adverse to quality, non-conformance reports (NCRs), program deficiency reports (PDRs), audit reports, and requests for corrective action (RCAs).

Following the assessment, the effectiveness of the QA program is documented. Further, areas for quality improvement root cause analysis (for severe non-conformances or high-risk items/activities), preventive or corrective actions, milestones for completion, responsibility assignments, trend analysis, and lessons learned are documented and transmitted to the DOE.

8.3.10 Independent Assessment

Independent Assessment is performed to verify procedure compliance. Independent assessment is also used to prove independent oversight of the self-assessment process performed by line management. Independent assessment focuses on improving items and processes by emphasizing line organization's achievement of quality. Results from independent assessments are transmitted to senior management as input for determination of the effectiveness of the integrated QA program. In this regard, personnel performing independent assessments act in a management advisory function.

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9.0 REQUIRED RECORDS AND REPORTS

9.1 GENERAL INFORMATION AND PURPOSE

The purpose of this chapter of the WIPP EMP is to define the environmental records and reports criteria regulations, and guidelines requirements with which the WID will comply.

The following regulations contain the reporting requirements applicable to the WID's environmental monitoring program:

- DOE/EH-0173T
- DOE Order 5400.1
- DOE Order 5400.5
- DOE Order 1324.2A
- Clean Air Act
- Clean Water Act
- Superfund Amendments and Reauthorization Act (SARA) Title 3
- Resource Conservation and Recovery Act (RCRA)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Office of Management and Budget (OMB) Circular A-196

Thorough reporting and recordkeeping will be performed at WID as essential elements of complying with state and federal regulations.

The environmental reports and notifications specified in DOE Orders 5400.1 and 5400.5 will be submitted to DOE within the required time periods.

Complete, accurate, and auditable environmental monitoring program records will be maintained. The WID record inventory and disposal system (RIDS) will govern environmental monitoring records management.

9.2 RECORD KEEPING

Records generated through environmental monitoring activities are controlled and maintained in accordance with the WIPP *Records Management Plan*, WP 15-PR. This plan interprets and implements the records management requirements contained in the *Carlsbad Area Office Information Management Plan*, CAO 94-1001. The requirements stated in this plan apply to all WID organizations. The plan provides the interpretations and the guidance necessary to meet the records management requirements for the creation, maintenance, use and disposition of records that document and support the WIPP mission.

9.3 REPORTING

The WIPP EMP is reviewed annually and updated at least every three years in accordance with DOE Order 5400.1 (DOE, 1988d). Changes are made as new regulations are promulgated which specify record-keeping, reporting, and other programmatic requirements applicable to the environmental monitoring program at the WIPP.

The Environmental Protection Implementation Plan (EPIP) is revised annually in accordance with DOE Order 5400.1 (DOE, 1988d). This document delineates how the WIPP implements the provisions of DOE Order 5400.1. The EPIP identifies compliance strategies and manpower allocations, and describes the WIPP organizational structure.

The WIPP Annual Site Environmental Report is prepared according to DOE Order 5400.1 (DOE, 1988d). This report summarizes the facility's compliance with applicable environmental regulations

and informs the public as to the impact of the operations at WIPP on the surrounding environment. The Annual Mitigation Report (AMR), required by DOE Order 5440.1E, is issued each July. This document describes the progress made in implementing the commitments made in the FEIS and SEIS Records of Decision. Several of the commitments that are being tracked pertain to environmental monitoring and environmental compliance.

The No-Migration Determination Annual Report is submitted annually to the EPA in November. This document meets the requirements of the *Conditional No-Migration Determination for the Department of Energy Waste Isolation Plant* (55 FR 47700). This report contains summaries of air monitoring and waste characterization data, as well as VOC monitoring results.

When WIPP begins to receive TRU waste, Radioactive Effluent and On-site Discharge Data Reports will be prepared and submitted to the Waste Information System Branch of EG&G Idaho, Inc., by April 1 of each year. DOE Order 5480.14 specifies instructions for implementing a DOE Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program (DOE, 1985c). No inactive hazardous-waste disposal sites requiring remedial action under CERCLA exist at WIPP. WIPP notifies the National Response Center in the case of a release of "reportable quantities" of radionuclides or other hazardous substances at the WIPP as required by CERCLA §102(a) (DOE, 1985c).

The EPA has promulgated environmental standards for the management and disposal of transuranic radioactive wastes under the authority of the EPA and the Nuclear Waste Policy Act (NWPA). The EPA has not specified reporting requirements applicable to the WIPP under this regulation.

The Office of Management and Budget Circular A-106, *Reporting Requirements in Connection with the Prevention, Control, and Abatement of Environmental Pollution at Existing Federal Facilities* (OMB, 1975), has established a semiannual reporting requirement for implementing Sections 1 through 4 of Presidential Executive Order 12088 and Presidential Executive Order 11752 pertaining to the control of environmental pollution from existing federal facilities. The plans, to be submitted on December 31 and June 30, identify projects necessary to bring federal facilities into compliance with applicable environmental standards.

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APPENDIX D6
SITE CHARACTERIZATION

APPENDIX D6
SITE CHARACTERIZATION

TABLE OF CONTENTS

List of Tables D6-iii

List of Figures D6-v

Introduction D6-1

D6-1 Geology D6-2
- D6-1a Data Sources D6-2
- D6-1b Geologic History D6-3
- D6-1c Stratigraphy and Lithology in the Vicinity of the WIPP Site D6-4
  - D6-1c(1) General Stratigraphy and Lithology below the Bell Canyon Formation D6-4
  - D6-1c(2) The Bell Canyon Formation D6-6
  - D6-1c(3) The Castile Formation D6-7
  - D6-1c(4) The Salado Formation D6-8
  - D6-1c(5) Rustler Formation D6-11
  - D6-1c(6) The Dewey Lake D6-16
  - D6-1c(7) The Santa Rosa D6-17
  - D6-1c(8) The Gatuña Formation D6-18
  - D6-1c(9) The Mescalero Caliche D6-18
  - D6-1c(10) Surficial Sediments D6-19
- D6-1d Physiography and Geomorphology D6-20
  - D6-1d(1) Regional Physiography and Geomorphology D6-20
  - D6-1d(2) Site Physiography and Geomorphology D6-21
- D6-1e Tectonic Setting and Site Structural Features D6-22
  - D6-1e(1) Basin Tilting D6-22
  - D6-1e(2) Faulting D6-22
  - D6-1e(3) Igneous Activity D6-24
  - D6-1e(4) Loading and Unloading D6-24
- D6-1f Nontectonic Processes and Features D6-27
  - D6-1f(1) Evaporite Deformation D6-27
  - D6-1f(2) Evaporite Dissolution D6-38

D6-2 Surface-Water and Groundwater Hydrology D6-42
- D6-2a Groundwater Hydrology D6-44
  - D6-2a(1) Conceptual Models of Groundwater Flow D6-44
  - D6-2a(2) Units Below the Salado D6-46
  - D6-2a(3) Units Above the Salado D6-49

TABLE OF CONTENTS
(CONTINUED)

D6-2a(4) Hydrology of Other Groundwater Zones of Regional Importance D6-58
D6-2b Surface-Water Hydrology D6-60
D6-2c Groundwater Discharge and Recharge D6-62
D6-2d Water Quality D6-63
D6-2d(1) Groundwater Quality D6-63
D6-2d(2) Surface-Water Quality D6-65

D6-3 Resources D6-65
D6-3a Extractable Resources D6-66
D6-3a(1) Potash Resources at the WIPP Site D6-67
D6-3a(2) Hydrocarbon Resources at the WIPP Site D6-67
D6-3b Cultural and Economic Resources D6-68
D6-3b(1) Demographics D6-68
D6-3b(2) Land Use D6-68
D6-3b(3) History and Archaeology D6-69

D6-4 Seismicity D6-72

D6-5 Rock Geochemistry D6-74

BIBLIOGRAPHY D6-91

SUBAPPENDIX . . . . . .

List of Tables

Table	*Title*	*Page*
D6-1	Culebra Thickness Data Sets	D6-129
D6-2	Hydrologic Characteristics of Rock Units at the WIPP Site	D6-129
D6-3	Capacities of Reservoirs in the Pecos River Drainage	D6-130
D6-4	Current Estimates of Potash Resources at the WIPP Site	D6-130
D6-5	In-Place Oil Within Study Area	D6-131
D6-6	In-Place Gas Within Study Area	D6-131
D6-7	Chemical Formulas, Distributions, and Relative Abundances of Minerals in Delaware Basin Evaporites	D6-132

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List of Figures

Figure	Title	Page
D6-1	WIPP Site Location in Southeastern New Mexico	D6-135
D6-2	Borehole Location Map	D6-136
D6-3	Major Geologic Events—Southeast New Mexico Region	D6-137
D6-4	Site Geological Column	D6-138
D6-5	Cross Section from Delaware Basin (Southeast) Through Marginal Reef Rocks to Back-Reef Facies	D6-139
D6-6	Generalized Stratigraphic Cross Section above the Bell Canyon at WIPP Site	D6-140
D6-7	Salado Stratigraphy	D6-141
D6-8	Rustler Stratigraphy	D6-142
D6-9	Halite Margins in Rustler	D6-143
D6-10	Isopach Map of the Entire Rustler	D6-144
D6-11	Percentage of Natural Fractures in the Culebra Filled with Gypsum	D6-145
D6-12	Log Character of the Rustler Showing Mudstone-Halite Lateral Relationships	D6-146
D6-13	Isopach of the Dewey Lake	D6-147
D6-14	Isopach of the Santa Rosa	D6-148
D6-15	Physiographic Provinces and Sections	D6-149
D6-16	Site Topographic Map	D6-150
D6-17	Structural Provinces of the Permian Basin Region	D6-151
D6-18	Loading and Unloading History Estimated for Base of Culebra	D6-152
D6-19	Location of Main Stratigraphic Drillholes	D6-153
D6-20	Seismic Time Structure of the Middle Castile Formation	D6-154
D6-21	Fence Diagram Using DOE-2 and Adjacent Holes	D6-155
D6-22	Isopach from the Top of the Vaca Triste to the Top of the Salad	D6-156
D6-23	Isopach from the Base of MB 103 to the Top of the Salado	D6-157
D6-24	Isopach from the Base of MB 123/124 to the Base of the Vaca Triste	D6-158
D6-25	Structure Contour Map of Culebra Dolomite Base	D6-159
D6-26	Drainage Pattern in the Vicinity of the WIPP Facility	D6-160
D6-27	Schematic West-East Cross Section through the Northern Delaware Basin	D6-161
D6-28	Schematic North-South Cross Section through the Northern Delaware Basin	D6-162
D6-29	Outline of the Groundwater Basin Model Domain on a Topographic Map	D6-163
D6-30	Transmissivities of the Culebra	D6-164
D6-31	Hydraulic Heads in the Culebra	D6-165

List of Figures
(Continued)

D6-32 Hydraulic Heads in the Magenta D6-166
D6-33 Interpreted Water Table Surface D6-167
D6-34 Brine Aquifer in the Nash Draw D6-168
D6-35 Measure Water Levels and Estimated Freshwater Heads of the Unnamed Lower Member and Rustler-Salado Contact Zone D6-169
D6-36 Location of Reservoirs and Gauging Stations in the Pecos River Basin D6-170
D6-37 Mariah Study Archaeological Sites D6-171
D6-38 Regional Earthquake Epicenters Occurring After 1961 . . . . . D6-172

APPENDIX D6
SITE CHARACTERIZATION

Introduction

This appendix describes the Waste Isolation Pilot Plant (WIPP) site in terms of its geology, hydrology, climatology, air quality, ecology, and cultural and natural resources. The purpose of this appendix is to provide information on the disposal system's natural characteristics that are relevant to the assessment of the WIPP site as a potential repository for transuranic (TRU) and TRU mixed waste and to establish the favorable characteristics of the site and background environmental quality. The U.S. Department of Energy (DOE) is developing the WIPP as a deep geologic repository for disposal of TRU waste from government defense installations across the country. In order for the DOE to formulate a reasonable expectation of site conditions far into the future, the site has been characterized in detail to provide basic data for a variety of geologic and hydrologic parameters. The DOE uses these parameters in computational models to predict the likelihood and possible consequences of various scenarios expected to apply to the WIPP site over a 10,000-year period

The DOE located the WIPP site 26 miles (mi) (41.8 kilometers [km]) east of Carlsbad, New Mexico, in Eddy County (Figure D6-1). The region surrounding the WIPP site has been under study for many years, and exploration of both potash and hydrocarbon deposits has provided extensive knowledge of the geology of the region. Two exploratory holes were drilled by the federal government during 1974 at a location northeast of the present site; that location was abandoned in 1975 as a possible repository site after a well, U.S. Energy Research and Development Administration (ERDA)-6, was drilled, and unacceptable structure and pressurized brine were encountered. The results of these investigations were reported by Powers et al. (1988, pp. 2-6). During late 1975 and early 1976, the ERDA identified the present site, and an initial exploratory hole (ERDA-9) was drilled. By the time an initial phase of site characterization was completed in August 1978, 47 holes had been drilled or were in progress for hydrologic and various geologic purposes. Since 1978, the DOE has drilled additional holes to support hydrologic programs, geologic programs, and facility design. Geophysical logs, cores, basic data reports, geochemical sampling and testing, and hydrological testing and analyses are reported by the DOE and its scientific advisor, Sandia National Laboratories (SNL), in numerous documents and are maintained in reference libraries that are available to the public, such as the Sandia WIPP Central File (in Albuquerque, New Mexico). Where necessary, specific references from these documents are cited to reinforce the statements being made. Additional sources of information on the various topics in this section are listed in a bibliography at the end of the chapter.

Biological studies of the site began in 1975 to gather information for the Environmental Impact Statement. Meteorological studies began in 1976, and economic studies were initiated during 1977. Baseline environmental data were initially reported in 1987 and are now updated annually by the DOE.

The DOE selected the WIPP disposal horizon to be located within a salt deposit known as the Salado Formation (hereafter referred to as the Salado) at a depth of 2,150 feet (ft) (650 meters [m]) below the ground surface. The present site was selected based on the following site selection criteria: the Salado is regionally extensive; includes continuous beds of salt without complicated structure; is deep enough for waste isolation, reducing the potential for dissolution of the rock salt by surface water or shallow groundwater; and is near enough to the surface to make access reasonable. Particular site-selection criteria narrowed the choices when the present site was located during 1975–76.

D6-1 Geology

Geological data have been collected from the WIPP site and surrounding area for use in evaluating the suitability of the site as a radioactive waste repository. These data have been collected principally by the DOE and its predecessor agencies, the United States Geological Survey (USGS), the New Mexico Bureau of Mines and Mineral Resources (NMBMMR), and private organizations engaged in natural resource exploration and extraction. The DOE has analyzed the data provided in the following discussion and believes the WIPP site is suitable for the long-term isolation of radioactive waste. Numerous questions have been raised and subsequently discussed, investigated, and resolved in order for the DOE to reach the conclusion that the site is suitable. The DOE discusses these questions in the following with emphasis on the resolution of the issues.

D6-1a Data Sources

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

Elements of the geology of southeastern New Mexico have been discussed or described in professional journals or technical documents from many different sources. These types of articles are an important source of information, and where there is no contrary evidence, the information in these articles is included through reference where subject material is relevant. Implicit rules of professional conduct of research and reporting are assumed to have been applied, and journal/editorial review has been applied as well. Certain elements of the geology

presented in such sources have been deemed critical to the WIPP and have been the subject of specific WIPP-sponsored studies.

Geological data have been developed by the DOE through a variety of WIPP-sponsored studies using drilling, mapping, or other direct observation; geophysical techniques; and laboratory work. Most of the techniques and statistics of data acquisition are incorporated by specific discussion. Boreholes are, however, a major source of geological data for the WIPP and surrounding area. From boreholes come raw data that provide the basis for point data and interpreted data sets. These data serve as the base for computing other useful elements such as structure maps for selected stratigraphic horizons or isopachs (thickness) of selected stratigraphic intervals.

The borehole data set in Sub-Appendix BH to this appendix is considered the usable reference information. Figure D6-2 provides a map of some borehole locations in the data set used in this chapter.

D6-1b Geologic History

This section summarizes the more important points of the geologic history within about a 200 mi (321.9 km) radius of the WIPP site, with emphasis on more recent or nearby events. Major elements of the geological history from the end of the Precambrian in the vicinity of the WIPP site were compiled in graphic form (Figure D6-3). The geologic time scale that the DOE uses for the WIPP is based on a compilation by Palmer (1983, pp. 503-504) for *The Decade of North American Geology* (DNAG). There are several compiled sources of chronologic data related to different reference sections or methods (see, for example, Harland et al. [1982] and Salvador [1985] in the bibliography). Although most of these sources show generally similar ages for chronostratigraphic boundaries, there is no consensus on either reference boundaries or most-representative ages. The DNAG scale is accepted by the DOE as a standard that is useful and sufficient for WIPP purposes, as no known critical parameters require more accurate or precise dates.

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

- A Precambrian period, represented by metamorphic and igneous rocks, ranging in age from about 1.5 to 1.0 billion years old
- A period principally of erosion from about 1.0 to 0.5 billion years ago, as there is no rock record from this time
- An interval from 0.5 billion years to the present; represented by a more complex deposition of mainly sedimentary rocks with shorter periods of erosion and dissolution.

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

Precambrian crystalline rocks have been penetrated in only a few deep boreholes in the vicinity of the WIPP, and therefore relatively little petrological information is available. Foster (1974, Fig. 3) extrapolated the elevation of the Precambrian surface under the area of the WIPP site as being between 14,500 ft (4.42 km) and 15,000 ft (4.57 km) below sea level; the site surface at the WIPP is about 3,400 ft (1,036 m) above sea level. Keesey (1977, Vol. I, Exhibit No. 2) projected a depth to the top of Precambrian rocks of 18,191 ft (5.55 km) based on the geology of a nearby borehole in Section 15, T22S, R31E.

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

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

D6-1c Stratigraphy and Lithology in the Vicinity of the WIPP Site

This section presents the stratigraphy and lithology of the Paleozoic and younger rocks underlying the WIPP site and vicinity (Figure D6-4), emphasizing the units nearer the surface. Details begin with the Permian (Guadalupian) Bell Canyon Formation (hereafter referred to as the Bell Canyon)—the upper unit of the Delaware Mountain Group—because this is the uppermost water-bearing formation below the evaporites. The principal stratigraphic data are the chronologic sequence, age, and extent of rock units, including some of the nearby relevant facies changes. Characteristics such as thickness and depth are summarized here from published sources for deeper rocks and are mainly based on data sets presented in Sub-Appendix BH for shallower rocks (above the Bell Canyon). The main lithologies for upper formations and members of some formations are described; some of the major stratigraphic divisions (e.g., Jurassic) are not described because they do not occur at or near the WIPP site.

D6-1c(1) General Stratigraphy and Lithology below the Bell Canyon Formation

As stated previously, the Precambrian basement near the site is projected to be about 18,200 ft (5,545 m) below the surface (Keesey, 1977 , Vol. II, Exhibit No. 2), consistent with information presented by Foster in 1974. Ages of similar rock suites in the region range from about 1.35 to 1.14 billion years.

The basal units overlying Precambrian rocks are clastic rocks commonly attributed either to the Bliss sandstone or the Ellenberger Group (Foster, 1974, p. 10*ff*), considered most likely to be Ordovician in age in this area. The Ordovician system comprises the Ellenberger, Simpson, and Montoya groups in the northern Delaware Basin. Carbonates are predominant in these groups, with sandstones and shales common in the Simpson group. Foster (1974, p. 12) reported 975 ft (297 m) of Ordovician north of the site area and extrapolated a thicker section of about 1,300 ft (396 m) at the present site (p. 17). Keesey (1977, Vol. II, Exhibit No. 2) projected a thickness of 1,200 ft (366 m) within the site boundaries.

Silurian-Devonian rocks in the Delaware Basin are not stratigraphically well defined, and there are various notions for extending nomenclature into the basin. Common drilling practice is not to differentiate, although the Upper Devonian Woodford shale at the top of the sequence is frequently distinguished from the underlying dolomite and limestone (Foster, 1974, p. 18). Foster (1974, p. 21) showed a reference thickness of 1,260 ft and 160 ft (384 m and 49 m) for the carbonates and the Woodford shale, respectively; he estimated thickness contours for the present WIPP site of about 1,150 ft (351 m) and 170 ft (52 m), respectively. Keesey (1977, Vol. II, Exhibit No. 2) projected 1,250 ft (381 m) of carbonate and showed 82 ft (25 m) of the Woodford shale.

The Mississippian system in the northern Delaware Basin is commonly attributed to "Mississippian limestone" and the overlying Barnett shale (Foster, 1974, p. 24), but the nomenclature is not well settled. At the reference well used by Foster (1974, p. 25), the limestone is 540 ft (165 m) thick and the shale is 80 ft (24 m) thick; isopachs at the WIPP are 480 ft (146 m) and less than 200 ft (61 m). Keesey (1977, Vol. II, Exhibit No. 2) indicates 511 ft (156 m) and 164 ft (50 m), respectively, within the site boundaries.

The nomenclature of the Pennsylvanian system applied within the Delaware Basin is both varied and commonly inconsistent with accepted stratigraphic rules. Chronostratigraphic, or time-stratigraphic, names are applied to these lithologic units: the Morrow, the Atoka, and the Strawn, from base to top (Foster, 1974, p. 31). Foster (1974, p. 34) extrapolated thicknesses of about 2,200 ft (671 m) for the Pennsylvanian at the WIPP site. Keesey (1977, Vol. II, Exhibit No. 2) reports 2,088 ft (636 m) for these units. The Pennsylvanian rocks in this area are mixed clastics and carbonates, with carbonates more abundant in the upper half of the sequence.

The Permian system in the northern Delaware Basin is the thickest system in the northern Delaware Basin, and it is divided into four series from the base to top: the Wolfcampian, the Leonardian, the Guadalupian, and the Ochoan. According to Keesey (1977, Vol. II, Exhibit No. 2), the three lower series total 8,684 ft (2,647 m) near the site. Foster (1974, p. 35*ff*) indicates a total thickness for the lower three series of 7,665 ft (2,336 m) from a reference well north of WIPP. Foster's 1974 isopach maps of these series indicate about 8,500 ft (2,591 m) for the WIPP site area. The Ochoan series at the top of the Permian is considered in more detail later, because the formations host and surround the WIPP repository horizon. Its thickness at DOE-2, about 2 mi (3.2 km) north of the site center, is 3,938 ft (1,200 m) according to Mercer et al. (1987, pp. 23-24).

The Wolfcampian series is also referred to as the Wolfcamp Formation (hereafter referred to as the Wolfcamp) in the Delaware Basin. In the site area, the lower part of the Wolfcamp is dominantly shale, with carbonate and some sandstone according to Foster (1974, p. 38); carbonate increases to the north. Clastics increase to the east toward the margin of the Central Basin Platform. Keesey (1977, Vol. II, Exhibit No. 2) reports the Wolfcamp to be 1,493 ft (455 m) thick at a well near the WIPP site. The Leonardian Series is represented by the Bone Spring Formation (hereafter referred to as the Bone Spring) (erroneously called the Bone Spring Limestone in many publications). According to Foster (1974, p. 39) the lower part of the formation is commonly interbedded carbonate, sandstone, and some shale, while the upper part is dominantly carbonate. Near the site, the Bone Spring is 3,247 ft (990 m) thick according to Keesey (1977, Vol. II, Exhibit No. 2).

The Guadalupian series is represented in the general area of the site by a number of formations exhibiting complex facies relationships (Figure D6-5). The Guadalupian series is known in considerable detail west of the site from outcrops in the Guadalupe Mountains, where numerous outcrops and subsurface studies have been undertaken. (See for example P. B. King [1948], Newell et al. [1953], and Dunham [1972] in the Bibliography.) According to Garber et al. (1989, p. 36), similar facies relationships are expected from the site to the north (Figure D6-5).

Within the Delaware Basin, the Guadalupian series comprises three formations: the Brushy Canyon, the Cherry Canyon, and the Bell Canyon, from base to top. These formations are dominated by submarine channel sandstones with interbedded limestone and some shale. A limestone (Lamar) generally tops the series, immediately underneath the Castile Formation (hereafter referred to as the Castile). Around the margin of the Delaware Basin, reefs developed during the same time the Cherry Canyon and the Bell Canyon were being deposited. These massive reef limestones, the Goat Seep and Capitan limestones, are equivalent in time to these basin sandstone formations but were developed much higher topographically around the basin margin. A complex set of limestone to sandstone and evaporite beds was deposited further away from the basin behind the reef limestones. The Capitan reef limestones are well known because the Carlsbad Caverns are partially developed in these rocks.

D6-1c(2) The Bell Canyon Formation

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

The Clayton Williams Badger Federal borehole near the WIPP site (Section 15, T22S, R31E) intercepted 961 ft (293 m) of the Bell Canyon, including the Lamar limestone, according to Keesey (1977, Vol. II, Exhibit No. 2). Reservoir sandstones of the Bell Canyon were deposited

in channels that are straight to slightly sinuous. Density currents flowed from shelf regions, cutting channels and depositing the sands that are identified in Harms and Williamson (1988, pp. 299-317).

Within the basin, the Bell Canyon (Lamar limestone)/Castile contact is distinctive on geophysical logs because of the contrast in low natural gamma of the basal Castile anhydrite compared to the underlying limestone. Density or acoustic logs are also distinctive because of the massive and uniform lithology of the anhydrite compared to the underlying beds. In cores, the transition is sharp, as described by Mercer et al. (1987, p. 312) for DOE-2.

D6-1c(3) The Castile Formation

The Castile is the lowermost lithostratigraphic unit of the Late Permian Ochoan series (Figure D6-6). It was originally named by Richardson for outcrops in Culberson County, Texas. The Castile crops out along a lengthy area along the western side of the Delaware Basin. The two distinctive lithologic sequences, now known as the Castile and the Salado, were separated into the upper and lower Castile by Cartwright in 1930. Lang, in 1939, clarified the nomenclature by restricting the Castile to the lower unit and naming the upper unit the Salado. By defining an anhydrite resting on the marginal Capitan limestone as part of the Salado, Lang, in 1939, effectively restricted the Castile to the Delaware Basin inside the ancient reef rocks.

Through detailed studies of the Castile, Anderson et al. (1972, pp. 59-86) introduced an informal system of names that are widely used and included in many WIPP reports. They named the units, beginning at the base, as anhydrite 1 (A1), halite 1 (H1), anhydrite 2 (A2), etc. The informal nomenclature varies throughout the basin upwards from A3 because of the complexity of the depositional system. The Castile consists almost entirely of thick beds of two lithologies: 1) interlaminated carbonate and anhydrite, and 2) high-purity halite. The interlaminated carbonate and anhydrite are well known as possible examples of annual layering or varves.

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

For borehole DOE-2, a primary objective was to ascertain whether a series of depressions in the Salado, 2 mi (3.3 km) north of the site, was due to dissolution in the Castile as proposed by Davies in his doctoral thesis in 1984. Studies have suggested that these depressions were not due to dissolution but to halokinesis in the Castile (for example, see Borns [1987] and Chaturvedi [1987] in the Bibliography). Robinson and Powers (1987, pp. 69-79) analyzed one such unit as partly due to synsedimentary, gravity-driven clastic deposition and suggested that the extent of

dissolution may be overestimated. No Castile dissolution is known to be present in the immediate vicinity of the WIPP site. The process of dissolution and the resulting features are further discussed later in this appendix.

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

In a portion of the area around the WIPP, the Castile has been significantly deformed, and there are pressurized brines associated with the deformed areas; borehole ERDA-6 encountered both. WIPP-12, 1 mi (1.6 km) north of the WIPP site , revealed lesser Castile structure, but it also encountered a zone of pressurized brine within the Castile. The Castile deformation is described and discussed later in Section 1.1.5 (structural features), and pressurized brines are described in Section 1.2, which details the area's hydrology.

The Castile continues to be an object of research interest unrelated to the WIPP program as an example of evaporites supposedly deposited in "deep water." Anderson (1993, pp. 12-13) discusses alternatives and contradictory evidence. Similar discussions may eventually affect concepts of the Castile deposition and dissolution; however, this issue is largely of academic interest and bears no impact on the suitability of the Los Medaños region for the WIPP site.

D6-1c(4) <u>The Salado Formation</u>

The Salado is dominated by halite, in contrast to the underlying Castile, and extends well beyond the Delaware Basin. Lowenstein (1988, pp. 592-608) has termed the Salado a "saline giant." The Fletcher Anhydrite Member, which is deposited on the Capitan reef rocks, is defined by Lang (1939, pp. 1569-1572; 1942, pp. 63-79) as the base of the Salado. Some investigators believe the Fletcher Anhydrite Member may interfinger with anhydrites normally considered part of the Castile. The Castile/Salado contact is not uniform across the basin, and whether it is conformable is still under consideration. Around the WIPP site, the Castile/Salado contact is commonly placed at the top of a thick anhydrite informally designated as A3; the overlying halite is called the infra-Cowden salt and is included within the Salado. Bodine (1978, pp. 28-29) suggests that the clay mineralogy of the infra-Cowden in ERDA-9 cores changes at about 15 ft (4.6 m) above the lowermost Salado and that the lowermost clays are more like the Castile clays. The top of the thick anhydrite remains the local contact for differentiating the Salado from the Castile, and there is no known significance to the WIPP from these differences.

The Salado in the northern Delaware Basin is broadly divided into three informal members. (Figure D6-7 details the Salado's stratigraphy.) The middle member is known locally as the McNutt potash zone, and it includes 11 defined potash zones, 10 of which are of economic significance in the Carlsbad Potash District. The lower and upper members remain unnamed. The WIPP repository level is located below the McNutt Potash Zone in the lower member.

Within the Delaware Basin, a system is used for numbering the more significant sulfate beds in the Salado, from Marker Bed 100 (near the top of the formation) to Marker Bed 144 (near the base). The system is generally used within the Carlsbad Potash District as well as the WIPP site. The facility horizon is located between Marker Bed 139 and Marker Bed 138.

In the central and eastern part of the Delaware Basin, the Salado is at its thickest, ranging up to about 2,000 ft (about 600 m) thick and consisting mainly of interbeds of sulfate minerals and halite, with halite dominating. The thinnest portions of the Salado consist of a brecciated residue of insoluble material a few tens of feet thick that are exposed at the surface in parts of the western Delaware Basin. The common sulfate minerals are anhydrite ($CaSO_4$), gypsum ($CaSO_4 \cdot 2H_2O$) near the surface, and polyhalite ($K_2SO_4 \cdot MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$). The sulfate minerals form beds and are also found along boundaries between halite crystals.

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

From detailed mapping of the Salado in the Air Intake Shaft at WIPP, Holt and Powers (1990, pp. 45-72) constructed a more detailed sedimentological analysis of the Salado depositional cycles, similar to the Type I cycle defined by Lowenstein in 1988. The details available from the shaft demonstrated the important role of syndepositional water level to water-table changes that created solution pits and pipes within the halitic beds while they were forming at the surface. Holt and Powers (1990, App. F, pp. 3-26) concluded that passive halite cements filled the pits and pipes, as well as less dramatic voids, as the water table rose. Early diagenetic to synsedimentary cements filled the porosity early, reducing the porosity to a very small volume according to Casas and Lowenstein in 1989. These void-filling halites are commonly clear and coarsely crystalline and might be mistaken for recrystallization textures. Although Holt and Powers did not find this in their 1988 study, other investigators have found much evidence for halite recrystallization (or halite diagenesis) in the Salado.

The effects of water-rock interactions resulting in evaporite dissolution in the Salado are observable near the surface in the Nash Draw and other localities where gypsum karst is developed and where overlying units, such as the Rustler, the Dewey Lake, and the post-Permian rocks, have subsided. Physical evidence of water-rock interaction (e.g., post-depositional accumulation of insoluble residues, brecciation from differential collapse, and mass

removal) in the Salado is less apparent, especially where it is buried at depths greater than 984 ft (300 m). However, given the susceptibility of evaporite minerals to dissolution by circulating groundwater, geochronological investigations provide a means of determining the approximation time of the latest episode of regional recrystallization of the evaporite minerals, which can be inferred as the approximate time of the latest episode of freely circulating groundwater. Radiometric dates for minerals of the Salado are available from several sources (Register and Brookins, 1980, pp. 29-31; Brookins, 1980, pp. 29-31; Brookins et al., 1980, pp. 635-637; Brookins 1981, pp. 147-152; Brookins and Lambert, 1987, pp. 147-152). The distribution of dates shows that rubidium-strontium (Rb-Sr) isochron determinations on evaporite minerals, largely sylvite (179-229 million years ago [Ma]), are in good agreement with potassium-argon (K-Ar) determinations on pure polyhalites (195-216 Ma).

The only recrystallization event found younger than Early Jurassic (200 Ma) was known to be a contact phenomenon associated with emplacement of an Oligocene lamprophyre dike (21 Ma for polyhalite versus 32-34 Ma for the dike; see Calzia and Hiss, 1978, pp. 39-45). Clay minerals have both Rb-Sr isochron and K-Ar ages significantly older (390 $\pm$ 77 Ma) than the evaporites.

It has been known that sylvite yields significantly younger K-Ar ages than Rb-Sr ages. This has been explained as loss of radiogenic Ar. Radiogenic Sr, as a solid, and dating by the Rb-Sr isochron method is not considered as likely to give spurious results, especially if the isochron is well defined. The results of radiometric determinations argue for the absence of pervasive recrystallization of the evaporites in the Salado in the last 200 Ma. The number of replicate determinations, the wide distribution of dated minerals throughout the Delaware Basin, and the concordance of dates obtained by various radiometric methods all indicate that this conclusion is supportable based on generally accepted interpretations.

Argillaceous halites and halitic mudstone at the top of many depositional cycles were interpreted by Holt and Powers (1990, pp. 45-78) in terms of modern features, such as those at the Devil's Golf Course at Death Valley National Monument, California. The evaporative basin was desiccated, and varying amounts of insoluble residues collected on the surface through surficial dissolution, eolian sedimentation, and some clastic sedimentation from temporary flooding caused by runoff from surrounding areas. The surface developed local relief that could be mapped in some cycles, while the action of continuing desiccation and exposure increasingly concentrated insoluble residues. Flooding, most commonly from marine sources, reset the sedimentary cycle by depositing a sulfate bed.

Within the Nash Draw, Robinson and Lang (1938, pp. 2-64 to 2-67) recognized a zone equivalent to the upper Salado but lacking halite. Test wells in the southern Nash Draw produced brine from this interval, and it has become known as the brine aquifer. Robinson and Lang in 1938 considered this zone a residuum from dissolution of Salado halite. Jones et al. (1960, p. 25) remarked that the residuum should be considered part of the Salado, though geophysical log signatures may resemble the lower Rustler.

At the center of the site, Holt and Powers in their 1984 report recognized clasts of fossil fragments and mapped channeling in siltstones and mudstones above halite; they considered these beds to be a normal part of the transition from shallow evaporative lagoons and desiccated salt pans of the Salado to the saline lagoon of the lower Rustler. Although the Salado salt may have been dissolved prior to deposition of the Rustler clastics, the process is detached from the concept of subsurface removal of salt from the Salado in more recent time to develop a residuum and associated "brine aquifer."

Based on the Salado isopachs, thickness begins to change significantly near Livingston Ridge, the eastern margin of the Nash Draw. That should be the approximate eastward limit to the residuum and "brine aquifer," although the normal sedimentary sequence may yield limited fluids east of this margin.

The DOE believes the Salado is of primary importance to the containment of waste. As the principal natural barrier, many of the properties of the Salado have been characterized, and numerical codes were developed to simulate the natural processes within the Salado that affect the disposal system performance.

D6-1c(5) Rustler Formation

The Rustler Formation (hereafter referred to as the Rustler) is the youngest evaporite-bearing formation in the Delaware Basin. It was originally named by Richardson for outcrops in the Rustler Hills of Culberson County, Texas. Adams (1944, p. 1614) first used the names "Culebra member" and "Magenta member" to describe the two carbonates in the formation, indicating that W. B. Lang favored the names, although Lang did not use these names in his most recent publication. Vine in his 1963 work described extensively the Rustler in the Nash Draw and proposed the four formal names and one informal term for the stratigraphic subdivisions still used for the Rustler (from the base): the unnamed lower member, the Culebra member, the Tamarisk member, the Magenta member, and the Forty-niner member (Figure D6-8). (The Culebra member, the Tamarisk member, the Magenta member, and the Forty-niner member are hereafter referred to as the Culebra, the Tamarisk, the Magenta, and the Forty-niner.) Although some investigators suggest that the unnamed lower member might be referred to as the Los Medaños member, the nomenclature has not been formalized.

An additional system of informal subdivisions was contributed by Holt and Powers (1988, Fig. 3.2), based on more detailed lithologic units of the noncarbonate members (Figure D6-8). These subdivisions have partially been related to hydrostratigraphic units for the Rustler.

Two studies of the Rustler since Vine's 1963 work contribute important information about the stratigraphy, sedimentology, and regional relationships while examining more local details as well. Eager (1983, pp. 273-283) reported on relationships of the Rustler observed in the southern Delaware Basin as part of sulfur exploration in the area. Holt and Powers (1988, Chapter 5.0) reported the details of sedimentologic and stratigraphic studies of WIPP shafts and cores as well as of geophysical logs from about 600 boreholes in southeastern New Mexico.

The Rustler is regionally extensive (a similar unit in the Texas panhandle is also called the Rustler). Within the area around the WIPP site, evaporite units of the Rustler are interbedded with significant siliciclastic beds and carbonates. Both the Magenta and the Culebra extend regionally beyond areas of direct interest to the WIPP. In the general area of the WIPP, both the Tamarisk and the Forty-niner have similar lithologies: lower and upper sulfate beds and a middle unit that varies principally from mudstone to halite from west to east (Figure D6-8).

In a general sense, halite in the unnamed lower member broadly persists to the west of the WIPP site, and halite is found east of the center of the WIPP in the Tamarisk and the Forty-niner (Figure D6-9). (Additional detail on the lithologies of these members follow.) Two differing depositional models have been generally used, either implicitly or explicitly, to account for the halite distribution. A longstanding and implicit model in many earlier documents is that halite was originally deposited relatively uniformly in the noncarbonate members across southeastern New Mexico, including the WIPP site area. The modern distribution is caused by dissolution of the Rustler halite to the west and progressing toward the east. As shown by Holt and Powers (1988), sedimentary features and textures within WIPP shafts and cores that led them to propose an explicit model of depositional facies for the mudstone-halite units; halite was dissolved syndepositionally from mud-flat facies, especially to the west, and was redeposited in a halite pan to the east. The Culebra transmissivity shows about six orders of magnitude variation across the area around the site, and the changes have commonly been attributed to post-depositional dissolution of the Rustler halite.

In the region around the WIPP, the Rustler reaches a maximum thickness of more than 500 ft (152 m) (Figure D6-10), while it is about 300 to 350 ft (91 to 107 m) thick within most of the WIPP site. Much of the difference in the Rustler thickness can be attributed to variations in the amount of halite contained in the formation from place to place. The Tamarisk accounts for a larger part of thickness changes than do either the unnamed lower member or the Forty-niner. Much project-specific information about the Rustler is contained in Holt and Powers (1988). The WIPP shafts were a crucial element in their study, exposing features not previously reported. Cores were available from several WIPP boreholes, and their lithologies were matched to geophysical log signatures to extend the interpretation throughout a larger area in southeastern New Mexico.

D6-1c(5)(a) <u>The Unnamed Lower Member</u>

The unnamed lower member rests on the Salado with apparent conformity at the WIPP site. It consists of significant proportions of bedded and burrowed siliciclastic sedimentary rocks with cross bedding and fossil remains. These beds record the transition from strongly evaporative environments of the Salado to saline lagoonal environments. The upper part of the unnamed lower member includes halitic and sulfitic beds within clastics. Holt and Powers (1988, p. 9-1*ff*) interpret these as facies changes within a saline playa environment. The implied model from earlier descriptions is that the nonhalitic areas of the upper unnamed lower member are dissolution residues from post-depositional dissolution.

As shown in Holt and Powers (1988, Fig. 4.7), the unnamed lower member ranges in thickness from about 96 to 126 ft (29 to 38 m) within the site boundaries. The maximum thickness recorded during that study was 208 ft (63 m) southeast of the WIPP site. Halite extends west of most of the site area in this unit (see Figure D6-9 for an illustration of the halite margins). Cross sections based on geophysical log interpretations in Holt and Powers (1988) show the relationship between the thickness of the unit and the presence of halite.

D6-1c(5)(b) The Culebra Member

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

The Culebra was described by Robinson and Lang in 1938 as a dolomite 35 ft (11 m) in thickness; Adams (1944, p. 78) noted that oölites are present in some outcrops as well. The Culebra is generally brown, finely crystalline, locally argillaceous and arenaceous dolomite, with rare to abundant vugs with variable gypsum and anhydrite filling. Holt and Powers (1988) describe the Culebra features in detail, noting that most of the Culebra is microlaminated to thinly laminated, while some zones display no depositional fabric. Holt and Powers (1984) described an upper interval of the Culebra consisting of waxy, golden-brown carbonate, dark organic claystone, and some coarser siltstone of probable algal origin. Because of the unique organic composition of this thin layer, Holt and Powers (1984) did not include it in the Culebra for thickness computations, and this will be factored into discussions of Culebra thickness. Based on core descriptions from the WIPP Project, Holt and Powers (1988, p. 5-11) concluded that there is very little variation of depositional sedimentary features throughout the Culebra.

Vugs are an important part of Culebra porosity (additional discussion on Culebra hydrologic characteristics is given in Section D6-2a[5]). They are commonly zoned parallel to bedding. In outcrop, vugs are commonly empty. In the subsurface, vugs may be filled with anhydrite or gypsum, or they may have some clay lining. Lowenstein (1988, pp. 20-21) noted similar features. Holt and Powers (1988) attribute vugs partly to syndepositional growth as nodules and partly, later, as replacive textures. Lowenstein (1988, pp. 592-608) also described textures related to later replacement and alteration of sulfates. Vugs or pore fillings vary across the WIPP site and contribute to the porosity structure of the Culebra. Natural fractures filled with gypsum are common east of the WIPP site center and in a smaller area west of the site center (Figure D6-11).

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

In the WIPP site area, the Culebra varies in thickness. Different data sources provide varying estimates (Table D6-1). Holt and Powers (1988, pp. 4-7) considered the organic-rich layer at the Culebra/Tamarisk contact separately from the Culebra in interpreting geophysical logs.

Comparing data sets, Holt and Powers (1988) typically interpret the Culebra as being about 3 ft (about 1 m) thinner than have other sources. In general, this reflects the difference between including or excluding the unit at the Culebra/Tamarisk contact. Each data set shows areal differences in thickness of the Culebra when it is examined township by township.

LaVenue et al. (1988) calculated a mean thickness of 25 ft (7.7 m) for the Culebra based on 78 boreholes. This mean thickness has been used uniformly for the Culebra in PA calculations. Many of the boreholes represented multiple drilling location (points) at individual hydrology drill pads H-2 through H-11. The multiple points at each drillhead normally would be considered a single location for statistical purposes. If each data point is considered to be distinct, the implication is that thickness varies significantly over the distances between these closely spaced boreholes, and it may not be consistent for calculations to use averaging thickness as a parameter. Mercer (1983, Table 1) reported a data set similar to LaVenue et al. (1988), but without statistics.

The borehole database in Sub-Appendix BH makes it possible to defend choices of the Culebra thicknesses for the area being modeled. If repository performance is insensitive to Culebra thickness, defining the specific thickness of the Culebra is not important.

D6-1c(5)(c) <u>The Tamarisk Member</u>

Vine (1963, p. B15) named the Tamarisk for outcrops near Tamarisk Flat in the Nash Draw. Outcrops of the Tamarisk are distorted, and subsurface information was used to establish member characteristics. Vine reported two sulfate units separated by a siltstone, about 5 ft (1.5 m) thick, interpreted by Jones et al. (1960) as a dissolution residue.

The Tamarisk is generally conformable with the underlying Culebra. The transition is marked by an organic-rich unit interpreted as being present over most of southeastern New Mexico. The Tamarisk around the site area consists of lower and upper sulfate units separated by a unit that varies from mudstone (generally to the west) to mainly halite (to the east). Near the center of the WIPP site, the lower anhydrite was partially eroded during deposition of the middle mudstone unit, as observed by in the WIPP Waste Shaft and the WIPP Exhaust Shaft. The lower anhydrite was completely eroded at WIPP-19. Before shaft exposures were available, the lack of the lower Tamarisk anhydrite at WIPP-19 was interpreted as the result of solution, and the mudstone was considered a cave filling.

Jones et al. (1960) interpreted halite to be present east of the center of the WIPP site based on geophysical logs and drill cuttings. Based mainly on cores and cuttings records from the WIPP potash drilling program, Snyder prepared a map in 1985 showing the halitic areas of each of the noncarbonate Rustler members. A very similar map based on geophysical log characteristics was prepared independently by Powers in 1984 (see Figure D6-9).

Holt and Powers (1988) describe the mudstones and halitic facies in the middle of the Tamarisk, and they interpreted the unit as formed in a salt pan to mud-flat system. They cited sedimentary features and the lateral relationships as evidence of syndepositional dissolution of halite in the marginal mud-flat areas. In contrast, other investigators interpreted the lateral decrease in thickness and absence of halite to the west as evidence of post-depositional dissolution (see for example Jones et al. [1960], Jones [1978], and Snyder [1985] in the bibliography). The differing concepts for halite distribution in the Rustler, and particularly the Tamarisk, have been used in explaining the large changes in hydrologic properties of the Culebra, as described in later sections.

The Tamarisk thickness varies greatly in southeastern New Mexico, principally as a function of the thickness of halite in the middle unit. Within T22S, R31E, Holt and Powers (1988) show a range from 84 to 184 ft (26 to 56 m) for the entire Tamarisk and a range from 6 to 110 ft (2 to 34 m) for the interval of mudstone-halite between lower and upper anhydrites. Expanded geophysical logs with corresponding lithology illustrate some of the lateral relationships for this interval (Figure D6-12).

D6-1c(5)(d) <u>The Magenta Member</u>

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

Holt and Powers (1988, p. 5-22) reported that the Magenta varies from 23 to 28 ft (7.0 to 8.5 m); they did not contour the thickness because of limited changes.

D6-1c(5)(e) <u>The Forty-niner Member</u>

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

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

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

D6-1c(6) <u>The Dewey Lake</u>

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

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

The Dewey Lake overlies the Rustler conformably though local examples of the contact (e.g., the Air Intake Shaft described by Holt and Powers [1990]) show minor disruption by dissolution of some of the upper Rustler sulfate). The formation is predominantly reddish-brown fine sandstone to siltstone or silty claystone with greenish-gray reduction spots. Thin bedding, ripple cross-bedding, and larger channeling are common features in outcrops, and additional soft sediment deformation features and early fracturing are described from the lower part of the formation by Holt and Powers (1990). Schiel (1988; 1994, p. 5-13) attributed the Dewey Lake to deposition on "a large, arid fluvial plain subject to ephemeral flood events."

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

Near the center of the WIPP site, Holt and Powers (1990, Fig. 5) mapped 498 ft (152 m) of the Dewey Lake (Figure D6-13). The formation is thicker to the east (Schiel, 1994, p. 6) of the WIPP site, in part because western areas were eroded before the overlying Triassic rocks were deposited.

The Dewey Lake is extensively fractured, and both cements and fracture fillings have been further examined to ascertain the possible contributions of surface infiltration to underlying units. Holt and Powers (1990, p. 3-8*ff*) described the Dewey Lake as cemented by carbonate above 164.5 ft (50 m) in the Air Intake Shaft; some fractures in the lower part of this interval were also filled with carbonate, and the entire interval surface was commonly moist. Below this point, the cement is harder (probably anhydrite), the shaft is dry, and fractures are filled with gypsum. Holt and Powers (1990, pp. 3-11, Fig. 16) suggested the cement change might be related to infiltration of meteoric water. They also determined that some of the gypsum-filled fractures are syndepositional. The Dewey Lake fractures include horizontal to subvertical trends, some of which were mapped in detail (Holt and Powers, 1986, Figs. 6–8).

Lambert (1991, pp. 5-65) analyzed the deuterium/hydrogen (D/H) ratios of gypsum from all of the various members of the Rustler and gypsum veins in the Dewey Lake and suggests that none of the gypsum formed from evaporitic fluid, such as Permian seawater. Rather, they last recrystallized in the presence of meteoric water. Several samples were collected from localities known or proposed as evaporitic karst features. Lambert (1991, pp. 5-66) infers that the gypsum D/H is not consistent with modern meteoric water, but it may be consistent with earlier meteoric fluids (Pleistocene or older) isotopically resembling Rustler meteoric water. There is no obvious correlation with depth indicating infiltration of modern surface-derived groundwaters or precipitation. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) indicate no intermixing or homogenization of fluids between the various Rustler members and between the Rustler and the Dewey Lake, but there may be lateral movement of water within the Dewey Lake. The Dewey Lake carbonate vein material shows a broader range of strontium ratios than does surface caliche, and the ratios barely overlap. Lambert (1987) concluded, based on isotopic data, that confined Rustler groundwaters have a minimal meteoric component, and have been isolated from the atmosphere for at least 12,000 to 16,000 years. These data also suggest that the present day Rustler hydrologic system is transient rather than at steady state.

D6-1c(7) The Santa Rosa

There have been different approaches to the nomenclature of rocks of the Triassic age in southeastern New Mexico. Bachman generally described the units in 1974 as "Triassic, undivided" or as the Dockum Group. Vine in 1963 used the term "Santa Rosa Sandstone." "The Santa Rosa" has become common usage. Lucas and Anderson in 1993 imported other formation names that are unlikely to be useful for WIPP.

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

Within the WIPP site boundary, the Santa Rosa is relatively thin to absent (Figure D6-14). At the Air Intake Shaft, Holt and Powers (1990, Fig. 5) attributed about 2 ft (0.6 m) of rock to the

Santa Rosa. The Santa Rosa is a maximum of 255 ft (78 m) thick in potash holes drilled for WIPP east of the site boundary. The Santa Rosa is thicker to the east.

D6-1c(8) The Gatuña Formation

Lang in 1938 named the Gatuña for outcrops in the vicinity of the Gatuña Canyon in the Clayton Basin. Rocks now attributed to the Gatuña in Pierce Canyon were once included in the "Pierce Canyon Formation," along with rocks now assigned to the Dewey Lake. The formation has been mapped from the Santa Rosa, New Mexico, area south to the vicinity of Pecos, Texas. It unconformably overlies different substrates.

Vine in 1963 and Bachman in 1974 provided some limited description of the Gatuña. The DOE's most comprehensive study of the Gatuña is based on WIPP investigations and landfill studies for Carlsbad and Eddy County. Much of the formation is colored light reddish-brown. It is broadly similar to the Dewey Lake and the Santa Rosa, though the older units have more intense hues. The formation is highly variable, ranging from coarse conglomerates to claystones with some highly gypsiferous sections. Sedimentary structures are abundant. Analysis of lithofacies indicates that the formation is dominantly fluvial in origin with areas of low-energy deposits and evaporitic minerals. It was deposited in part over areas actively subsiding in response to dissolution.

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

The Gatuña has been considered to be Pleistocene in age based on a volcanic glass in the upper Gatuña that has been identified as the Lava Creek B ash dated at 0.6 million years by Izett and Wilcox (1982). An additional volcanic ash from the Gatuña in Texas yields consistent K-Ar and geochemical data, indicating it is about 13 million years (Powers and Holt 1993, p. 272). Thus the Gatuña ranges in age over a period of time that may be greater than the Ogallala Formation (hereafter referred to as the Ogallala) on the High Plains east of the WIPP.

D6-1c(9) The Mescalero Caliche

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

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

The Mescalero overlies the Gatuña and was interpreted by Bachman on basic stratigraphic grounds as having accumulated during the early-to-middle Pleistocene. Samples of the Mescalero from the vicinity of the WIPP were studied using uranium-trend methods. Based on early written communication from Rosholt, Bachman (1985, 20) reports that the basal Mescalero began to form about 510,000 years ago and the upper part began to form about 410,000 years ago; these ages are commonly cited in WIPP literature. The samples are interpreted by Rosholt and McKinney (1980, Table 5) in the formal report as indicating ages of 570,000 ± 110,000 years for the lower part of the Mescalero and 420,000 ± 60,000 years for the upper part.

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

D6-1c(10) Surficial Sediments

Soils of the region have developed mainly from Quaternary and Permian parent material. Parent material from the Quaternary system is represented by alluvial deposits of major streams, dune sand, and other surface deposits. These are mostly loamy and sandy sediments containing some coarse fragments. Parent material from the Permian system is represented by limestone, dolomite, and gypsum bedrock. Soils of the region have developed in a semiarid, continental climate with abundant sunshine, low relative humidity, erratic and low rainfall, and a wide variation in daily and seasonal temperatures. Subsoil colors normally are light brown to reddish brown but are often mixed with lime accumulations (caliche) that result from limited, erratic rainfall and insufficient leaching. A soil association is a landscape with a distinctive pattern of soil types (series). It normally consists of one or more major soils and at least one minor soil. There are three soil associations within 5 mi (8.3 km) of the WIPP site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. Of these three associations, only the Kermit-Berino have been mapped across the WIPP site (by Chugg et al. [1952, Sheet No. 113]). These are sandy soils developed on eolian material. The Kermit-Berino include active dune areas. The Berino soil has a sandy A horizon; the B horizons include more argillaceous material and weak to moderate soil structures. A and B horizons are described as noncalcareous, and the underlying C horizon is commonly caliche. Bachman in 1980 interpreted the Berino soil as a paleosol that is a remnant B horizon of the underlying Mescalero.

Generally, the Berino which covers about 50 percent of the site, consists of deep, noncalcareous, yellow-red to red sandy soils that developed in wind-worked material of mixed origin. These soils are described as undulating to hummocky and gently sloping (ranging from 0 to 3 percent slopes). The soils are the most extensive of the deep, sandy soils in the Eddy County area. The Berino is subject to continuing wind and water erosion. If the vegetative cover is seriously

depleted, the water-erosion potential is slight, but the wind-erosion potential is very high. These soils are particularly sensitive to wind erosion in the months of March, April, and May, when rainfall is minimal and winds are highest.

The Kermit consists of deep, light-colored, noncalcareous, excessively drained loose sands, typically yellowish-red fine sand. The surface is undulating to billowy (from 0 to 3 percent slopes) and consists mostly of stabilized sand dunes. The Kermit is slightly to moderately eroded. Permeability is very high, and if vegetative cover is removed, the water-erosion potential is slight, but the wind-erosion potential is very high. In 1980, Rosholt and McKinney applied uranium-trend methods to samples of the Berino from the WIPP site area. They interpreted the age of formation of the Berino as 330,000 ± 75,000 years.

D6-1d Physiography and Geomorphology

In this section, the DOE presents a discussion of the physiography and geomorphology of the WIPP site and surrounding area.

D6-1d(1) Regional Physiography and Geomorphology

The WIPP site is in the Pecos Valley section of the southern Great Plains physiographic province (Figure D6-15), a broad highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range Province to the Central Lowlands Province. The Pecos Valley section itself is dominated by the Pecos River Valley, a long north-south trough that is from 5 to 30 mi (8.3 to 50 km) wide and as much as 1,000 ft (305 m) deep in the north. The Pecos River system has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched some time after the middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent because of the semiarid climate. The surface locally has a karst terrain containing superficial sinkholes, dolines, and solution-subsidence troughs from both surface erosion and subsurface dissolution. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying Upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, including such erosional features as scarps, cuestas, terraces, and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations range from more than 6,000 ft (1,829 m) in the northwest to about 2,000 ft (610 m) in the south.

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

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

D6-1d(2) Site Physiography and Geomorphology

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest and is hummocky with sand ridges and dunes. A hard caliche layer (Mescalero caliche) is typically present beneath the sand blanket and on the surface of the underlying Pleistocene Gatuña. Figure D6-16 is a topographic map of the area. Elevations at the site range from 3,570 ft (1,088 m) in the east to 3,250 ft (990 m) in the west. The average east-to-west slope is 50 ft per mi (9.4 m per km).

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

About 18 mi (24 km) east of the site is the southeast-trending San Simon Swale, a depression due, at least in part, to subsurface dissolution (Figure D6-1). Between San Simon Swale and the site is a broad, low mesa named "the Divide." Lying about 6 mi (9.7 km) east of the site and about 100 ft (30 m) above the surrounding terrain, the Divide is a boundary between southwestern drainage toward the Nash Draw and southeastern drainage toward the San Simon Swale. The Divide is capped by the Ogallala and the overlying caliche, upon which have formed small, elongated depressions similar to those in the adjacent High Plains section to the east.

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

Dissolution-caused subsidence in the Nash Draw and elsewhere in the Delaware Basin has caused a search for geomorphic indications of subsidence near the site. One feature that has attracted some attention is a very shallow sink about 2 mi (3 km) north of the center of the site. It is very subdued, about 1,000 ft (305 m) in diameter, and about 30 ft (9 m) deep. Resistivity studies indicate a very shallow surficial fill within this sink and no disturbance of underlying beds, implying a surface, rather than subsurface, origin. Resistivity surveys in the site area showed an anomaly in Section 17 within the WIPP site boundary. It resembles the pattern over a known

sink, a so-called breccia pipe, but drilling showed a normal subsurface structure without breccia, and the geophysical anomaly is assumed to be caused by low-resistivity rock in the Dewey Lake.

D6-1e Tectonic Setting and Site Structural Features

The processes and features included in this section are those more traditionally considered part of tectonics, broad-scale processes that develop the features of the earth. Salt dissolution is a different process that can develop some features resembling those of tectonics.

Broad-scale structural elements of the area around the WIPP developed over geological time, and most formed during the late Paleozoic. There is little historical or recent geological evidence of significant tectonic activity in the vicinity. More recently, the entire region has tilted, and activity related to Basin and Range tectonics formed major structures southwest of the area. Seismic activity is specifically addressed in Section D6-4.

Broad subsidence began in the area as early as the Ordovician, developing a sag called the Tabosa Basin. By late Pennsylvanian to early Permian time, the Central Basin Platform developed (Figure D6-17), separating the Tabosa Basin into two parts: the Delaware Basin to the west and the Midland Basin to the east. The Permian Basin refers to the collective set of depositional basins in the area during the Permian period. Southwest of the Delaware Basin, the Diablo Platform began developing either late in the Pennsylvanian or early Permian. The Marathon Uplift and Ouachita tectonic belt limited the southern extent of the Delaware Basin. Most of these broader scale features surrounding the Delaware Basin formed during the late Paleozoic and have remained relatively constant in their relationships since.

D6-1e(1) Basin Tilting

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

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

D6-1e(2) Faulting

Fault zones are well known along the Central Basin Platform, east of the WIPP, from extensive drilling for oil and gas as reported by Hills (1984, pp. 250-267). Holt and Powers performed a

more recent analysis in 1988 of geophysical logs to examine regional geology for the Rustler that showed these faults displaced, at least, the Rustler rocks of late Permian age. The overlying Dewey Lake shows marked thinning along the same trend as the fault line or zone according to Schiel (1988, Fig. 21), but the structure contours of the top of the Dewey Lake are not clearly offset. Schiel (1988) concluded that the fault was probably reactivated during Dewey Lake deposition, but movement ceased at least by the time the Santa Rosa was deposited. No surface displacement or fault has been reported along this trend, indicating movement has not been significant enough to rupture the overlying materials since Permian time.

Within the Delaware Basin, there are few examples of faults that may offset part of the evaporite section. At the northern end of the WIPP site, Snyder in Borns et al. (1983, p. 17*ff*) drew structure contours on the top of the basal A1 of the Castile for boreholes WIPP-11, WIPP-12, and WIPP-13. Northeast-southwest-trending faults were interpreted to displace this unit both north and south of WIPP-11 (Borns et al., 1983). Snyder inferred that the Bell Canyon/Castile contact is also faulted and displaced along the same trend. Barrows in Borns et al. (1983, pp. 58-60) interpreted seismic reflection data to indicate, with varying confidence, faults within Castile rocks but not in underlying units.

The faults interpreted by Snyder (Borns et al., 1983) around WIPP-11 depend on the correct identification of the basal Castile anhydrite (A1) in that borehole. The evaporite structure is complex, and some of the upper units of the Castile and the lower Salado differ from surrounding boreholes. The diagnostic Castile/Bell Canyon contact was not reached by this borehole, and the faults inferred for the Castile/Bell Canyon contact also depend on correct identification of A1 and projection of A1 thickness by Snyder (Borns et al., 1983). Inferred connections with the underlying Bell Canyon or deeper units could signify circulation of fluids to the evaporite section within the site boundaries. This is unlikely, given the Castile geology within boreholes WIPP-13 and DOE-2 near the trend of the inferred fault. The structure contour maps by Snyder were based on data obtained from WIPP-II, however, when WIPP-13 and DOE-2 were drilled much later, the projected trends by Snyder were not valid. WIPP-13 and DOE-2 did not show evidence of complex structure in the upper limits of the Castile and lower Salado. Drilling for hydrocarbon exploration has been extensive around the northern and western boundaries of the site since the mid-1980s.

Muehlberger et al. (1978, pp. 337-340) have mapped quaternary fault scarps along the Salt Basin graben west of both the Guadalupe and the Delaware Mountains. These are the nearest known Quaternary faults of tectonic origin to the WIPP. Kelley in 1971 inferred the Carlsbad and Barrera faults along the eastern escarpment of the Guadalupe Mountains based mainly on vegetative linaments. Hayes and Bachman reexamined the field evidence for these faults in 1979 and concluded that they were nonexistent.

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

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

In summary, there are no known Quaternary or Holocene faults of tectonic origin offsetting rocks at the surface nearer to the site than the western escarpment of the Guadalupe Mountains. A significant part of the tilt of basin rocks is attributed to a mid-Miocene to Pliocene uplift along the Guadalupe/Sacramento mountains trend that is inferred on the basis of High Plains sediments of the Ogallala. Seismic activity is low and is commonly associated with secondary oil recovery along the Central Basin Platform.

D6-1e(3) Igneous Activity

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

An early radiometric determination by Urry (1936, pp. 35-40) for the dike yielded an age of 30 ± 1.5 million years. More recent work by Calzia and Hiss (1978, pp. 39-45) on dike samples are consistent with early work, indicating an age of 34.8 ± 0.8 million years. Work by Brookins et al. (1980, pp. 28-31) on dike samples in contact with polyhalite indicated an age of about 21.4 million years.

Volcanic ashes found in the Gatuña were airborne from distant sources such as Yellowstone and represent no volcanic activity at the WIPP.

D6-1e(4) Loading and Unloading

Loading and unloading during the geological history since deposition is considered an influence on the hydrology of the Permian units because of its possible effect on the development of fractures (Powers and Holt, 1995).

The sedimentary loading, depth of total burial, and erosion events combine in a complex history reconstructed here from regional geological trends and local data. The history is presented in Figure D6-18 with several alternatives, depending on the inferences that are drawn, ranging from minimal to upper-bound estimates. The estimates are made with a reference point and depth to the Culebra at the AIS (Holt and Powers, 1990).

Given the maximum local thickness of the Dewey Lake, the maximum load at the end of the Permian was no more than approximately 787 feet (240 meters). Given the present depth to the Culebra from the top of the Dewey Lake in the AIS, approximately 115 feet (35 meters) of Dewey Lake might have been eroded during the Early Triassic before additional sediments were

deposited. The Triassic thickness at the AIS is approximately 26 feet (8 meters). Northeast of the WIPP site (T21S, R33E), Triassic rocks (Dockum Group) have a maximum local thickness of approximately 1,233 feet (373 meters). This thickness is a reasonable estimate of the maximum thickness also attained at the WIPP site prior to the Jurassic Period. At the end of the Triassic, the total thickness at the WIPP site may have then attained approximately 1,863 feet (586 meters) in two similar loading stages of a few million years each, over a period of approximately 50 million years.

The Jurassic outcrops nearest to the WIPP site are in the Malone Mountains of west Texas. There is no evidence that Jurassic rocks were deposited at or in the vicinity of the WIPP site. As a consequence, the Jurassic is considered a time of erosion or nondeposition at the site, though erosion is most likely.

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

Lang (1947) reported fossils from Lower Cretaceous rocks in the Black River Valley southwest of the WIPP site. Bachman (1980) also reported similar patches of probable Cretaceous rocks near Carlsbad and south of White's City. From these reports, it is likely that some Cretaceous rocks were deposited at the WIPP site. Approximately 70 miles (110 kilometers) south-southwest of the WIPP site, significant Cretaceous outcrops of both Early and Late Cretaceous age have a total maximum thickness of approximately 1,000 feet (300 meters). Southeast of the WIPP, the nearest Cretaceous outcrops are thinner and represent only the Lower Cretaceous. Based on outcrops, a maximum thickness of 1,000 feet (300 meters) of Cretaceous rocks could be estimated for the WIPP site. Compared to the estimate of Triassic rock thickness, it is less likely that Cretaceous rocks were this thick at the site. The uppermost lines of Figure D6-18 summarize the assumptions of maximum thickness of these units.

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

In the general vicinity of the WIPP site, there are outcrops of Cenozoic rock from the Late Miocene (Gatuña and Ogallala Formations). There is little reason to infer any significant Early Cenozoic sediment accumulation at the WIPP site. Erosion is the main process inferred to have occurred during this period and an average erosion rate of approximately 11 meters per million

years is sufficient during the Cenozoic to erode the maximum inferred Triassic and Cretaceous thickness prior to Gatuña and Ogallala deposition. Significant thicknesses of Cretaceous rocks may not have been deposited, however, and average erosion rates could have been lower.

Maximum-known Gatuña thickness in the area around the WIPP is approximately 330 feet (100 meters); at the WIPP site the Gatuña is very thin to absent. Ogallala deposits are known from the Divide east of the WIPP site, as well as from the High Plains further east and north. On the High Plains northeast of the WIPP, the Upper Ogallala surface slopes to the southeast at a rate of approximately 20 feet per mile (4 meters per kilometer). A straight projection of the 4,100-foot (1,250-meter) contour line from this High Plains surface intersects the site area, which is at an elevation slightly above 3,400 feet (1,036 meters). This difference in elevation of 700 feet (213 meters) represents one estimate, probably near an upper bound, of possible unloading subsequent to deposition of the Ogallala Formation.

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

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

It also seems unlikely that a significant thickness of Cretaceous rock accumulated at the WIPP site. Erosion probably began during the Jurassic, slowed or stopped during the Early Cretaceous as the area was nearer or at base level, and then accelerated during the Cenozoic, especially in response to uplift as Basin and Range tectonics encroached on the area and the basin was tilted more. Erosional beveling of Dewey Lake and Santa Rosa suggest considerable erosion since tilting in the mid-Cenozoic. Erosion rates for this shorter period could have been relatively high, resulting in the greatest stress relief on the Culebra and surrounding units. Some filling occurred during the Late Cenozoic as the uplifted areas to the west formed an apron of Ogallala sediment across much of the area, but it is not clear how much Gatuña or Ogallala sediment was deposited in the site area. From general reconstruction of Gatuña history in the area (Powers and Holt 1993), the DOE infers that Gatuña or Ogallala deposits likely were not much thicker at the WIPP site than they are now. The loading and unloading spike (Figure D6-18) representing Ogallala thickness probably did not occur. Cutting and headward erosion by the Pecos River has created local relief and unloading by erosion. At the WIPP site, this history is little complicated by dissolution, though locally (for example, Nash Draw) the effects of erosion and dissolution are more significant. The underlying evaporites have responded to foundering of anhydrite in less dense halite beds. These have caused local uplift of the Culebra (as at ERDA 6) but little change in the overburden at the WIPP. Areas east of the WIPP site are likely to have

histories similar to that of the site. West of the site, the final unloading is more complicated by dissolution and additional erosion leading to exposure of the Culebra along stretches of the Pecos River Valley.

D6-1f Nontectonic Processes and Features

Halite in evaporite sequences is relatively plastic, which can lead to the process of deformation; it is also highly soluble, which can lead to the process of dissolution. Both processes (deformation and dissolution) can develop structural features similar to those developed by tectonic processes. The features developed by dissolution and deformation can be distinguished from similar-looking tectonic features where the underlying units do not reflect the same feature as do the evaporites. As an example, the evaporite deformation can commonly be shown not to affect the underlying Bell Canyon. The deformation also tends to die out in overlying units, and the Rustler or the Dewey Lake may show little, if any, of the effects of the deformed evaporites. Beds underlying areas of dissolved salt are not affected, but overlying units to the surface may be affected.

D6-1f(1) Evaporite Deformation

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

D6-1f(1)(a) Basic WIPP History of Deformation Investigations

Gravity-Driven Structure in the Castile Formation

This document describes the structural features in the Castile that are commonly attributed to gravity-driven deformation. In order to properly present this subject, the data will first be presented in a general historical overview. The known extent of deformation in the Castile, how these structures are likely to develop in the future, how well they can be predicted, and the potential impact law act of these structures on the WIPP will also be discussed. Apart from the general geological impact, the performance of the WIPP as it might be affected by such structures is not specifically assessed here.

Background Information

Parts of the Castile have been known for a number of years to be deformed. Cross sections of the basin geology through its margins have shown some evidence of deformation. Jones et al. (1973) provided a map of the isopachs of part of the Castile that clearly show much thicker portions in some of the areas along the northwestern to northern Delaware Basin, just inside the margin of the Capitan reef. Very little information was collated concerning deformation within the Delaware Basin prior to studies of the basin as a possible site for radioactive waste disposal.

Jones et al. (1973) is probably the most lucid early presentation of this information, although a dissertation by Snider (1966) and a paper by Anderson et al. (1972) also reflect thicker sections in some Castile units adjacent to the reef.

In 1975, SNL drilled a borehole, ERDA-6, at a site (Figure D6-19) that had been partially investigated by Oak Ridge National Laboratories (ORNL) during 1974. Two boreholes (AEC-7 and AEC-8) had been drilled in 1974 by ORNL . Formation boundaries and marker beds in ERDA-6 were structurally high compared to AEC-7 and AEC-8, and the degree of deformation increased downward. At about the 2,711-ft (826-m) depth, ERDA-6 began to produce pressurized brine and gas. The hole was eventually tested extensively to determine the nature and origin of the brine. Beds within the Castile were displaced structurally upward, apparently by hundreds of feet (Jones, 1981; Anderson and Powers, 1978), and some of the lower units may have actually pierced upper units (Anderson and Powers, 1978). Because of the desire for structurally uncomplicated units to simplify mining for a repository, the site under investigation at ERDA-6 was abandoned in 1975. In 1975-76 the current site was initially selected, and investigations were begun (Powers et al., 1978). As part of the selection criteria, a zone about 6 mi (10 km) wide inside the Capitan reef was avoided because it included known deformed Castile and Salado (Griswold, 1977). This is the first instance in which the site investigations were directly influenced by discovery of deformation in the Castile and the lower Salado.

The present site for the WIPP was selected and initially investigated in 1976 to determine if the desired characteristics for the preliminary site selection were present (Griswold, 1977; Powers et al.,1978). As the general criteria appeared to be met during this phase, the site and surrounding areas were characterized much more extensively and intensively beginning in 1977. Extensive new seismic reflection data were collected in 1977 and 1978 that began to reveal the deformed Castile north of the center of the site (Figure D6-20). Because the principal effect was that the good quality Castile reflectors from the area south of the site center were "disturbed," the area to the north was dubbed the "disturbed zone" (DZ). It also became known as "the area of anomalous seismic reflectors," or the "zone of anomalous seismic reelection data." The boundary of the DZ was variously described as being from about 0.5 to 1 mi (0.8 to 1.6 km) north of the center of the site, depending on the criteria to define the DZ. Powers et al. (1978) generally defined the DZ as beginning about 1 mi (1.6 km) north of the site center, where the seismic reflector character was poor to uninterpretable or "anomalous" (Borns et al., 1983). About 0.5 mi (0.8 km) north of the site center, it appeared that beds within the Castile began to steepen in gradient, dipping to the south from a higher area to the north. The Environmental Evaluation Group (EEG) summarized various map limits to the DZ, including the area where the Castile dip begins to steepen (Neill et al., 1983). Borns et al. (1983) included two separate areas south of the site as part of the DZ based seismic character.

The first new drillhole within the area encompassed by the DZ was WIPP-11, and it was located about 3 mi (5 km) north of the center of the WIPP site (Figure D6-19). Long and Associates (1977) examined proprietary petroleum company data in 1976, and they identified anomalous areas around the WIPP site, including the structural anomaly at the WIPP-11 location. Seismic reflection data acquired in 1977 indicated possible salt flowage within the Castile and a structure

that could be similar to that at ERDA-6 (SNL and USGS, 1979). WIPP-11 was drilled early in 1978, demonstrating the extensive deformation within the Castile and extending upward into the Salado. WIPP-11 did not encounter any brine or gas flows.

Seismic reflection data acquired in 1977 not only showed a zone of steepened dip of the Castile north of the site center, it also showed a possible fault offsetting parts of the Salado and the Rustler. A series of five boreholes were planned to provide detailed information on the structure of the Rustler/Salado contact. Four boreholes (WIPP 18, 19, 21, and 22) were required to demonstrate that there was no detectable offset on that contact in the area interpreted from 1977 seismic reflection data (Figure D6-19). Later epochs (1978 and 1979) of seismic data in the same area, along with the drilling, continued to show generally poor resolution or uninterpretable data in the area of the DZ. These studies generally showed that the acoustic velocity of the upper section changes laterally, complicating further the interpretation of the deeper Castile structure. Through the WIPP 18-22 drilling program, the upper Salado and the Rustler were determined to be fundamentally undisturbed over the southern margin of the disturbed zone where the Castile appears to dip to the south (SNL and USGS, 1979).

The upper part of the Castile about 1 mi (1.6 km) north of the WIPP site center was interpreted to range from about 250 ft to as much as 400 ft (100 to 120 m) (SNL and D'Appolonia Consulting Engineers, 1982a) above the elevation of the top of the Castile at about the center of the WIPP site. WIPP-12 was located approximately 1 mi (1.6 km) north of the site center to test the amount the Castile was elevated (Figures D6-19 and D6-20). It was drilled late in 1978 to the top of the Castile and detected approximately 160 ft (50 m) of structural elevation compared to ERDA-9 and the center of the site (SNL and D'Appolonia Consulting Engineers, 1982a). The amount of disturbance of the Salado was not considered to be an impediment to underground development, although the underground storage facility was later reoriented from this northern area to an area south of the site center. From drilling WIPP-12 and the WIPP 18-22 series, the southern margin of the DZ was considered to be much more gentle in structure, while the seismic character and WIPP-11 indicated much more severe deformation of the Castile further to the north.

Two additional phases of seismic reflection data were acquired in 1978 and 1979. These data mainly concerned the immediate site area (about 4 square mi [10 square km]) and the southern edge of the DZ. They indicated much the same problems and margins associated with the DZ from the 1977 data. The latest seismic data (1979) were principally acquired to facilitate construction and Site and Preliminary Design Validation (SPDV) activities. As the project moved into SPDV activities, the DZ was little investigated directly during the period from about late 1979 until mid-1981.

A microgravity survey of the site area was conducted to determine if the structure within the DZ could be partially resolved (Barrows et al., 1983; Barrows and Fett, 1985). The large differences in density of halite and anhydrite could cause detectable differences in the gravity field locally if the units were displaced and/or thickened relative to the surrounding areas. The microgravity survey covered an area of "normal" stratigraphy from south of the WIPP site center to the area

of WIPP-11 (Figure D6-21). As interpreted (Barrows et al., 1983), the microgravity does not resolve the larger scale deformation within the Castile. Based on the interpretation of probable shallow disturbance of the gravity field, WIPP-14 and WIPP-34 were drilled about 2 mi (3 km) north and about 0.5 mi (0.8 km) east of the site center (Figure D6-19). These boreholes encountered normal stratigraphy within the Rustler and upper Salado (SNL and D'Appolonia Consulting Engineers, 1982b; SNL and USGS, 1981), with some slight structural depression made apparent mainly by the deformation northeast of this area around ERDA-6 (Holt and Powers, 1988). Barrows et al. (1983) attributed the gravity anomaly around WIPP-14 to decreased density within parts of the Rustler, mainly from the difference in density due to anhydrite versus gypsum in WIPP-14. The overall difference in mass was attributed to karst processes by Barrows et al. (1983) rather than to deformation of any of the units associated with the DZ.

During the mapping of the first shaft drilled at the WIPP site (the Salt Handling Shaft), Marker Bed 139 was observed to have a few inches of relief on the basal contact and 2 to 3 ft (0.6 to 0.9 m) of relief on the upper surface. Jarolimek et al. (1983) interpreted the internal structure on these high points of Marker Bed 139 as showing a radial structure due apparently to gypsum growth textures and subsequent crushing, indicating a fundamentally depositional origin to the relief rather than any structural disturbance related to the DZ. Borns and Shaffer (1985) conducted an investigation of additional cores and holes drilled through Marker Bed 139, as there was concern on the part of the EEG that the apparent structure was related to the DZ. Borns and Shaffer (1985) also concluded that the relief was not due to structural deformation, but instead, was due mainly to erosional processes that carved part of the relief found on the top of the Marker Bed. From either point of view, the difference in relief on the upper and basal contacts of Marker Bed 139, in such a thin unit, were convincing evidence that a form of tectonic deformation was not involved.

In late 1981, WIPP-12 was deepened to test for the possible presence of brine and/or pressurized gas within the structure in the Castile (D'Appolonia Consulting Engineers, 1982). The probability of producing brine/gas from WIPP-12 was considered reasonably low at the time, because most known pressurized brine/gas was associated with much more deformed units in the Castile at WIPP-12. Fractured anhydrite in the upper Castile did begin to yield pressurized brine and gas when intercepted late in 1981, and WIPP-12 and ERDA-6 were further tested. Later geophysical work (Earth Technology Corporation, 1987) suggests that the brine may underlie part of the WIPP facility, beyond the area usually included in the DZ. Though the DOE and the EEG agreed that the structure did not constitute a threat to health and safety, the proposed underground facilities were reoriented south of the site center, avoiding longer haulage and the slight structure encountered at the facility horizon. As a consequence of the deepening and testing of WIPP-12, the link between structure and pressurized brine and gas was strengthened.

The last direct investigation of the DZ was a by-product of another investigation. DOE-2 was drilled approximately 2 mi (3.2 km) north of the center of the WIPP site to investigate the origin of a modest depression on Marker Bed 124 (Griswold, 1977; Powers et al., 1978) that was

detected in a core hole drilled by a potash company. DOE-2 was principally a test of the hypothesis that the depression was caused by ductile flow of halite in response to deep dissolution of halite by water from the Bell Canyon (Mercer et al., 1987). Halite layers in the lower Salado were thicker than usual, indicating that part of the sequence had not been dissolved, and the Castile was very deformed. The Castile stratigraphy was not normal; the second halite was apparently squeezed out of the area during deformation. The stratigraphy in DOE-2 is apparently the result of processes which caused the DZ and is not the result of any dissolution (Borns, 1987; Mercer et al., 1987).

The preceding paragraphs describe most of the direct investigations of the disturbed zone and place them in their historical context. In the following text, more of the specific features of the DZ will be described, interpreted, and discussed to indicate the significance of the structures and processes of formation for the WIPP.

Specific Features of the Disturbed Zone

The first specific feature of the DZ is its boundary. As discussed above, the different concepts of the boundary depend on ideas of where the Castile began to change and steepen its dip (about one-half mi [0.8 km] north of the site center) or where the seismic data became unreliable to uninterpretable. Borns et al. (1983) present one diagram (Figure D6-20) of the seismic time structure for the top of the Castile that illustrates the variously defined boundaries. The principal part of the disturbed zone is defined by a lobate area (Figure D6-20) shown as an "area of complex structure" where the seismic data are considered "ambiguous." The structurally deformed area clearly includes an area about halfway between boreholes WIPP-12 and ERDA-9, as well as a larger area to the northeast. The two-way travel time contoured on the map is a function of depth; as the reflector is nearer the surface, the travel time to the reflector and back to the surface decreases. Thus, the areas enclosed with contours of smaller values should be interpreted as structurally higher. (The top of the Castile in WIPP-12 was 160 ft [50 m] higher than it is in ERDA-9.) The map was not directly converted to depth because the seismic reflection and borehole geophysical logging programs clearly demonstrate that there are also lateral velocity variations within the upper part of the rock section, especially within the Rustler and the Dewey Lake. These velocity variations cannot be extracted from the travel times adequately to permit converting the travel time to depth. Nonetheless, the map demonstrates the general best information about the extent of the DZ. The central and southern parts of the WIPP site area display relatively uniform seismic travel time structure, and nothing within the geological data contradicts that information to date.

The broad forms of the structures within the DZ are generally anticlinal and synclinal (Borns, 1987), although they are not necessarily regular shapes. The best known shape for part of the DZ is between WIPP-12 and ERDA-9, where seismic information and several drillholes constrain part of the interpretation of the stratigraphy. There the structure tends to be a gently dipping limb of an anticlinal structure. Most of the remaining shapes attributed to the Castile within the DZ or related areas are based more on one drill hole or a few drill holes that somewhat constrain the interpretation of the structure. WIPP-11, WIPP-13, DOE-1, and ERDA-6

are all examples. A generalized cross section of the structure at ERDA-6 (Anderson and Powers, 1978) shows a piercement structure and a regular shape; the piercement is based on stratigraphic inferences, but the shape is fundamentally uncontrolled by closely spaced data. WIPP-11 and WIPP-12 are both believed to penetrate anticlinal forms, though the structure is only partially known from drilling and seismic reflection data. DOE-2 is believed to lie in a synclinal structure, and contacts on various units show a nested series of depressions in the upper Salado (Borns, 1987). There are too few drill holes into the Castile to reconstruct the detailed shapes of Castile structures. The seismic data are not well enough constrained to calculate depths to reflectors, and most reflectors are too "disturbed" to interpret in this area. The specific shapes of individual structures are unlikely to be defined in the near future.

Anderson and Powers (1978) contoured several structures within the Delaware Basin, including structures at Poker Lake at least grossly similar to ERDA-6. Borns and Shaffer (1985) reexamined the information from Poker Lake and concluded that the actual shape is poorly constrained. Outside of the area on the north side of the current WIPP site, the information available is too sparse to define the individual shapes of structural features on borehole data.

It is important to note that, to date, none of the structures are demonstrably associated with comparable structure on the underlying Delaware Mountain Group. Snyder (in Borns et al., 1983) does show an upthrown block (horst) through WIPP-11 on the top of the Bell Canyon that is based on his projection of the thickness of the lower Castile; WIPP-11 did not penetrate the complete Castile section. Other areas, such as the Poker Lake structures, may display some relief on the top of the Delaware Mountain Group, but Borns and Shaffer (1985) do not attribute the relief to faulting. They believe the relief existed before and during deposition of the overlying Castile units. The underlying units to the Castile are, for the most part, uninvolved in the structures displayed by the Castile.

Structure contour and isopach maps of the Salado and the Rustler over areas of the complicated Castile structure also show that the overlying units are successively less involved in the structure (e.g., Borns and Shaffer, 1985; Borns et al., 1983; Holt and Powers, 1988). Lower units that are thicker and deformed are overlain by units that are thinner and less structurally involved in the deformation. Under normal geological circumstances, e.g., dealing with a rock sequence of carbonates or siliciclastics, the deformation would be considered to be completed by the time of deposition of the lowermost undeformed rock unit. Here, within a much more plastic set of rocks, the same geological reasoning is of less value, as the rocks may compensate laterally for late deformation effects and produce the same results.

Borns (1983; 1987; Borns et al., 1983) has extensively examined the macroscopic to microscopic features from cores taken within the structurally deformed areas. These studies follow earlier, broader studies of macroscopic features from the "state line outcrop" (Kirkland and Anderson, 1970) and ERDA-6 (Anderson and Powers, 1978). Kirkland and Anderson (1970) reported that small-scale folding within the Castile outcrops is oriented consistently along the general north-south strike of beds in the Delaware Basin. From this they concluded that the deformation was related to tilt of the basin, generally believed to be Cenozoic in age (e.g., Anderson, 1978;

King, 1948; Borns et al., 1983), although authors differ in opinions on when this took place by tens of millions of years. Anderson and Powers (1978) used this apparent relationship to estimate that folding at ERDA-6 took place after the tilt of the basin. Jones (1981) estimated that deformation took place before the Ogallala was deposited because that unit is undeformed at the location of ERDA-6. Bachman (1980) and Madsen and Raup (1988) are among investigators who interpret angular relationships between various formations of the Ochoan Series, beginning with the Castile/Salado contact. These relationships require tilting of the existing beds to the east, as the angular unconformities are always placed on the western side of the basin. Tilting of the basin may well have occurred through much of the time when the Ochoan Series was being deposited, as Holt and Powers (1988) present evidence that the depocenter for the Rustler was displaced eastward from the Castile and the Salado patterns and overlies part of the Capitan reef on the northeastern side of the Delaware Basin. The Delaware Basin appears to have tilted at various times from the late Permian to at least the Cenozoic, and the conditions for deformation may well have existed since the late Permian. Direct evidence of the time of affirmation has been difficult to obtain, and tilting of the basin, as a condition for the deformation, appears to have occurred at times beginning in the late Permian. Jones (1981) argues that the structure at ERDA-6 must be in part younger than Triassic because Triassic rocks are also deformed over the deformed evaporates, and that the structure must be older than late Cenozoic because the Ogallala over part of the structure is undeformed and erosionally truncates the upper part of the Triassic rocks. This may be the most conclusive age relationship demonstrated for any of these related structures. Conventional relationships with beds overlying deformed evaporites, such as that cited by Jones (1981) for the Ogallala, are suspect if the deformation ends or dies out vertically within the evaporites because of the potential for compensating deformation in evaporates (e.g., Borns, 1983).

Borns (1983, 1987) reexamined the "state line outcrop" as well as the cores from various boreholes and concluded that the styles of deformation present in these cores indicate a very complicated history, including episodes of deformation that are probably synsedimentary. The folding may, for example, display disharmonic or opposing styles that would not normally be attributed to a single episode of strain in a pervasive stress field. If the deformation all occurred in response to a single event such as the tilting of the Delaware Basin, the folds and other strain indicators should all have a common orientation. Isoclinal folding may occur very early, while asymmetric folding is often penetrative, indicating later time of origin. Fractures in more brittle units such as the Castile anhydrites are often very high-angle to vertical and are considered one of the late deformation features in cores. These fractures in the larger anticlinal structures of the DZ are apparently the proximate source of pressurized brines and gases. Borns (Borns and Shaffer, 1985; Borns, 1987) recognized that tilting of the basin, among other possible sources of stress, may have occurred at several different times and is not limited to a single Cenozoic event.

Hypotheses of Formation of Deformation in Castile

Several hypotheses have been advanced for the formation of the Castile structures in the DZ and other parts of the Delaware Basin (Borns et al., 1983). The five principal processes

hypothesized as causes of the DZ are gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes (Borns et al., 1983). Each of these hypotheses will be briefly summarized, though gravity foundering due to density differences between halite and anhydrite is considered the leading hypothesis (Borns, 1987).

Gravity foundering is based on the fact that anhydrite (about 181 pounds per cubic ft [lb/ft^3], or 2.9 grams per cubic centimeter [gm/cc]) is much more dense than halite (about 134 lb/ft^3 [2.15 gm/cc]). When anhydrite beds overlie halite, there is considerable potential for the anhydrite to sink and for the halite to rise. This potential exists throughout much of the Delaware Basin in the Castile. Mathematical and centrifuge models of similar systems confirm the potential for such deformation and even suggest that the rate of deformation is about 0.02 inch (in)/year (yr) (0.05 centimeters [cm]/yr) (Borns et al., 1983). At such a rate, the DZ could be inferred to have developed over about 700,000 years (Borns et al., 1983). The principal difficulty with this hypothesis is that there are large areas of the Delaware Basin that remain undeformed, though the stratigraphy is similar to that within the DZ. The potential for gravity foundering exists over most of the basin, yet only a small part actually manifests such deformation. A special condition, such as a localized higher water content or an anomalous distribution of water, is hypothesized to explain why deformation is localized despite the pervasive density inversion (Borns et al., 1983). The presence of pressurized brine and gas associated with some of these structures is at least consistent with this explanation.

Halite could potentially be removed from the evaporite section by dissolution and change the form of the evaporites. The density structure could be changed by removing salt near the surface, causing collapse and fill with sediment that is more dense than the removed salt (Anderson and Powers, 1978). Borns et al. (1983) reviewed some of the evidence that evaporites were deformed near surficial sinks and concluded that there was certainly some association but that the pattern of deformation did not match the shallow dissolution. If salt is dissolved from the lower Salado or the Castile, then overlying beds should deform in response to the removal of mass. DOE-2 was drilled to test that hypothesis. Recrystallized halite has been offered as evidence of the passage of fluids, but there appears to be no unique relationship between recrystallized halite and deformation. In addition, certain halite sections appear much overthickened, which is clearly not directly due to halite removal. These features indicate generally that the halite can be squeezed and will "move" laterally. The fact that the Rustler shows no discernable overall structural lowering over the DZ (Holt and Powers, 1988) suggests that neither the dissolution of the lower Salado nor the Castile is the origin of the deformation. The one area in which the Rustler is structurally affected is around ERDA-6, and there it is warped upward as noted by Jones (1981). Borns et al. (1983) do not believe that the Bell Canyon has been a source for brines in the Castile because of the chemistry (Lambert, 1978; 1983a) and the small volume.

Gravity sliding in the Delaware Basin could be driven by two physical situations: the general eastward dip and the dip off the Capitan reef and forereef into the basin. In contrast to the gravity foundering mechanism, where movement is dominantly vertical, gravity would result in sliding blocks moving mainly laterally as well as downslope in this mechanism. Some of the

deformation is adjacent to the reef (Jones et al., 1973), lending some substance to the hypothesis that the reef-forereef slope and facies changes could cause such sliding. Some deformation is in somewhat isolated portions of the basin (e.g. Poker Lake) (Anderson and Powers, 1978; Borns and Shaffer, 1985), and these structures were originally interpreted to align along the strike of the basin (Anderson and Powers, 1978). Borns and Shaffer (1985) conclude that the data do not uniquely support that interpretation, and these structures may or may not support the concept of gravity sliding within the basin. Borns et al. (1983) also concluded that the timing of the various structures is an important factor in evaluating this hypothesis. As discussed above, neither the age of the various structures nor the timing of the basin tilt are well constrained. If tilting of the basin is an important event in forming these structures, the various macro to microstructures should probably be consistently related. As in gravity foundering, much of the basin area has not reacted to what appears to be widespread similar stresses. Special circumstances, such as an anomalous distribution of water, may be necessary to overcome a threshold for deformation to occur.

In general, as temperature and pressure increase, gypsum dehydrates to form anhydrite and release free water. Borns et al. (1983) discuss the effects this process has in experiments that weaken the anhydrite. Borns et al. (1983) suggest, however, that a major difficulty with this hypothesis is that there should remain relics of the original gypsum within the sedimentary column; these are not observed. Borns et al. (1983) suggest that mostly anhydrite was deposited in the Castile, and as a consequence, the dehydration hypothesis has little observable support. More recently pseudomorphs after gypsum have been recorded in every major anhydrite of the Castile (Harwood and Kendall, 1988; Hovorka, 1988; Powers, unpublished data; SNL and D'Appolonia Consulting Engineers, 1982c). Gypsum certainly has been present in the Castile, though anhydrite cannot be dismissed as possibly an important primary mineral. Delicate forms of original gypsum crystals are sometimes preserved and pseudomorphed by anhydrite or halite. Each requires volume-for-volume replacement, probably through dissolution and crystallizing the replacement mineral. There are no observed fluid escape paths, and the gypsum may have been replaced very early in the sedimentary history. The additional major drawback to this hypothesis is that the process should be pervasive, while the deformation is localized. Special pleading for an additional factor is necessary in this process as in some other hypotheses.

Depositional or syndepositional processes have been invoked for some of the deformation in the Castile. Borns et al. (1983) list four main mechanisms that have been suggested: penecontemporaneous folding, resedimentation, slump blocks off of reef margins, and sedimentation on inclined surfaces. Penecontemporaneous folding requires consolidation of the units over relatively short times. Borns et al. (1983) also cite the lack of observed features that indicate the rocks were reexposed. Evaporite units in the Mediterranean contain resedimented material: turbidities, slumping, and mud flows with other clastic sediment. Borns et al. (1983) report that "the units of the WIPP area show little chaotic or clastic structures." They also apply the same argument of Kirkland and Anderson (1970) that the deformed units would have to be consolidated by the time of resedimentation.

In a more recent study of cores from the western part of the Delaware Basin, Robinson and Powers (1987) report a lobate unit of the resedimented Castile anhydrite clasts overlying both the lower anhydrite and halite of the Castile and underlying the second anhydrite. The apparently unconformable contact with both anhydrite 1 and halite 1 lies across the extension of the Huapache monocline, which appears to have been still active during the time part of the Castile was deposited. Polyclasts within some beds of this unit demonstrate that the original anhydrite was partially consolidated and that a unit of clasts was also at least partially consolidated to provide the polyclasts. These units were consolidated early between the time halite 1 was deposited and anhydrite began to be deposited.

In the rest of the basin there is no apparent interval between the end of the halite and beginning of the anhydrite deposition. The relationship clearly indicates that the western margin was an area of sulfate clast formation, deposition, and lithification over a very short interval of geologic time. Hovorka (1988) indicates that similar clastic deposits occur in cores from nearer the eastern margin of the Delaware Basin. Snider (1966) proposed much earlier that sedimentation caused anomalous thickness of Castile units near the basin margin, and Billo (1986) presented a similar conclusion. Neither reported any textural evidence to support their conclusions.

Clearly, Castile rock has been resedimented, but in the area where textural data are available, only modest deformation appears to be present (Robinson and Powers, 1987). At this time, there is little to suggest that such sedimentation resulted in the deformation in the DZ. There is also no direct evidence from the WIPP area that suggests slump blocks off of the reef margin moved into the area, causing deformation. The high inferred slopes of some of these structures argues strongly against sedimentation on inclined surfaces (Borns et al., 1983).

The concept that deformation was syndepositional or penecontemporaneous with deposition appears to mainly be driven by the fact that deformation decreases upward through successive units. Normal geologic reasoning would support penecontemporaneous deformation but does not take into account the rather plastic behavior of halite, allowing flow from over high areas to move halite into low areas. Overlying units, such as the Rustler, are made of much less plastic material and do not respond as the Salado does. The deformation appears to be compensated in overlying units through deposition.

Overall, both gravity-driven mechanisms require some special additional conditions restricting deformation to small areas though most of the basin appears to be equally susceptible. Dissolution permits a more localized effect, but there does not appear to be an overall loss of mass in these areas, and the chemistry of the fluids and hydrology of the units do not readily support the concept. Most of the syndepositional processes have no evidence to support them in the area of the DZ. The most favored hypothesis at the moment is gravity foundering, with a yet undetected anomalous distribution of fluid lowering the viscosity of halite locally to permit deformation.

Timing of Deformation

Most of the arguments about timing of deformation have already been discussed. Standard geologic arguments about relative timing, based on involvement of the overlying units, is unlikely to hold for the evaporite units. Jones (1981) notes that uplifted and arched Triassic rocks near the ERDA-6 borehole are truncated by the flat-lying, undeformed Pliocene Ogallala. This was interpreted as an indication that salt movement was complete before deposition of the Ogallala (Jones, 1981). However, he does not explain either how the Triassic structure relates to the deeper DZ or how it is distinguished from near surface dissolution effects (Borns et al., 1983). The Castile rocks may have been deformed during any time period from Permian to the present. More to the point, for some hypotheses, the general conditions thought necessary to deform the Castile and the Salado are still present, and mechanisms such as gravity foundering are potentially active (Borns et al., 1983).

An additional piece of data is relevant. Brines from ERDA-6 and WIPP-12 were analyzed, and the brines were calculated to last have moved after about 800,000 years ago (Lambert and Carter, 1984; Barr et al., 1979). One set of reasonable assumptions about brine chemistry and interactions with the rock leads to calculated residence times of about 25,000 to 50,000 years for these brines. This may relate to the last time deformation was active on this structure, although it is not uniquely an indicator of deformation. The interaction between rock and water may have been strictly hydrologically driven and may not require deformation at that time.

The second point of interest is that some modelling calculations indicate, as stated above, that the kinds of structures observed in the DZ may require periods on the order of 700,000 years to form. There is no indication when the structures formed by this calculation, but it is relevant to timing and assessing how these structures might affect the WIPP.

Importance to the WIPP

The structures interpreted from core retrieved from WIPP-12 and ERDA-6 serve as possible analogs to effects of deformation on the WIPP. The DOE and the EEG have analyzed the effects of brine and structure at WIPP-12 and the southern portion of the site and have concluded that the geologic conditions represent no threat to health and safety. In addition, both boreholes encountered brine only within the anhydrite units, and that is the experience of all other encounters of these larger brine inflows (Popielak et al., 1983). Anhydrite supports the fractures that provide porosity for the brine, and the anhydrite/halite units form an effective seal, as the pressurized brines and gas did not escape upward. The principal concern for isolation would be that the deformation, and its associated phenomena such as pressurized brine and gas could cause breaching of the repository and provide or make a pathway for the escape of the waste constituents. The period of time expected for development of the structure (700,000 years) is well beyond periods of regulatory concern. In addition, the evidence of the pressurized brine and gas occurrences is that they are confined to these Castile anhydrite layers and do not

breach the lower Salado to reach the stratigraphic level of the repository. There is nothing at present to indicate that these features will form in the time period of concern or that they can directly cause a breach of the repository.

D6-1f(2) Evaporite Dissolution

Because evaporites are much more soluble than most other rocks, project investigators have considered it important to understand the dissolution processes and rates that take place within the site considered for long-term isolation. These dissolution processes and rates constitute the limiting factor in any evaluation of the site. Over the course of the WIPP Project, extensive resources have been committed to identify and study a variety of features in southeastern New Mexico interpreted to have been caused by dissolution. The subsurface distribution of halite for various units has been mapped. Several different kinds of surface features have been attributed to dissolution of salt or karst formation. The processes proposed or identified include point-source (brecciation), "deep" dissolution, "shallow" dissolution, and karst. The categories are not well defined. Nonetheless, as discussed in the following sections, dissolution is not considered a threat to isolation of waste at the WIPP.

D6-1f(2)(a) Brief History of Project Studies

Well before the WIPP Project, several geologists recognized that dissolution is an important process in southeastern New Mexico and that it contributed to the subsurface distribution of halite and to the surficial features. A number of these are listed in the Bibliography to this appendix, including Lee (1925, pp. 107-121), Maley and Huffington (1953, pp. 539-546), and Olive (1957, pp. 351-358). Robinson and Lang identified an area in 1938 under the Nash Draw where brine occurred at about the stratigraphic position of the upper Salado/basal Rustler and considered that salt had been dissolved to produce a dissolution residue. Vine mapped the Nash Draw and surrounding areas, reporting in 1963 on various dissolution features. Vine (1963) reported surficial domal structures later called "breccia pipes" and identified as deep-seated dissolution and collapse features.

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

During the early 1970s, the basic ideas about shallow dissolution of salt (generally from higher stratigraphic units and within a few hundred feet of the surface) were set out in a series of

reports by Bachman, Jones, and collaborators. Piper independently evaluated the geological survey data for ORNL. Claiborne and Gera concluded that salt was being dissolved too slowly from the near-surface units to affect a repository for several million years, at least.

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

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

A set of annular or ring fractures is evident in the surface around the San Simon Sink, about 18 mi (30 km) east of the WIPP site. Nicholson and Clebsch (1961, p. 14) suggested that San Simon Sink developed as a result of deep-seated collapse. WIPP-15 was drilled at about the center of the sink to a depth of 811 ft (245 m) to obtain samples for paleoclimatic data and stratigraphic data to interpret collapse. Anderson and Bachman both interpret San Simon Sink as dissolution and collapse features, and the annular fractures are not considered evidence of tectonic activity.

Following the work by Anderson, Bachman mapped surficial features in the Pecos Valley, especially at the Nash Draw, and differentiated between those surface features in the basin that were formed by karst and deep collapse features over the Capitan reef. WIPP-32, WIPP-33, and two boreholes over the Capitan reef were eventually drilled. Their data, which demonstrated the concepts proposed by Bachman, are documented in Snyder and Gard (1982, p. 65).

A final program concerning dissolution and karst was initiated following a microgravity survey of a portion of the site during 1980. Based on localized low-gravity anomalies, Barrows et al., in 1983 interpreted several areas within the site as locations of karst. WIPP-14 was drilled during 1981 at a low-gravity anomaly. It revealed normal stratigraphy through the zones previously alleged to be affected by karst. As a followup in 1985, Bachman also reexamined surface

features around the WIPP and concluded there was no evidence for active karst within the WIPP site. The nearest karst feature is northwest of the site boundaries at WIPP-33 and is considered inactive.

D6-1f(2)(b) Extent of Dissolution

Within members of the Rustler, the margins of halite have been mapped by differing methods and summarized by Beauheim (1987). There are few differences, despite the difference in methods (Figure D6-9). Lower members of the Rustler are halitic west of the site, and higher members generally show halite only further east. Snyder interprets these margins as a consequence of post-depositional dissolution of halite. Holt and Powers (1988, pp. 6-8 to 6-9) interpret sedimentary structures within the Rustler mudstone as being equivalents to halite in order to indicate that most halite was removed during the depositional process and redeposited in a salt pan in the eastern part of the depositional basin.

Upper intervals of the Salado thin dramatically west and south of the WIPP site (Figures D6-22 and D6-23) compared to deeper Salado intervals (Figure D6-24). There are no cores for further consideration of possible depositional variations. As a consequence, this margin is interpreted as the edge of dissolution of the upper Salado.

General margins of halite for the Castile are well west of the WIPP site and are generally accepted. Although Robinson and Powers (1987, pp. 69-79) question the volume of salt that may have been dissolved from the Castile, the general boundaries are not disputed.

D6-1f(2)(c) Timing of Dissolution

The dissolution of Ochoan-Epoch evaporites through the near-surface processes of weathering and groundwater recharge has been studied extensively (Anderson, 1981, pp. 133-145; Lambert, 1983a; Lambert, 1983b, pp. 291-298; Bachman, 1984, pp. 1-22; see also Holt and Powers, 1988). The work of Lambert (1983a) was specifically mandated by the DOE's agreement with the State of New Mexico in order to evaluate, in detail, the conceptual models of evaporite dissolution proposed by Anderson (1981, pp. 133-145). There was no clear consensus of the volume of rock salt removed. Hence, estimates of the instantaneous rate of dissolution vary significantly. Dissolution may have taken place as early as the Ochoan, during or shortly after deposition. For the Delaware Basin as a whole, Anderson (1981, pp. 133-145) proposed that up to 40 percent of the rock salt in the Castile and the Salado was dissolved during the past 600 thousand years ago (ka). Lambert (1983b, pp. 291-298) suggested that in many places the variations in salt-bed thicknesses inferred from borehole geophysical logs that were the basis for Anderson's (1981) calculation were depositional in origin, compensated by thickening of adjacent nonhalite beds, and were not associated with the characteristic dissolution residues. Borns and Shaffer also suggested in 1985 a depositional origin for many apparent structural features attributed to dissolution.

Snyder (1985, pp. 85-229), as do earlier workers (e.g., Vine, 1963; Lambert, 1983b, pp. 291-298; Bachman, 1984, pp. 1-22), attributes the variations in thickness in the Rustler, which crops out in the Nash Draw, to post-depositional evaporite dissolution. Holt and Powers (1988, pp. 7-1 to 7-27) have challenged this view and attribute the east-to-west thinning of salt beds in the Rustler to depositional facies variability rather than postdepositional dissolution. Bachman (1974, pp. 74-194; 1976, pp. 135-144; 1980, pp. 80-109) envisioned several episodes of dissolution since the Triassic, each dominated by greater degrees of evaporite exhumation and a wetter climate, interspersed with episodes of evaporite burial and/or a drier climate. Evidence for dissolution after deposition of the Salado and before deposition of the Rustler along the western part of the Basin was cited by Adams (1944, pp. 1596-1625). Others have argued that the evaporites in the Delaware Basin were above sea level and therefore subject to dissolution during the Triassic, Jurassic, Tertiary, and Quaternary periods. Because of discontinuous deposition, not all of these times are separable in the geological record of southeastern New Mexico. Bachman (1984) contends that dissolution was episodic during the past 225 million years as a function of regional base level, climate, and overburden.

Some investigators have reasoned that wetter climate accelerated the dissolution. Various estimates of middle Pleistocene climatic conditions have indicated that climate was more moist during the time of the Gatuña than during the Holocene. An example of evidence of mass loss from dissolution since Mescalero time (approximately 500 ka) is found in displacements of the Mescalero caliche as large as 180 ft (55 m) in collapse features in the Nash Draw. However, given the variations in Pleistocene climate, it is unrealistic to apply a calculated average rate of dissolution, determined over 500 ka, to shorter periods, much less extrapolate such a rate into the geological future.

There have been several attempts to estimate the rates of dissolution in the basin. Bachman provided initial estimates of dissolution rates in 1974 based on a reconstruction of the Nash Draw relationships. Although these rates do not pose a threat to the WIPP, Bachman later reconsidered the Nash Draw relationships and concluded that pre-Cenozoic dissolution had also contributed to salt removal. Thus the initial estimated rates were too high. Anderson concluded in 1978 that the integrity of the WIPP to isolate radioactive waste would not be jeopardized by dissolution within about 1 million years. Anderson and Kirkland (1980, pp. 66-69) expanded on the concept of brine-density flow proposed by Anderson in 1978 as a means of dissolving evaporites at a point by circulating water from the underlying Bell Canyon. Wood et al. (1982) examined the mechanism and concluded that, while it was physically feasible, it would not be effective enough in removing salt to threaten the ability of the WIPP to isolate TRU waste.

There is local evidence of Cenozoic dissolution taking place at the same time that part of the Gatuña was being deposited in the Pierce Canyon area. Nonetheless, there is no indicator that the rates of dissolution in the Delaware Basin are sufficient to affect the ability of the WIPP to isolate TRU waste.

D6-1f(2)(d) Features Related to Dissolution

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

South of the WIPP site, there is a clear relationship between a subsurface structure on the Culebra (Figure D6-25) and dissolution. Salt has been removed from the underlying Salado to create a general anticline from near the Laguna Grande de la Sal to the southeast. Beds generally dip to the east, and salt removed to the west created the other limb of the structure. Units below the evaporites do not apparently show the same structure.

D6-2 Surface-Water and Groundwater Hydrology

The DOE believes the hydrological characteristics of the disposal system require evaluation to determine if contaminant transport via fluid flow is a pathway of concern. At the WIPP site, one of the DOE's selection criteria was to choose a location that would minimize fluid-related impacts. This was accomplished when the DOE selected: 1) a disposal medium that contains very small quantities of groundwater, 2) a location where the effects of groundwater circulation on the disposal system are limited and reasonably predictable, 3) an area where groundwater use is very limited, 4) an area where there are no surface waters, 5) an area where future groundwater use is unlikely, and 6) a repository host rock that will not likely be affected by anticipated long-term climate changes possible within 10,000 years.

The following discussion summarizes the characteristics of the groundwater and surface water at and around the WIPP site. This summary is based on data-collection programs that were initiated at the inception of the WIPP program and which continue to some extent today. These programs have several purposes as follows:

- To provide sufficient information to develop predictive models of the groundwater movement within the vicinity of the WIPP site
- To collect data to evaluate the predictive models and to adapt them to the specific conditions of the WIPP site
- To develop an understanding of the surface water characteristics and the interaction between surface waters and groundwater
- To develop predictive models of the interaction between surface water and groundwater during reasonably expected climate changes.

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

- Groundwater
  - General flow direction
  - Flow type
  - Horizontal and vertical flow velocities
  - Hydraulic interconnectivity between rock units
  - General groundwater use
  - Chemistry (including, but not limited to, salinity, mineralization, age, Eh, and pH)
- Surface Water
  - Regional precipitation and evapotranspiration rates
  - Location and size of surface-water bodies
  - Water volume, flow rate, and direction
  - Drainage network
  - Hydraulic connection with groundwater
  - Soil hydraulic properties (infiltration)
  - General water chemistry and use.

For the purposes of groundwater modeling, the hydrological system is divided into three segments. These are 1) the Salado, which for the most part concerns the undisturbed performance of the disposal system; 2) the non-Salado rock units, which essentially are impacted by the disturbed (human intrusion) performance of the disposal system; and 3) the surface waters, which are impacted by the natural variability of the climate.

The WIPP site lies within the Pecos River drainage area (Figure D6-26). The climate is semiarid, with a mean annual precipitation of about 12 in. (0.3 m), a mean annual runoff of from 0.1 to 0.2 in. (2.5 to 5 millimeters [mm]), and a mean annual pan evaporation of more than 100 in. (2.5 m). Brackish water with total dissolved solids (TDS) concentrations of more than 3,000 parts per million (ppm) is common in the shallow wells near the WIPP site. Surface waters (Section 1.2.2) typically have high TDS concentrations, particularly of chloride, sulfate, sodium, magnesium, and calcium (Appendix D4).

At the WIPP site, the DOE obtains hydrologic data from conventional and special-purpose test configurations in multiple surface and underground boreholes. (Figure D6-2 is a map of surface borehole locations.) Geophysical logging of the surface boreholes has provided hydrologic information on the rock strata intercepted. Pressure measurements, fluid samples, and ranges of rock permeability have been obtained for selected formations through the use of standard and modified drill-stem and packer tests. Slug injection or withdrawal and tracer tests have provided additional data to aid in the estimation of transmissivity and storage of several water-bearing

units. Also, the hydraulic head of groundwaters within many water-bearing zones in the region has been mapped from measured depths to water and fluid pressure measurements in the surface boreholes.

D6-2a Groundwater Hydrology

Rock units that are important to WIPP hydrology are the Bell Canyon of the Delaware Mountain Group, the Castile, the Salado, the Rustler, the Dewey Lake, and the Santa Rosa (or Dockum Group) (Figures D6-27 and D6-28). Of these rock units, the Castile and the Salado are defined as aquitards (nonwater-transmitting layers of rock that bound an aquifer).

The Bell Canyon is of interest to the DOE because it is the first regionally continuous water-bearing unit beneath the WIPP. The Castile provides a hydrologic barrier underlying the Salado, though it may contain isolated occurrences of pressurized brine.

The Culebra is the first laterally continuous unit located above the WIPP underground facility to display hydraulic conductivity sufficient to warrant concern over lateral contaminant transport. Barring a direct breach to the surface, the Culebra provides the most direct pathway between the WIPP underground and the accessible environment. The hydrology and fluid geochemistry of the Culebra are very complex and, as a result, have received a great deal of study in WIPP site characterization. (See for example LaVenue et al. (1988), Haug et al. (1987), and Siegel et al. (1991) in the Bibliography.)

At the site, the Dewey Lake is 60 ft (18 m) below the surface and about 490 ft (149 m) thick. These units appear to be mostly unsaturated hydrologically in the vicinity of the WIPP shafts and over the waste emplacement panels.

At the WIPP site, the DOE recognizes the Culebra and the Magenta of the Rustler as the most significant water-bearing units. The DOE's sampling and analysis of groundwater has focused on these two rock units, and the hydrologic background presented here is more detailed than for other rock units. The hydrologic properties of the interface between the Rustler and the Salado will also be discussed. Table D6-2 provides an overview of the hydrologic characteristics of the rock units of interest at the WIPP site and the Rustler/Salado contact zone.

D6-2a(1) Conceptual Models of Groundwater Flow

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

An idealized groundwater basin is a three-dimensional closed hydrologic unit bounded on the bottom by an impermeable rock unit (units with much smaller permeability than the units above),

on the top by the ground surface, and on the sides by groundwater divides. The water table is the upper boundary of the region of saturated liquid flow. All rocks in the basin are expected to have finite permeability; in other words, hydraulic continuity exists throughout the basin. This means that the potential for liquid flow from any unit to any other units exists, although the existence of any particular flow path is dependent on a number of conditions related to gradients and permeabilities. All recharge to the basin is by infiltration of precipitation to the water table and all discharge from the basin is by flow across the water table to the land surface.

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

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

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

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

parallel to the direction between the highest and lowest points in a groundwater basin. Thus, flow rates, volumes, and directions in conductive units in a groundwater basin are generally not expected to be the same.

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

D6-2a(2) Units Below the Salado

Units of interest to the WIPP project below the Salado are the Bell Canyon and the Castile. These units have quite different hydrologic characteristics. Because of its potential to contain brine reservoirs below the repository, the hydrology of the Castile is regarded as having the most potential of all units below the Salado to impact the performance of the disposal system.

D6-2a(2)(a) Hydrology of the Bell Canyon Formation

The Bell Canyon is considered for the purposes of regional groundwater flow to form a single hydrostratigraphic unit about 1,000 feet (300 meters) thick. Tests at five boreholes (AEC-7, AEC-8, ERDA-10, DOE-2, and Cabin Baby) indicate a range of hydraulic conductivities for the Bell Canyon from 5×10^{-2} feet per day to 1×10^{-6} feet per day (1.7×10^{-7} to 3.5×10^{-12} meters per second). The pressure measured in the Bell Canyon at the DOE-2 and Cabin Baby boreholes ranges from 12.6 to 13.3 megapascals (Mercer 1983, 29–31; DOE 1983, 4-9 to 4-12; Beauheim 1986, 61–71). Fluid flow in the Bell Canyon is markedly influenced by the presence of the extremely low-permeability Castile and Salado above it, which effectively isolate it from interaction with overlying units except where the Castile is absent because of erosion or nondeposition, such as in the Guadalupe Mountains, or where the Capitan Reef is the overlying unit (Figures D6-27 and D6-28). Because of the isolating nature of the Castile and Salado, fluid flow directions in the Bell Canyon are sensitive only to gradients established over very long distances. At the WIPP, the brines in the Bell Canyon flow northeasterly under an estimated hydraulic gradient of 25 to 40 feet per mile (4.7 to 7.6 meters per kilometer) and discharge into the Capitan aquifer. Velocities are on the order of tenths of feet per year, and groundwater yields from wells in the Bell Canyon are 0.6 to 1.5 gallons (2.3 to 5.8 liters) per minute. The fact that flow directions in the Bell Canyon under the WIPP are inferred to be almost opposite to the flow directions in units above the Salado is not of concern because the presence of the Castile

and Salado makes the flow in the Bell Canyon sensitive to gradients established over long distances, whereas flow in the units above the Salado is sensitive to gradients established by more local variations in water table elevation.

D6-2a(2)(b) Castile Hydrology

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

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

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

D6-2a(2)(c) Hydrology of the Salado

The Salado consists mainly of halite and anhydrite. A considerable amount of information about the hydraulic properties of these rocks has been collected through field and laboratory experiments. Appendix D16 summarize this information.

Hydraulic testing in the Salado in the WIPP underground provided quantitative estimates of the hydraulic properties controlling brine flow through the Salado. The tests are interpreted by Beauheim et al. in 1991 and 1993 using models based on potentiometric flow. The tests influence rock as far as 10 meters distant from the test zone and are not thought to significantly alter the pre-test conditions of the rock. The stratigraphic intervals tested include both pure and

impure halite. Because tests close to the repository are within the DRZ that surrounds the excavated regions, it is reasonable to use the results of the tests farthest from the repository as most representative of undisturbed conditions.

Twenty-two hydraulic tests have been performed in impure halite, and two in pure halite. Interpreted permeabilities using a Darcy-flow model vary from 1×10^{-23} to 4×10^{-18} square meters for impure halite intervals. Interpreted formation pore pressures vary from 0.3 to 9.7 megapascals (MPa) for impure halite, with the lower pressures believed to show effects of the DRZ. Tests in pure halite show no observable response, indicating either extremely low permeability ($<10^{-23}$ square meters), or no flow whatsoever, even though appreciable pressures are applied to the test interval. Appendix D16 contains a summary of the results of field permeability tests to date.

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

The properties of anhydrite interbeds have also been investigated in the laboratory. Tests were performed on three groups of core samples from MB 139 as part of the Salado Two-Phase Flow Laboratory Program. The laboratory experiments provided porosity, intrinsic permeability, and capillary pressure data. Preliminary analysis of capillary pressure test results indicate a threshold pressure of less than 1 MPa. The laboratory-measured effective porosity and intrinsic permeability data are shown in Appendix D16.

Fluid pressure above hydrostatic is a hydrologic characteristic of the Salado (and the Castile) that plays a potentially important role in the repository behavior. It is difficult to accurately measure natural pressures in these formations because the boreholes or repository excavations required to access the rocks decrease the stress in the region measured. Stress released instantaneously decreases fluid pressure in the pores of the rock, so measured pressures must be considered as a lower bound of the natural pressures. Stress effects related to test location and the difficulty of making long-duration tests in lower-permeability rocks result in higher pore pressures observed to date in anhydrites. The highest observed pore pressure in halite-rich units, near Room Q, is on the order of 9 MPa, whereas the highest pore pressures observed in anhydrite are 12.5 MPa. It is expected that the far-field pore pressures in halite-rich and anhydrite beds in the Salado at the repository level are similar because the anhydrites are too thin and of too low permeabilities to have liquid pressures much different than those of the surrounding salt. For comparison, the hydrostatic pressure for a column of brine at the depth of the repository is about 7 MPa, and the lithostatic pressure calculated from density measurements in ERDA-9 is about 15 MPa.

Fluid pressure in sedimentary basins that are much higher or much lower than hydrostatic are referred to as abnormal pressures by the petroleum industry, where they have received considerable attention. In the case of the Delaware Basin evaporites, the high pressures are

almost certainly maintained because of the large compressibility and plastic nature of the halite and, to a lesser extent, the anhydrite. The lithostatic pressure at a particular horizon must be supported by a combination of the stress felt by both the rock matrix and the pore fluid. In highly deformable rocks, the portion of the stress that must be borne by the fluid exceeds hydrostatic pressure but cannot exceed lithostatic pressure.

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

Observation of the response of pore fluids in the Salado to changes in pressure boundary conditions at walls in the repository, in boreholes without packers, in packer-sealed boreholes, or in laboratory experiments is complicated by low permeability and low porosity. Qualitative data on brine flow to underground workings and exploratory boreholes have been collected routinely since 1985 under the Brine Sampling and Evaluation Program (BSEP) and have been documented in a series of reports (Deal and Case 1987; Deal et al. 1987, 1989, 1991a, 1991b, and 1993). Additional data on brine inflow are available from the Large-Scale Brine Inflow Test (Room Q). Flow has been observed to move to walls in the repository, to boreholes without packers, and to packer-sealed boreholes. In certain cases, evidence for flow is no longer observed where it once was; in others, flow has begun where it once was not observed. In many cases, observations and experiments must last for months or years to obtain useful results. In part because of design requirements such as duration (the experimental period is short relative to the time required for the geological materials to fully respond), few quantitative data have been obtained for brine flow into the excavated region at atmospheric pressure. For performance assessment modeling, brine flow is a calculated term dependent on local pressure gradients and hydraulic properties of the Salado units. Data on pore pressure and permeability of halite and anhydrite layers are available from the Room Q test and other borehole tests, and these data form the basis for the quantification of the material properties used in the performance assessment. See Appendix D16 for additional discussions of the properties of the Salado.

D6-2a(3) Units Above the Salado

In evaluating groundwater flow above the Salado, the DOE considers the Rustler, Dewey Lake, Santa Rosa, and overlying units to form a groundwater basin with boundaries coinciding with selected groundwater divides as discussed in Section D6-2a(i). The boundary follows Nash Draw and the Pecos River valley to the west and south and the San Simon Swale to the east (Figure D6-29). The boundary continues up drainages and dissects topographic highs along its northern part. It is assumed that these boundaries represent groundwater divides whose positions remain fixed over the past several thousand years and 10,000 years into the future. For reasons described in Section D6-2a(1), the lower boundary of the groundwater basin is the upper surface of the Salado.

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

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

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

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

The groundwater basin conceptual model described above has been implemented as a numerical model used to simulate the interactive nature of flow through conductive layers and confining units for a variety of possible rock properties and climate futures. Thus, this model has allowed insight into the magnitude of flow through various units.

One conclusion from the regional groundwater basin modeling is pertinent here. In general, vertical leakage through confining layers is directed downward over all of the area within the WIPP Site Boundary. This downward leakage uniformly over the WIPP site is the result of a well-developed discharge area, Nash Draw and the Pecos River, along the western and southern boundaries of the groundwater basin. This area acts as a drain for the laterally conductive units in the groundwater basin, causing most vertical leakage in the groundwater basin to occur in a downward direction. This conclusion is important in numerical modeling simplifications related to the relative importance of lateral flow in the Magenta versus the Culebra.

D6-2a(3)(a) Hydrology of the Rustler Formation

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

D6-2a(3)(a)(i) Unnamed Lower Member

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

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

D6-2a(3)(a)(ii) The Culebra

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

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

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

The hydraulic tests are designed to yield pressure data for the interpretation of such characteristics as transmissivity, permeability, and storativity. The pressure data from long-term pumping tests and the interpreted transmissivity values for individual wells are used for the generation of transmissivity fields in flow modeling. Some of the hydraulic test data and interpretations are also important for the interpretation of transport characteristics. For instance, the permeability values interpreted from the hydraulic tests at a given hydropad are needed for interpretations of tracer test data at that hydropad.

To evaluate transport properties of the Culebra, a series of tracer tests have been conducted at six locations (the H-2, H-3, H-4, H-6, H-11, and H-19 hydropads) near the WIPP site. The first five of these tests consisted of both two-well dipole tests and multi-well convergent flow tests and are described in detail in Jones et al. (1992). The more recent tracer test program consists of single-well injection-withdrawal tests and multi-well convergent flow tests. Unique features of this testing program include the injection of tracers into seven wells and the injection of tracer into an upper and a lower zone of Culebra at the H-19 hydropad, repeated injections under different convergent-flow pumping rates, and the use of tracers with different free-water diffusion coefficients at both the H-19 and H-11 hydropads. The recent tracer tests were specifically designed to evaluate the importance of heterogeneity and diffusion on transport processes.

The Culebra is a fractured dolomite with nonuniform properties both horizontally and vertically. There are multiple scales of porosity (and permeability) within the Culebra, including fractures ranging from microscale to potentially large, vuggy zones, and inter- and intragranular porosity. Flow occurs within fractures, vuggy zones and probably to some extent in intergranular porosity. (In other words, flow occurs in response to hydraulic gradients in all places that are permeable). When the permeability contrast is large between different scales of connected porosity, transport processes can be distinguished as those occurring within advective porosity ϕ_a (typically referred to as fracture porosity) and those occurring within diffusional porosity ϕ_d (typically referred to as matrix porosity). Matrix porosity traditionally refers to inter- and intragranular porosity.

Diffusional (matrix) porosity in the Culebra may include other features such as microfractures and/or vugs. In some regions, the effective advective porosity of the Culebra is limited because a portion of the porosity has been partially or even almost totally filled by gypsum.

For the Culebra in the vicinity of the WIPP site, defining advective porosity is not a simple matter. Three regions with different types of advective porosity may be present: (1) regions with no open fractures, where matrix flow dominates and ϕ_a would refer to the connected matrix porosity; (2) regions with some open fractures, where advective flow occurs through matrix and fractures having permeabilities of similar magnitudes, where ϕ_a refers to some combination of the connected matrix porosity and the connected fracture porosity; and (3) regions with some large-aperture, open fractures with most advective flow in the fractures, where ϕ_a refers to the connected fracture porosity. It is thought that the dominant mode of advective transport may vary from location to location within the Culebra at the WIPP site.

The major physical transport processes that affect actinide transport through the Culebra include advection (through fractures and possibly other permeable porosity), matrix diffusion (between fractures and matrices [the matrix may include vugs and small fractures] or, more generally, diffusion between adjacent regions with large permeability contrasts), and dispersive spreading due to heterogeneity. For locations with advective transport occurring primarily within large-aperture fractures, the Culebra can most likely be considered to behave as a double-porosity medium (i.e., ϕ_a and ϕ_d are present).

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

There is strong evidence that the permeability of the Culebra varies spatially and varies sufficiently that it cannot be characterized with a uniform value or range over the region of interest to the WIPP. The transmissivity of the Culebra varies spatially over six orders of magnitude from east to west in the vicinity of the WIPP (Figure D6-30). Over the site, Culebra transmissivity varies over three to four orders of magnitude. Figure D6-30 shows variation in transmissivity in the Culebra in the WIPP region. Transmissivities are from 1×10^{-3} square feet per day (1×10^{-9} square meters per second) at well P-18 east of the WIPP site to 1×10^{3} square feet per day (1×10^{-3} square meters per second) at well H-7 in Nash Draw.

Transmissivity variations in the Culebra are believed to be controlled by the relative abundance of open fractures rather than by primary (that is, depositional) features of the unit. Lateral variations in depositional environments were small within the mapped region, and primary

features of the Culebra show little map-scale spatial variability, according to Holt and Powers 1988. Direct measurements of the density of open fractures are not available from core samples because of incomplete recovery and fracturing during drilling, but observation of the relatively unfractured exposures in the WIPP shafts suggests that the density of open fractures in the Culebra decreases to the east. Qualitative correlations have been noted between transmissivity and several geologic features possibly related to open-fracture density, including (1) the distribution of overburden above the Culebra, (2) the distribution of halite in other members of the Rustler, (3) the dissolution of halite in the upper portion of the Salado, and (4) the distribution of gypsum fillings in fractures in the Culebra.

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

Geochemical and radioisotope characteristics of the Culebra have been studied. There is considerable variation in groundwater geochemistry in the Culebra. The variation has been described in terms of different hydrogeochemical facies that can be mapped in the Culebra. A halite-rich hydrogeochemical facies exists in the region of the WIPP site and to the east, approximately corresponding to the regions in which halite exists in units above and below the Culebra, and in which a large portion of the Culebra fractures are gypsum filled. An anhydrite-rich hydrogeochemical facies exists west and south of the WIPP site, where there is relatively less halite in adjacent strata and where there are fewer gypsum-filled fractures. Radiogenic isotopic signatures suggest that the age of the groundwater in the Culebra is on the order of 10,000 years or more (see, for example, Lambert 1987, Lambert and Carter 1987, and Lambert and Harvey 1987).

The radiogenic ages of the Culebra groundwater and the geochemical differences provide information potentially relevant to the groundwater flow directions and groundwater interaction with other units and are important constraints on conceptual models of groundwater flow. Previous conceptual models of the Culebra (see for example, Chapman 1986, Chapman 1988, LaVenue et al. 1990, and Siegel et al. 1991) have not been able to consistently relate the hydrogeochemical facies, radiogenic ages, and flow constraints (that is, transmissivity, boundary conditions, etc.) in the Culebra.

The groundwater basin modeling that has been conducted, although it did not model solute transport processes, provides flow fields that reasonably explain observed hydrogeochemical facies and radiogenic ages. The groundwater basin model combines and tests three fundamental processes: (1) it calculates vertical leakage, which may carry solutes into the Culebra; (2) it calculates lateral fluxes in the Culebra (directions as well as rates); and (3) it calculates a range of possible effects of climate change. The presence of the halite facies is explained by vertical leakage of solutes into the Culebra from the overlying halite-containing Tamarisk by advective or diffusive processes. Because lateral flow rates here are low, even slow rates of solute transport into the Culebra can result in high solute concentration. Vertical

leakage occurs slowly over the entire model region, and thus the age of groundwater in the Culebra is old, consistent with radiogenic information. Lateral fluxes within the anhydrite zone are larger because of higher transmissivity, and where the halite and anhydrite facies regions converge, the halite facies signature is lost by dilution with relatively large quantities of anhydrite facies groundwater.

Groundwater levels in the Culebra in the WIPP region have been measured continuously for several decades. Water-level rises have been observed in the WIPP region and are attributed to three causes as discussed below. The extent of water-level rise observed at a particular well depends on several factors, but the proximity of the observation point to the cause of the water-level rise appears to be a primary factor.

In the vicinity of the WIPP site, water-level rises are unquestionably caused by recovery from drainage into the shafts. Drainage into shafts has been reduced by a number of grouting programs over the years, most recently in 1993 around the AIS. Northwest of the site, in and near Nash Draw, water levels appear to fluctuate in response to effluent discharge from potash mines. Correlation of water-level fluctuation with potash mine discharge cannot be proven because sufficient data on the timing and volumes of discharge are not available. Head distribution in the Culebra (Figure D6-31) is consistent with groundwater basin modeling results indicating that the generalized directional flow of groundwater is north to south. However, caution should be used when making assumptions based on groundwater-level data alone. Studies in the Culebra have shown that fluid density variations in the Culebra can affect flow direction. One should also be aware that the fractured nature of the Culebra, coupled with variable fluid densities, can also cause localized flow patterns to differ from general flow patterns. Water-level rises in the vicinity of the H-9 hydropad, about 6.5 miles south of the site, are thought to be caused by either WIPP activities or potash mining discharge. They remain unexplained. The DOE continues to monitor groundwater levels throughout the region, but only water level changes at or near the site have the potential to affect performance.

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

D6-2(a)(3)(a)(iii) <u>The Tamarisk</u>

The Tamarisk acts as a confining layer in the groundwater basin model. Attempts were made in two wells, H-14 and H-16, to test a 7.9-foot (2.4-meter) sequence of the Tamarisk that consists of claystone, mudstone, and siltstone overlain and underlain by anhydrite. Permeability was too low to measure in either well within the time allowed for testing; consequently, Beauheim (1987a, 108–110) estimated the transmissivity of the claystone sequence to be one or more orders of magnitude less than that of the tested interval in the unnamed lower member (that is, less than approximately 2.5×10^{-5} square feet per day [2.7×10^{-11} square meters per second]). The

porosity of the Tamarisk was measured in 1995 as part of testing at the H-19 hydropad. Two claystone samples had an effective porosity of 21.3 to 21.7 percent. Five anhydrite samples had effective porosities of 0.2 to 1.0 percent.

D6-2(a)(3)(a)(iv) The Magenta

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

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

The hydraulic gradient across the site varies from 16 to 20 feet per mile (3 to 4 meters per kilometer) on the eastern side, steepening to about 32 feet per mile (6 meters per kilometer) along the western side near Nash Draw (see Figure D6-32).

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

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

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

D6-2a(3)(a)(v) The Forty-niner

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

D6-2a(3)(b) Hydrology of the Dewey Lake and the Santa Rosa

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

D6-2a(3)(b)(i) The Dewey Lake

The Dewey Lake contains a productive zone of saturation, probably under water-table conditions, in the southwestern to south-central portion of the WIPP site and south of the site. Several wells operated by the J.C. Mills Ranch south of the WIPP site produce sufficient quantities of water from the Dewey Lake to supply livestock. Short-term production rates of 25 to 30 gallons per minute (5.7 to 6.8 cubic meters per hour) were observed in boreholes P-9 (Jones 1978, Vol. 1., 167 and 168), WQSP-6, and WQSP-6a. The productive zone is typically found in the middle of the Dewey Lake, 180 to 265 feet (55 to 81 meters) below ground surface and appears to derive much of its transmissivity from open fractures. Where present, the saturated zone may be perched or simply underlain by less transmissive rock. Fractures below the productive zone tend to be completely filled with gypsum. Open fractures and/or moist (but not fully saturated) conditions have been observed at similar depths north of the zone of saturation, at the H-1, H-2, and H-3 boreholes (Mercer 1983). The Dewey Lake has not produced water within the WIPP shafts or in boreholes in the immediate vicinity of the panels. For modeling purposes, the hydraulic conductivity of the Dewey Lake, assuming saturation, is estimated to be 3×10^{-3} feet per day (10^{-8} meters per second), corresponding to the hydraulic conductivity of fine-grained sandstone and siltstone. The porosity of the Dewey Lake was measured as part of testing at the H-19 hydropad. Four samples taken above the gypsum-sealed region had measured effective porosities of 14.9 to 24.8 percent. Four samples taken from within the gypsum-sealed region had porosities from 3.5 to 11.6 percent.

The groundwater basin conceptual model relies on gradients established from the position of the water table for the driving force for flow. The DOE has estimated the position of the water table in the southern half of the WIPP site from an analysis of drillers' logs from three potash exploration boreholes and five hydraulic test holes. These logs record the elevation of the first moist cuttings recovered during drilling. Assuming that the first recovery of moist cuttings indicates a minimum elevation of the water table, an estimate of the water table elevation can be made, and the estimated water table surface can be contoured. This method indicates that the elevation of the water table over the WIPP waste panels may be about 980 meters above sea level, as shown in Figure D6-33.

D6-2a(3)(b)(ii) The Santa Rosa

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

D6-2a(4) Hydrology of Other Groundwater Zones of Regional Importance

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

D6-2a(4)(a) The Capitan Limestone

The Capitan, which outcrops in the southern end of the Guadalupe Mountains, is a massive limestone unit that grades basinward into recemented, partly dolomitized reef breccia and shelfward into bedded carbonates and evaporites. A deeply incised submarine canyon near the Eddy-Lea county line has been identified. This canyon is filled with sediments of lower permeability than the Capitan and, according to Hiss (1976) restricts fluid flow. The hydraulic conductivity of the Capitan ranges from 1 to 25 feet per day (3×10^{-6} to 9×10^{-5} meters per second) in southern Lea County and is 5 feet per day (1.7×10^{-5} meters per second) east of the Pecos River at Carlsbad. Hiss reported in 1976 that average transmissivities around the northern and eastern margins of the Delaware Basin are 10,000 square feet per day (0.01 square meters per second) in thick sections and 500 square feet per day (5.4×10^{-4} square meters per second) in incised submarine canyons. Water table conditions are found in the Capitan aquifer southwest of the Pecos River at Carlsbad; however, artesian conditions exist to the north and east. The hydraulic gradient to the southeast of the submarine canyon near the Eddy-Lea county line has been affected by large oil field withdrawals. The Capitan limestone is recharged by percolation through the northern shelf aquifers, by flow from the south and west from underlying basin aquifers and by direct infiltration at its outcrop in the Guadalupe

Mountains. The Capitan is important in the regional hydrology because breccia pipes in the Salado have formed over it, most likely in response to the effects of dissolution by groundwater flowing in the Castile along the base of the Salado (see Davies 1984).

D6-2a(4)(b) Hydrology of the Rustler-Salado Contact Zone in Nash Draw

In Nash Draw the contact between the Rustler and the Salado is an unstructured residuum of gypsum, clay, and sandstone created by the dissolution of halite and has been known as the brine aquifer, Rustler-Salado residuum, and residuum. The residuum is absent under the WIPP site. It is clear that dissolution in Nash Draw occurred after deposition of the Rustler. As described previously, the topographic low formed by Nash Draw is a groundwater divide in the groundwater basin conceptual model of the units above the Salado. The brine aquifer is shown in Figure D6-34.

Robinson and Lang described the brine aquifer in 1938 and suggested that the structural conditions that caused the development of Nash Draw might control the occurrence of the brine; thus, the brine aquifer boundary may coincide with the topographic surface expression of Nash Draw. Their studies show brine concentrated along a strip from 2 to 8 miles (3.3 to 13 kilometers) wide and about 26 miles (43 kilometers) long. Data from the test holes that Robinson and Lang drilled indicate that the residuum (containing the brine) ranges in thickness from 10 to 60 feet (3 to 18 meters) and averages about 24 feet (7 meters).

In 1954, hydraulic properties were determined by Hale et al., primarily for the area between Malaga Bend on the Pecos River and Laguna Grande de la Sal. They calculated a transmissivity value of 8,000 square feet per day (8.6×10^{-3} square meters per second) and estimated the potentiometric gradient to be 1.4 feet per mile (0.27 meter per kilometer). In this area, the Rustler-Salado residuum apparently is part of a continuous hydrologic system, as evidenced by the coincident fluctuation of water levels in the test holes (as far away as Laguna Grande de la Sal) with pumping rates in irrigation wells along the Pecos River.

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

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

The average hydraulic gradient within the residuum in Nash Draw is about 10 feet per mile (1.9 meters per kilometer); in contrast, the average gradient at the WIPP site is 39 feet per mile (7.4 meters per kilometer). This difference reflects the changes in transmissivity, which are as much as five orders of magnitude greater in Nash Draw. The transmissivity determined from aquifer tests in test holes completed in the Rustler-Salado contact residuum of Nash Draw ranges from 2×10^{-4} square feet per day (2.1×10^{-10} square meters per second) at WIPP-27 to 8 square feet per day (8.6×10^{-6} square meters per second) at WIPP-29. This is in contrast to the WIPP site proper, where transmissivities range from 3×10^{-5} square feet per day (3.2×10^{-11} square meters per second) at test holes P-18 and H-5c to 5×10^{-2} square feet per day (5.4×10^{-8} square meters per second) at test hole P-14. Locations and estimated hydraulic heads of these wells are illustrated in Figure D6-35.

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

According to Mercer (1983, 55), water in the Rustler-Salado contact residuum in Nash Draw contains the largest concentrations of dissolved solids in the WIPP area, ranging from 41,500 milligrams per liter in borehole H-1 to 412,000 milligrams per liter in borehole H-5c. These waters are classified as brines. The dissolved mineral constituents in the brine consist mostly of sulfates and chlorides of calcium, magnesium, sodium, and potassium; the major constituents are sodium and chloride. Concentrations of the other major ions vary according to the spatial location of the sample, are probably directly related to the interaction of the brine and the host rocks, and reflect residence time within the rocks. Residence time of the brine depends upon the transmissivity of the rock. For example, the presence of large concentrations of potassium and magnesium in water is correlated with minimal permeability and a relatively undeveloped flow system.

D6-2b Surface-Water Hydrology

The WIPP site is in the Pecos River basin, which contains about 50 percent of the drainage area of the Rio Grande Water Resources Region. The Pecos River headwaters are west of Las Vegas, New Mexico, and the river flows to the south through eastern New Mexico and western Texas to the Rio Grande. The Pecos River has an overall length of about 500 mi (805 km), a maximum basin width of about 130 mi (209 km), and a total drainage area of about 44,535 mi^2 (115,301 km^2) (about 20,500 mi^2 [53,075 mi^2] contained within the basin have no external surface drainage and their surface waters do not contribute to Pecos River flows). Figure D6-36 shows the Pecos River drainage area.

The Pecos River is generally perennial, except in the reach below Anton Chico and between Fort Sumner and Roswell, where the low flows percolate into the stream bed. The main stem of the Pecos River and its major tributaries have low flows, and the streams are frequently dry. About

75 percent of the total annual precipitation and 60 percent of the annual flow result from intense local thunderstorms between April and September. The principal tributaries of the Pecos River in New Mexico, in downstream order, are the Gallinas River, Salt Creek, the Rio Hondo, the Rio Felix, the Eagle Creek, the Rio Peñasco, the Black River, and the Delaware River.

There are no perennial streams at the WIPP site. At its nearest point, the Pecos River is about 12 mi (19 km) southwest of the WIPP site boundary. The drainage area of the Pecos River at this location is 19,000 mi^2 (47,500 km^2). A few small creeks and draws are the only westward-flowing tributaries of the Pecos River within 20 mi (32 km) north or south of the site. A low-flow investigation has been initiated by the USGS within the Hill Tank Draw drainage area, the most prominent drainage feature near the WIPP site. The drainage area is about 4 mi^2 (10 km^2) with an average channel slope of 1 to 100, and drainage westward into the Nash Draw. Two years of observations showed only four flow events. The USGS estimates that the flow rate for these events was under 2 cubic ft (ft^3) per sec (0.057 cubic meters [m^3] per sec). The Black River (drainage area: 400 mi^2 [1,035 km^2]) joins the Pecos from the west about 16 mi (25 km) southwest of the site. The Delaware River (drainage area: 700 mi^2 [1,812 km^2] and a number of small creeks and draws also join the Pecos River along this reach. The flow in the Pecos River below Fort Sumner is regulated by storage in Sumner Lake, Brantley Reservoir, Lake Avalon, and several other smaller irrigation dams.

Four major reservoirs are located in the Pecos River basin: Sumner Lake, Brantley Reservoir, Lake Avalon, and Red Bluff Reservoir, the last located just over the border in Texas (Figure D6-36). The storage capacities of these reservoirs and other Pecos River reservoirs adjacent to the Pecos River basin are shown in Table D6-3.

With regards to surface drainage onto and off of the WIPP site, there are no major lakes or ponds within 5 mi (8 km) of the site. The Laguna Gatuña, Laguna Tonto, Laguna Plata, and Laguna Toston are playas more than 10 mi (16 km) north of the site and are at elevations of 3,450 ft (1050 m) or higher. Thus, surface runoff from the site (elevation 3,310 ft [1010 m] above sea level) would not flow toward any of them. To the north, west, and northwest, Red Lake, Lindsey Lake, the Laguna Grande de la Sal, and a few unnamed stock tanks are more than 10 mi (16 km) from the site, at elevations of from 3,000 to 3,300 ft (914 to 1,006 m).

The mean annual precipitation in the region is about 12 in. (0.3 m), and the mean annual runoff is 0.1 to 0.2 in. (2.5 to 5 mm). The maximum recorded 24-hour precipitation at Carlsbad was 5.12 in. (130 mm) in August 1916. The predicted maximum 6-hour, 100-year precipitation event for the site is 3.6 in. (91 mm) and is most likely to occur during the summer.

The maximum recorded flood on the Pecos River occurred near the town of Malaga, New Mexico, on August 23, 1966, with a discharge of 120,000 ft^3 (3,396 m^3) per sec and a stage elevation of about 2,938 ft (895 m) above mean sea level. The minimum surface elevation of the WIPP site is over 500 ft (152 m) above the river bed and over 400 ft (122 m) above the elevation of this maximum historical flood elevation (DOE, 1980, §7.4.1).

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

Water quality in the Pecos River basin is affected by mineral pollution from natural sources and from irrigation return flows. At Santa Rosa, New Mexico, the average suspended-sediment discharge of the river is about 1,650 tons (1,819 metric tons [1,000 kg]) per day. Large amounts of chlorides from Salt Creek and Bitter Creek enter the river near Roswell. River inflow in the Hagerman area contributes increased amounts of calcium, magnesium, and sulfate; and waters entering the river near Lake Arthur are high in chloride. Below Brantley Reservoir, springs flowing into the river are usually submerged and difficult to sample; springs that could be sampled had TDS concentrations of from 3,350 to 4,000 ppm (3,350 to 4,000 mg/L). Concentrated brine entering at Malaga Bend adds an estimated 70 tons per day of chloride to the Pecos River.

D6-2c Groundwater Discharge and Recharge

The only documented points of naturally occurring groundwater discharge in the vicinity of the WIPP are the saline lakes in the Nash Draw and the Pecos River, primarily near Malaga Bend. Although this is local flow associated with the Nash Draw and unrelated to groundwater flow at the WIPP site, it is presented here for completeness. Discharge into one of the lakes from Surprise Spring (see Figure D6-1) was measured by Hunter in 1985 at a rate of less than 0.35 ft^3 (0.01 m^3) per second in 1942. Hunter also estimated total groundwater discharge into the lakes is 24 ft^3 (0.67 m^3) per second. According to Mercer (1983) discharge from the spring comes from fractured and more transmissive portions of the Tamarisk of the Rustler, and the lakes are hydraulically isolated from the Culebra and lower units.

Groundwater discharge into the Pecos River is greater than discharge into the saline lakes. Groundwater discharge into the Pecos River between Avalon Dam north of Carlsbad and a point south of Malaga Bend was no more than approximately 32.5 ft^3 (0.92 m^3) per sec . Most of this gain in stream flow occurs near Malaga Bend (see Figure D6-1) and is the result of groundwater discharge from the residuum at the Rustler/Salado contact zone.

The only documented point of groundwater recharge is also near Malaga Bend, where an almost immediate water-level rise has been reported by Hale et al. in 1954 in a Rustler-Salado well following a heavy rainstorm. This location is hydraulically downgradient from the repository, and recharge here has little relevance to flow near the WIPP. Examination of the potentiometric surface map for the Rustler/Salado contact zone indicates that some inflow may occur north of the WIPP, where freshwater equivalent heads are highest. Additional inflow to the contact zone may occur as leakage from overlying units, particularly where the units are close to the surface and under water-table conditions.

No direct evidence exists for the location of either recharge to or discharge from the Culebra. The freshwater-head surface map (Figure D6-31) implies inflow from the north and outflow to the

south. Recharge from the surface probably occurs 9 to 19 mi (15 to 30 km) northwest of the WIPP in and north of Clayton Basin where the Rustler crops out. An undetermined amount of inflow may also occur as leakage from overlying units throughout the region.

The freshwater-head contour map (Figure D6-31) indicates that flow in the Culebra is toward the south. Some of this southerly flow may enter the Rustler/Salado contact zone under water table conditions near Malaga Bend and may ultimately discharge into the Pecos River. Additional flow may discharge directly into the Pecos River or into alluvium in the Balmorhea/Loving Trough to the south.

Recharge to the Magenta may also occur north of the WIPP in Bear Grass Draw and Clayton Basin. The potentiometric surface map indicates that discharge is toward the west in the vicinity of the WIPP, probably into the Tamarisk and the Culebra near the Nash Draw. Some discharge from the Magenta may ultimately reach the saline lakes in the Nash Draw. According to Brinster in 1991, additional discharge probably reaches the Pecos River at Malaga Bend or the alluvium in the Balmorhea/Loving Trough.

Isotopic data from groundwater samples suggest that groundwater travel time from the surface to the Dewey Lake and the Rustler is long and rates of flow are extremely slow. Based on observations by Lambert and Harvey reported in 1987, low tritium levels in all WIPP-area samples indicate minimal contributions from the atmosphere since 1950. Lambert in 1987 indicated four modeled radiocarbon ages from the Rustler and the Dewey Lake groundwater are between 12,000 and 16,000 years. The uranium isotope activity ratios observed require a conservative minimum residence time in the Culebra of several thousands of years and more probably reflect minimum ages of from 10,000 to 30,000 years.

Potentiometric data from four wells support the conclusion that little infiltration from the surface reaches the transmissive units of the Rustler. Hydraulic head data are available for a claystone in the Forty-niner from wells DOE-2, H-3, H-4, H-5, and H-6. Beauheim, in 1987, compared these heads to heads in the surrounding Magenta wells and showed that flow between the units at all four wells may be upward. This observation offers no insight into the possibility of infiltration reaching the Forty-niner, but it rules out the possibility of infiltration reaching the Magenta or any deeper units at these locations.

D6-2d Water Quality

This section presents a discussion of the quality of groundwater and surface water in the WIPP area.

D6-2d(1) Groundwater Quality

Based on the major solute compositions described by Siegel et al. in 1991, four hydrochemical facies are delineated for the Culebra.

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

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

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

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

This zonation is consistent with that described by Ramey in 1985, who defined three zones. The fourth zone (D) was added by Siegel et al. in 1991 to account for the local potash contamination. Together, the variations in solutes and the distribution of halite in the Rustler exhibit a mutual interdependence. Concentrations of solutes are lowest where Rustler halite is less abundant, consistent with the hypothesis that solutes in Rustler groundwaters are derived locally by dissolution of minerals (e.g., halite, gypsum, and dolomite) in adjacent strata.

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

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

D6-2d(2) Surface-Water Quality

The Pecos River is the nearest permanent water source to the WIPP site. Natural brine springs, representing outfalls of the brine aquifers in the Rustler, feed the Pecos River at Malaga Bend, 12 mi (19 km) southwest of the site. This natural saline inflow adds approximately 70 tons of chloride per day to the Pecos River. Return flow from irrigated areas above Malaga Bend further contributes to the salinity. The concentrations of potassium, mercury, nickel, silver, selenium, zinc, lead, manganese, cadmium, and barium also show significant elevations at Malaga Bend but tend to decrease downstream. The metals presumably are rapidly adsorbed onto the river sediments. Natural levels of certain heavy metals in the Pecos River below Malaga Bend exceed the water quality standards of the World Health Organization, the U.S. Environmental Protection Agency, and the State of New Mexico. For example, the water quality standards specify a maximum level for lead is 50 parts per billion (ppb); however, levels of up to 400 ppb have been measured.

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

D6-3 Resources

The topic of resources is used to broadly define both economic (mineral and nonmineral) and cultural resources associated with the WIPP site. These resources are important since they 1) provide evidence of past uses of the area, and 2) indicate potential future use of the area with the possibility that such use could lead to disruption of the closed repository. Because of the depth of the disposal horizon, it is believed that only the mineral resources are of significance in predicting the long-term performance of the disposal system. However, the nonmineral and cultural resources are presented for completeness.

This section refers to the significance of specific natural resources that lie beneath the WIPP site. Resources are minerals or hydrocarbons that are potentially of economic value. Reserves are the portion of resources that are economic at today's market prices and with existing technology.

For hydrocarbons, proven reserves can be expected to be recovered from new wells on undrilled acreage or from existing wells where a relatively major expenditure is required to establish production. Probable reserves refer to reserves of hydrocarbons suspected of existing in certain locations based on favorable engineering and/or geologic data. Possible reserves are based on conditions where limited engineering and/or geologic data support recoverable potential.

Mineral resource discussions are focused principally on hydrocarbons and potassium salts, both of which have long histories of development in the region and both of which could be disruptive to the disposal system. The information regarding the mineral resources concentrates on the following factors:

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

In addition to extractable resources, this section includes cultural and economic resources. These are focused on a description of past and present land uses unrelated to the development of minerals. The archaeological record supports the observation that changes on land use are principally associated with climate and the availability of forage for wild and domestic animals. In no case does it appear that past or present land use has had an impact on the subsurface beyond the development of shallow groundwater wells for watering livestock.

D6-3a Extractable Resources

The geologic studies of the WIPP site have included the investigation of potential natural resources to evaluate the impact of denying access to these resources and other consequences of their occurrence. This study was completed in support of the *Final Environmental Impact Statement* (FEIS) (DOE, 1980) to ensure knowledge of natural resources once the impacts of their denial was included in the decision-making process for the WIPP. Of the natural resources expected to occur beneath the site, five are of practical concern: first, the two potassium salts sylvite and langbeinite, which occur in strata above the repository salt horizon, and , the three hydrocarbons crude oil, natural gas, and distillate liquids associated with natural gas, which occur in strata below the repository horizon. Other mineral resources beneath the site are caliche, salt, gypsum, and lithium; enormous deposits of these minerals near the site and elsewhere in the country are more than adequate (and more economically attractive) to meet future requirements for these materials. In 1995 the NMBMMR performed a reevaluation of the mineral resources at and within 1 mi (1.6 km) around the WIPP site.

D6-3a(1) Potash Resources at the WIPP Site

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

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

The 1995 study contains a comprehensive summary of all previous evaluations.

Griswold (in NMBMMR, 1995, Chapter VII) used 40 existing boreholes drilled on and around the WIPP site to perform a reevaluation of potash resources. Holes were drilled using brine so that the dissolution of potassium salts was inhibited. The results of the chemical analyses of the ore-bearing intervals were adjusted to calculate the percentage equivalent as individual natural mineral species. Only the K_2O (potassium oxide) percentages as either sylvite or langbeinite were used to compute ore reserves. The conclusion reached by Griswold is that only the 4th and 10th ore zones contain economic potash reserves. The quantities are summarized in Table D6-4.

D6-3a(2) Hydrocarbon Resources at the WIPP Site

In 1974 the NMBMMR conducted a hydrocarbon resource study in southeastern New Mexico under contract to ORNL. The study included an area of 1,512 mi^2 (3,914 km^2). At the time of that study, the proposed repository site was about 5 mi (8 km) northeast of the current site. The NMBMMR evaluation included a more detailed study of a four-township area centered on the old site; the present site is in the southwest quadrant of that area. The NMBMMR hydrocarbon resources study is presented in more detail in the FEIS (DOE, 1980, §9.2.3.5). The reader is referred to the FEIS or the original study (Foster, 1974) for additional information.

The resource evaluation was based both on the known reserves of crude oil and natural gas in the region and on the probability of discovering new reservoirs in areas where past unsuccessful drilling was either too widely spread or too shallow to have allowed discovery. All potentially productive zones were considered in the evaluation; therefore, the findings may be used for determining the total hydrocarbon resources at the site. A fundamental assumption in this study was that the WIPP area has the same potential for containing hydrocarbons as the much larger region in which the study was conducted and for which exploration data are available. Whether such resources actually exist can be satisfactorily established only by drilling at spacings close enough to give a high probability of discovery. A 1995 mineral resource reevaluation by the NMBMMR contains a comprehensive summary of this and other previous evaluations.

Broadhead et al. (NMBMMR, 1995, Chapter XI) provided a reassessment of hydrocarbon resources within the WIPP site boundary and within the first mile adjacent to the boundary. Calculations were made for resources that are extensions of known, currently productive oil and gas resources that are thought to extend beneath the study area with reasonable certainty (called probable resources in the report). Qualitative estimates are also made concerning the likelihood that oil and gas may be present in undiscovered pools and fields in the area (referred to as possible resources). Possible resources were not quantified in the study. The results of the study are shown in Tables D6-5 and D6-6.

D6-3b Cultural and Economic Resources

D6-3b(1) Demographics

The WIPP facility is located 26 mi (42 km) east of Carlsbad in Eddy County in southeastern New Mexico and includes an area of 10,240 acres (ac) (4,143 hectares [ha]). The facility is located in a sparsely populated area with fewer than 30 permanent residents living within a 10-mi (16-km) radius of the facility. The area surrounding the facility is used primarily for grazing, potash mining, and hydrocarbon production. No resource development that would affect WIPP facility operations or the long-term integrity of the facility is allowed within the 10,240 ac (4,143 ha) that have been set aside for the WIPP Project.

The community nearest to the WIPP site is the town of Loving, New Mexico, 18 mi (29 km) west-southwest of the site center. The population of Loving decreased from 1,355 in 1980 to 1,243 in 1990. The nearest population center is the city of Carlsbad, New Mexico, 26 mi (42 km) west of the site. The population of Carlsbad has decreased from 25,496 in 1980 to 24,896 in 1990. Hobbs, New Mexico, 36 mi (58 km) to the east of the site had a 1980 population of 29,153 and a 1990 population of 29,115. Eunice, New Mexico, 40 mi (64 km) east of the site, had a 1980 population of 2,970 and a 1990 population of 2,731. Jal, New Mexico, 45 mi (72 km) southeast of the site, had a population of 2,575 in 1980 and of 2,153 in 1990.

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

D6-3b(2) Land Use

At present, land within 10 mi (16 km) of the site is used for potash mining operations, active oil and gas wells, and grazing. This pattern is expected to change little in the future.

The WIPP Land Withdrawal Act of 1992 (LWA) provided for the transfer of the WIPP site lands from the Department of the Interior to the DOE and effectively withdraws the lands, subject to existing rights, from entry, sale, or disposition; appropriation under mining laws; and operation of the mineral and geothermal leasing laws. The LWA directed the Secretary of Energy to produce a management plan to provide for grazing, hunting and trapping, wildlife habitat, mining,

and the disposal of salt tailings.

There are no producing hydrocarbon wells within the volumetric boundary defined by the land withdrawal (T22S, R31E, S15-22, 27-34). One active well, referred to as James Ranch 13, was drilled in 1982 to tap gas resources beneath Section 31. This well was initiated in Section 6, outside the WIPP site boundary. The well enters Section 31 below a depth of 6,000 ft (1.82 km) beneath ground level.

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

D6-3b(3) History and Archaeology

The WIPP site boundary consists of a 10,240-ac (16-m^2) area located in southeastern New Mexico. From about 10,000 B.C. to the late 1800s, this region was inhabited by nomadic aboriginal hunters and gatherers who subsisted on various wild plants and animals. From about A.D. 600 onward, as trade networks were established with Puebloan peoples to the west, domesticated plant foods and materials were acquired in exchange for dried meat, hides, and other products from the Pecos Valley and Plains. In the mid-1500s, the Spanish Conquistadors encountered Jumano and Apachean peoples in the region practicing hunting and gathering and engaging in trade with Puebloans. After the Jumanos abandoned the southern Plains region, the Comanches became the major population of the area. Neighboring populations, with whom the Comanches maintained relationships ranging from mutual trade to open warfare, included the Lipan, or Southern Plains Apache; several Puebloan groups; Spaniards; and the Mescalero Apaches.

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

A peace accord reached between the Comanches and the Spaniards in 1768 resulted in two historically important economic developments: 1) organized buffalo hunting by Hispanic and Puebloan "ciboleros," and 2) renewal and expansion of the earlier extensive trade networks by Comancheros. These events placed eastern New Mexico in a position to receive a wide array of both physical and ideological input from the Plains culture area to the east and north and from Spanish-dominated regions to the west and south. Comanchero trade began to mesh with the Southwest American trade influence in the early nineteenth century. However, by the late 1860s the importance of Comanchero trade was cut short by Texan influence.

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

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

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

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

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

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

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

Since 1976, cultural resource investigations have recorded 98 archaeological sites and numerous isolated artifacts within the 16-mi^2 (41.5-km^2) area enclosed by the WIPP site boundary. In the central 4-mi^2 (10.4-km^2) area, 33 sites were determined to be eligible for inclusion on the National Register as an archaeological district. Investigations since 1980 have recorded an additional 14 individual sites outside the central 4-mi^2 (10.4-km^2) area that are considered eligible for inclusion on the National Register. The major cultural resource investigations to date are broken out in the following. Additional information can be found in the bibliography.

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

1979 MacLennan and Schermer of ACA performed the next survey in 1979. It was conducted for access roads and a railroad right-of-way for Bechtel, Inc. The survey encountered 2 sites and 12 isolated artifacts.

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

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

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

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

1987 Mariah Associates, Inc., identified 40 sites and 75 isolates in 1987 in an inventory of 2,460 ac in 15 quarter-section units surrounding the WIPP site. In this investigation, 19 of the sites were located within the WIPP site's boundary. Sites encountered in this investigation tended to lack evident or intact features. Of the 40 new sites defined, 14 were considered eligible for inclusion in the National Register, 24 were identified as having insufficient data to determine eligibility, and 2 were determined to be ineligible for inclusion. The eligible and potentially eligible sites have been mapped and are being avoided by the DOE in its current activities at the WIPP site. Figure D6-37 maps out the 40 archaeological sites identified by the Mariah study.

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

The Delaware Basin has been used in the past for an isolated nuclear test. This test, Project Gnome, took place in 1961 at a location approximately 8 mi (13 km) southwest of the WIPP. The primary objective of Project Gnome was to study the effects of an underground nuclear explosion in salt. The Gnome experiment involved the detonation of a 3.1-kiloton nuclear device at a depth of 1,200 ft (361 m) in the bedded salt of the Salado. The explosion created a cavity of approximately 1,000,000 ft^3 (27,000 m^3), and caused surface displacements over an area of about a 1,200-ft (360-m) radius. Fracturing and faulting caused measurable changes in rock permeability and porosity at distances up to approximately 330 ft (100 m) from the cavity. No earth tremors were reported at distances over 25 mi (40 km) from the explosion. Project Gnome was decommissioned in 1979.

D6-4 Seismicity

Seismic data are presented in two time frames, before and after the time when seismographic data for the region became available. The earthquake record in southern New Mexico dates back only to 1923, and seismic instruments have been in place in the state since 1961. Various records have been examined to determine the seismic history of the area within 180 mi (288 km) of the site. With the exception of a weak shock in 1926 at Hope, New Mexico, and shocks in 1936 and 1949 felt at Carlsbad, all known shocks before 1961 occurred to the west and southwest of the site more than 100 mi (160 km) away.

The strongest earthquake on record within 180 mi (288 km) of the site was the Valentine, Texas, earthquake of August 16, 1931. It has been estimated to have been of magnitude 6.4 on the Richter scale (Modified Mercalli Intensity of VIII). The Valentine earthquake was 130 mi (208 km) south-southwest of the site. Its Modified Mercalli Intensity at the site is estimated to have been V; this is believed to be the highest intensity felt at the site in this century.

In 1887, a major earthquake occurred in northeast Sonora, Mexico. Although about 335 mi (536 km) west-southwest of the site, it is indicative of the size of earthquakes possible in the eastern portion of the Basin and Range Province, west of the province containing the site. Its

magnitude was estimated to have been 7.8 (VIII to IX in Modified Mercalli Intensity). It was felt over an area of 0.5 million mi^2 (1.3 million km^2) (as far as Santa Fe to the north and Mexico City to the south); fault displacements near the epicenter were as large as 26 ft (18 m).

Since 1961, instrumental coverage has become comprehensive enough to locate most of the moderately strong earthquakes (local magnitude >3.5) in the region. Instrumentally determined shocks that occurred within 180 mi (288 km) of the site between 1961 and 1979 are shown in Figure D6-38. The distribution of these earthquakes may be biased by the fact that seismic stations were more numerous and were in operation for longer periods north and west of the site.

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

A station operating for 10 months at Fort Stockton, Texas, indicated many small shocks from the Central Basin Platform (See Figure D6-38). Activity was observed at the time the station opened on June 21, 1964. This activity may be related to the injection of water underground for oil recovery. In the Ward-Estes North oilfield, operated by the Gulf Oil Corporation, the cumulative total of water injected up to 1970 was over 1 billion barrels. Accounting for 42 percent of the water injected in Ward and Winkler counties, Texas, the quantity is three times the total injected in all the oil fields of southeastern New Mexico during the same period. Water injection has not been used in the region of the WIPP site to stimulate gas production. The nearest oil fields in the Delaware Basin, where any recovery might be attempted, are adjacent to the WIPP site boundary in the Delaware Formations. The source of this seismicity is insignificant because the seismic design basis uses the observed seismicity regardless of its cause.

A recent earthquake felt at the WIPP site occurred in January 1992 and is referred to as the Rattlesnake Canyon Earthquake.[1] It occurred 60 mi (100 km) east-southeast of the WIPP site. The earthquake was assigned a magnitude of 5.0. This event had no effect on any of the structures at the WIPP as documented by post-event inspections by the WIPP staff and the New Mexico Environment Department. This event was within the parameters used to develop the seismic risk assessment of the WIPP facility for the purposes of construction and operation.

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[1]An earthquake occurred on April 13, 1995, near the town of Alpine, Texas. This earthquake has been assigned a local magnitude of M = 5.5. Details of the earthquake have not yet been published. The Alpine earthquake was felt at the WIPP site; however, no damage to WIPP facilities occurred as the result of this earthquake.

The Rattlesnake Canyon event likely was tectonic in origin based on a 7 ± 1 mi (12 ± 2 km) depth. This suggests some uncertainty regarding the origin of earthquakes associated with the Central Basin Platform.

D6-5 Rock Geochemistry

An understanding of the mineralogy/geochemistry of the host repository rock is considered critical to predicting the long-term waste isolation capability of the repository. Chemical composition of the different minerals and any impurities are important to understand and predict waste-rock compatibility of the Salado. This section emphasizes the following topics:

- Mineral content and composition
- Fluid inclusions
- Fracture fillings.

The Salado is dominated by various evaporite salts; the dominant mineral is halite (NaCl) of varying purity and accessory minerals. The major accessory minerals are anhydrite ($CaSO_4$), clays, polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$), and gypsum ($CaSO_4 \cdot 2H_2O$). In the vicinity of the repository, authigenic quartz (SiO_2) and magnesite ($MgCO_3$) are also present as accessory minerals. The marker beds in the salt are described as anhydrite with seams of clay. The clays within the Salado are enriched in magnesium and depleted in aluminum. The magnesium enrichment probably reflects the intimate contact of the clays with brines derived from evaporating sea water, which are relatively high in magnesium.

A partial list of minerals found in the Delaware Basin evaporites, together with their chemical formulas, is given in Table D6-7. The table also indicates the relative abundances of the minerals in the evaporite rocks of the Castile, the Salado, and the Rustler. Minerals found either only at depth, removed from influence of weathering, or only near the surface, as weathering products, are also identified. Although the most common Delaware Basin evaporite mineral is halite, the presence of less soluble interbeds (dominantly anhydrite, polyhalite, and claystone) and more soluble admixtures (e.g., sylvite, glauberite, and kainite) has resulted in chemical and physical properties significantly different from those of pure NaCl. In particular, the McNutt Potash Member, between Marker Beds 116 and Marker Bed 126, is locally explored and mined for K-bearing minerals of economic interest. Under differential stress, brittle interbeds (anhydrite, polyhalite, magnesite, and dolomite) may fracture while, under the same stress regime, pure NaCl would undergo plastic deformation. Fracturing of brittle interbeds, for example, has locally enhanced the permeability, allowing otherwise nonporous rock to carry groundwater (e.g., fractured dolomite beds in the Rustler). Some soluble minerals incorporated in the rock salt (e.g., polyhalite, sylvite, leonite, and langbeinite) can be radiometrically dated, their longevity marking the time of most recent water-incursion into the evaporite section. The survival of such minerals is significant, in that such dating is impossible in pure NaCl or calcium sulfate.

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

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TABLES

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TABLE D6-1
CULEBRA THICKNESS DATA SETS

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

Key:
n = Number of boreholes or data points
ave = Average or mean
st dev = Standard deviation

TABLE D6-2
HYDROLOGIC CHARACTERISTICS OF ROCK UNITS AT THE WIPP SITE

Member Name	Thickness (m)		Hydraulic Conductivity (m/s)		Porosity	
	max	min	max	min	max	min
Forty-niner	20	–	5.0×10^{-9}	5.0×10^{-10}	–	–
Magenta	8	4	5.0×10^{-5}	5.0×10^{-10}	–	–
Tamarisk	84	8	–	–	–	–
Culebra	11.6	4	1×10^{-4}	2×10^{-10}	0.30	0.03
Unnamed	36	–	1×10^{-11}	6×10^{-15}	–	–
Rustler/ Salado Contact Zone	33	2.4	1×10^{-6}	1×10^{-12}	0.33	0.15

m = meters
m/s = meters per
max = maximum
min = minimum

TABLE D6-3
CAPACITIES OF RESERVOIRS IN THE PECOS RIVER DRAINAGE

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

[a]Capacity below the lowest uncontrolled outlet or spillway.
[b]Key:
FC = Flood control
IR = Irrigation
R = Recreation

TABLE D6-4
CURRENT ESTIMATES OF POTASH RESOURCES AT THE WIPP SITE

Mining Unit	Product	Recoverable Ore (10^6 tons)	
		Within the WIPP site	Outside the WIPP site
4th Ore Zone	Langbeinite	40.5 @ 6.99%	126.0 @ 7.30%
10th Ore Zone	Sylvite	52.3 @ 13.99%	105.0 @ 14.96%

Source: NMBMMR, 1995, Chapter VII

TABLE D6-5
IN-PLACE OIL WITHIN STUDY AREA

Formation	Within WIPP site (10^6 bbl)	Outside WIPP site (10^6bbl)	Total (10^6 bbl)
Delaware	10.33	20.8	31.13
Bone Spring	0.44	0.8	1.25
Strawn	0.4	0.4	0.8
Atoka	1.1	0.1	0.2
Total	12.3	22.9	35.3

Source: NMBMMR 1995, Chapter XI.

TABLE D6-6
IN-PLACE GAS WITHIN STUDY AREA

Formation	Gas Reserves	
	Within WIPP Site Boundary (mcf)	Adjacent to WIPP Site Boundary (mcf)
Delaware	18,176	32,873
Bone Springs	956	1,749
Strawn	9,600	9,875
Atoka	123,336	94,410
Morrow	32,000	28,780

Source: NMBMMR, 1995, Chapter XI

TABLE D6-7
CHEMICAL FORMULAS, DISTRIBUTIONS, AND RELATIVE ABUNDANCES OF MINERALS IN DELAWARE BASIN EVAPORITES

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

Key to Occurrence/Abundance notations:
C = Castile Formation; S = Salado Formation; R = Rustler Formation
3 letters = abundant; 2 letters = common; 1 letter = rare or accessory

FIGURES

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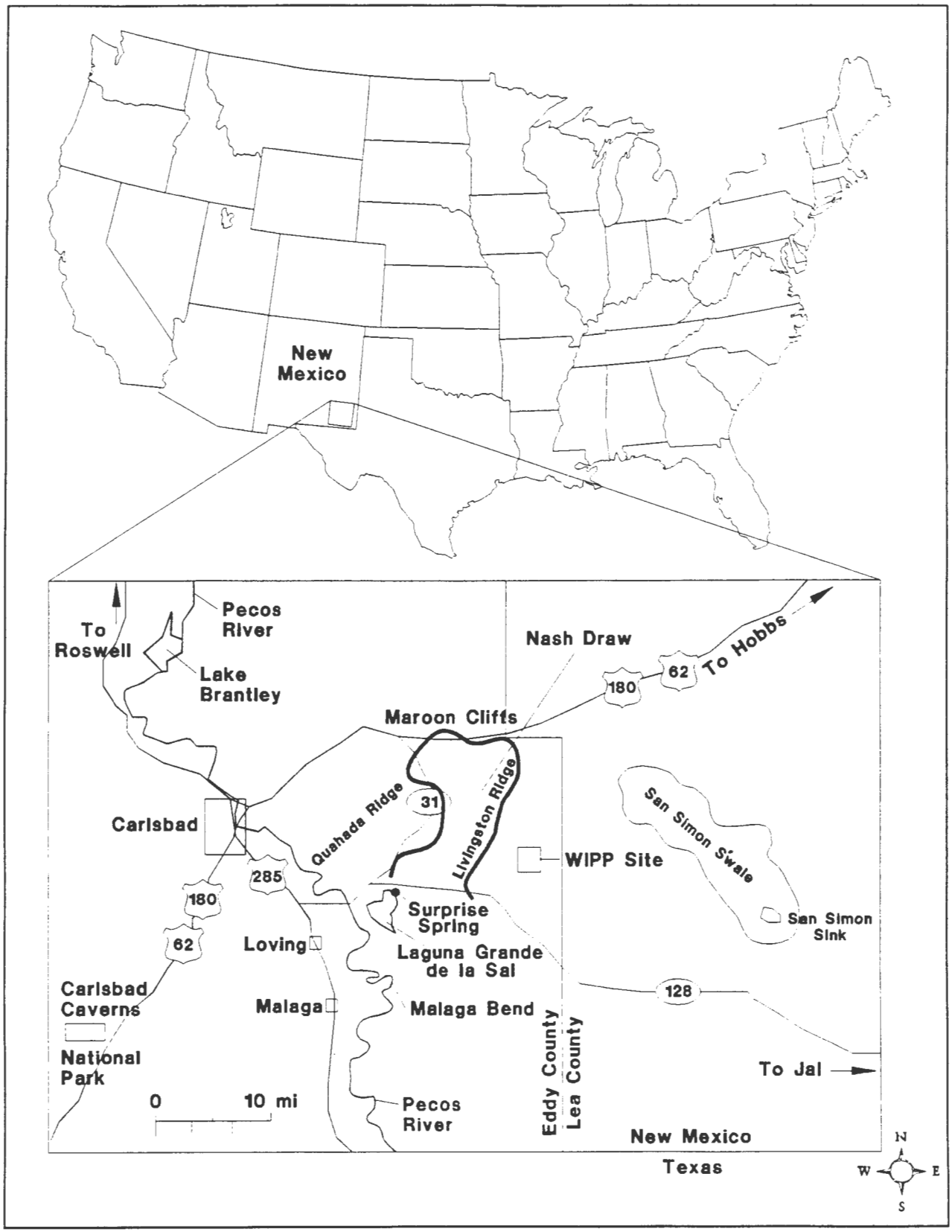


Figure D6-1
WIPP Site Location in Southeastern New Mexico

PORAD601

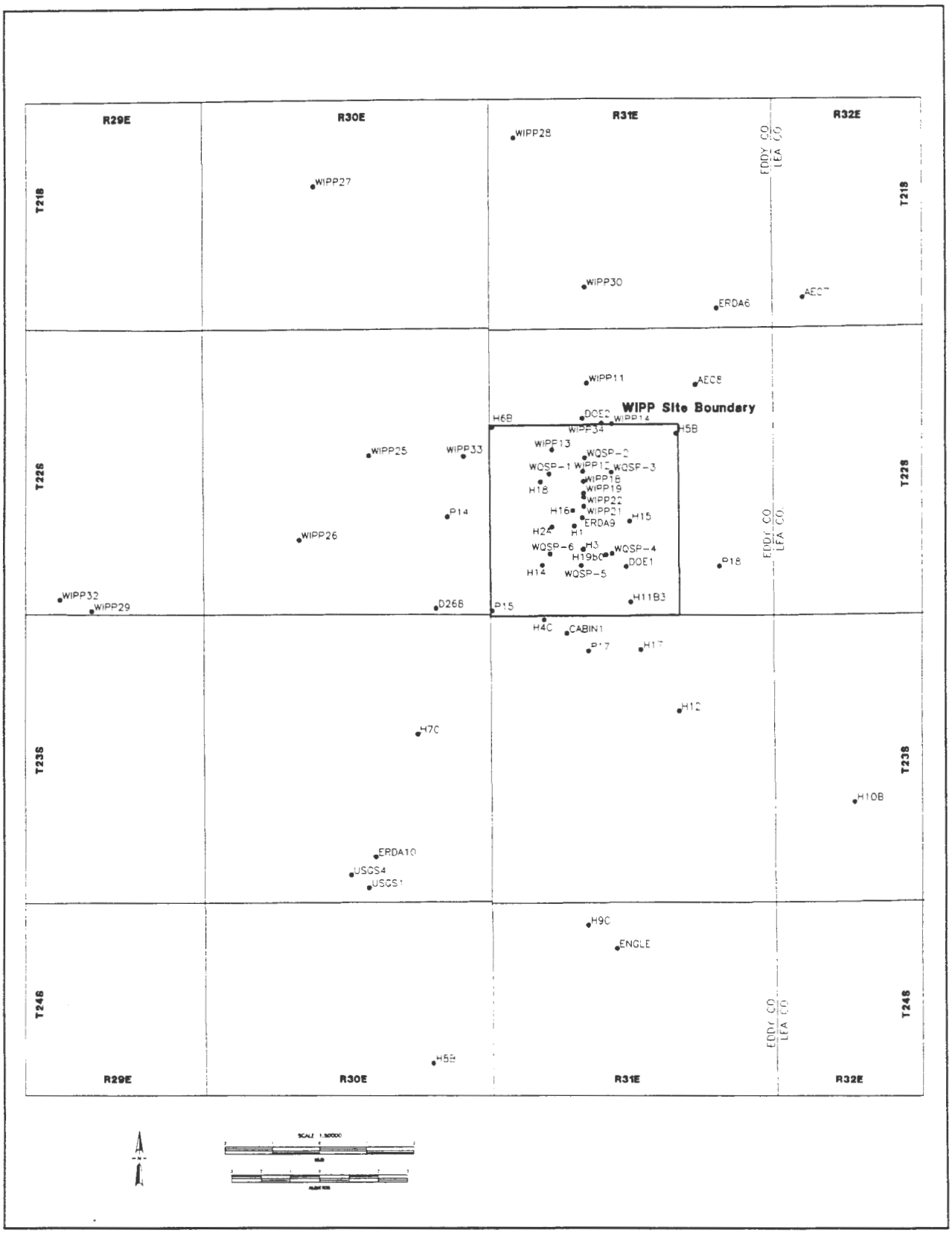


Figure D6-2
Borehole Location Map

RCRAD602

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

Source: Powers, et al., 1978; Palmer, 1983.

Figure D6-3

Major Geological Events - Southeast New Mexico Region

SYSTEM	SERIES	GROUP	FORMATION	MEMBER
RECENT	RECENT		SURFICIAL DEPOSITS	
QUATERN-ARY	PLEISTO-CENE		MESCALERO CALICHE	
			GATUNA	
TERTIARY	MID-PLIOCENE		OGALLALA	
TRIASSIC		DOCKUM	SANTA ROSA	
PERMIAN	OCHOAN		DEWEY LAKE	
			RUSTLER	Forty-niner
				Magenta Dolomite
				Tamarisk
				Culebra Dolomite
				Unnamed
			SALADO	Upper
				McNutt Potash Zone
				Lower
			CASTILE	
	GUADALUPIAN	DELAWARE MOUNTAIN	BELL CANYON	
			CHERRY CANYON	
			BRUSHY CANYON	

Figure D6-4

Site Geologic Column

RCRAD604

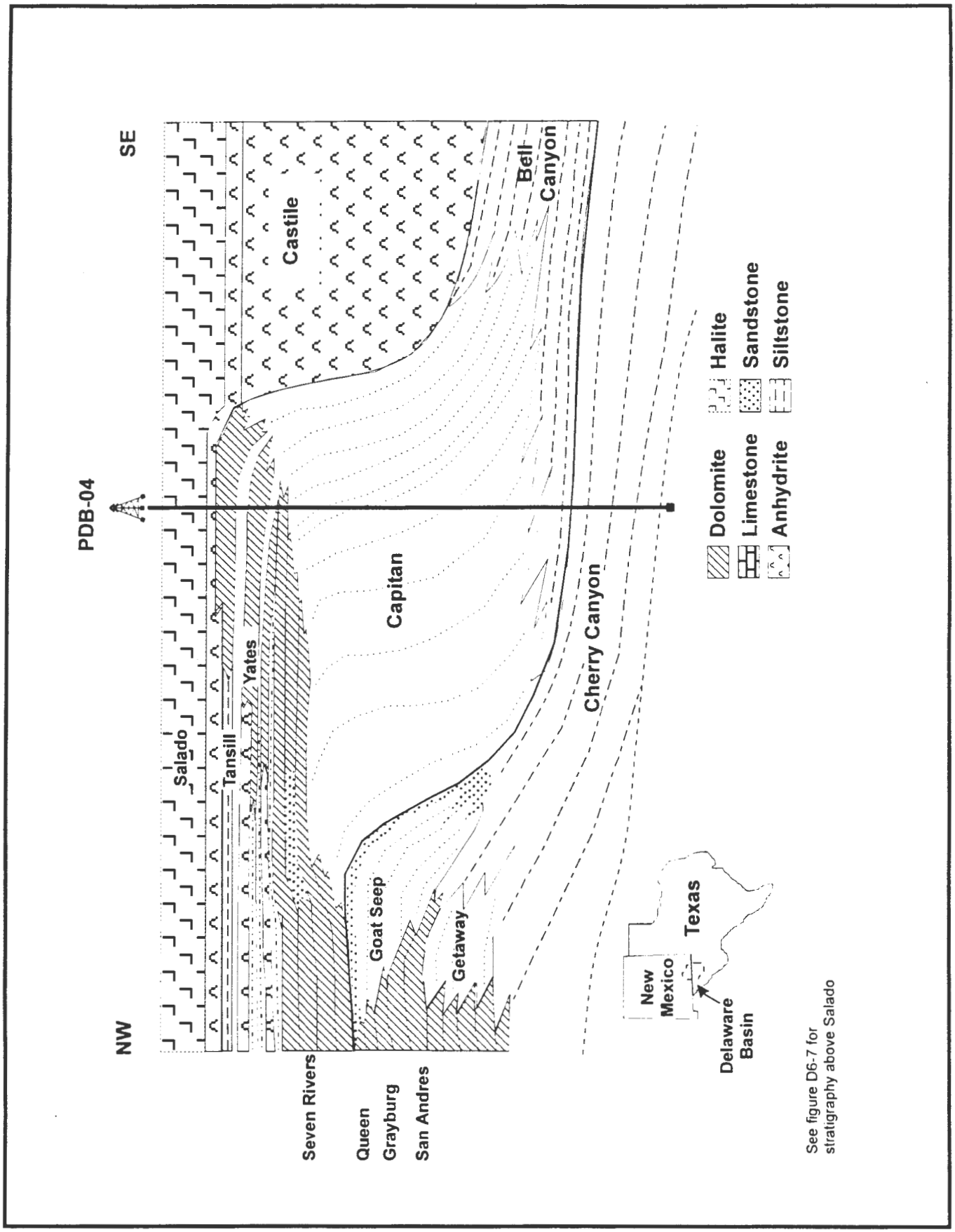


Figure D6-5

Cross Section from Delaware Basin (S.E.) Through Marginal Reef Rocks to Back-Reef Facies

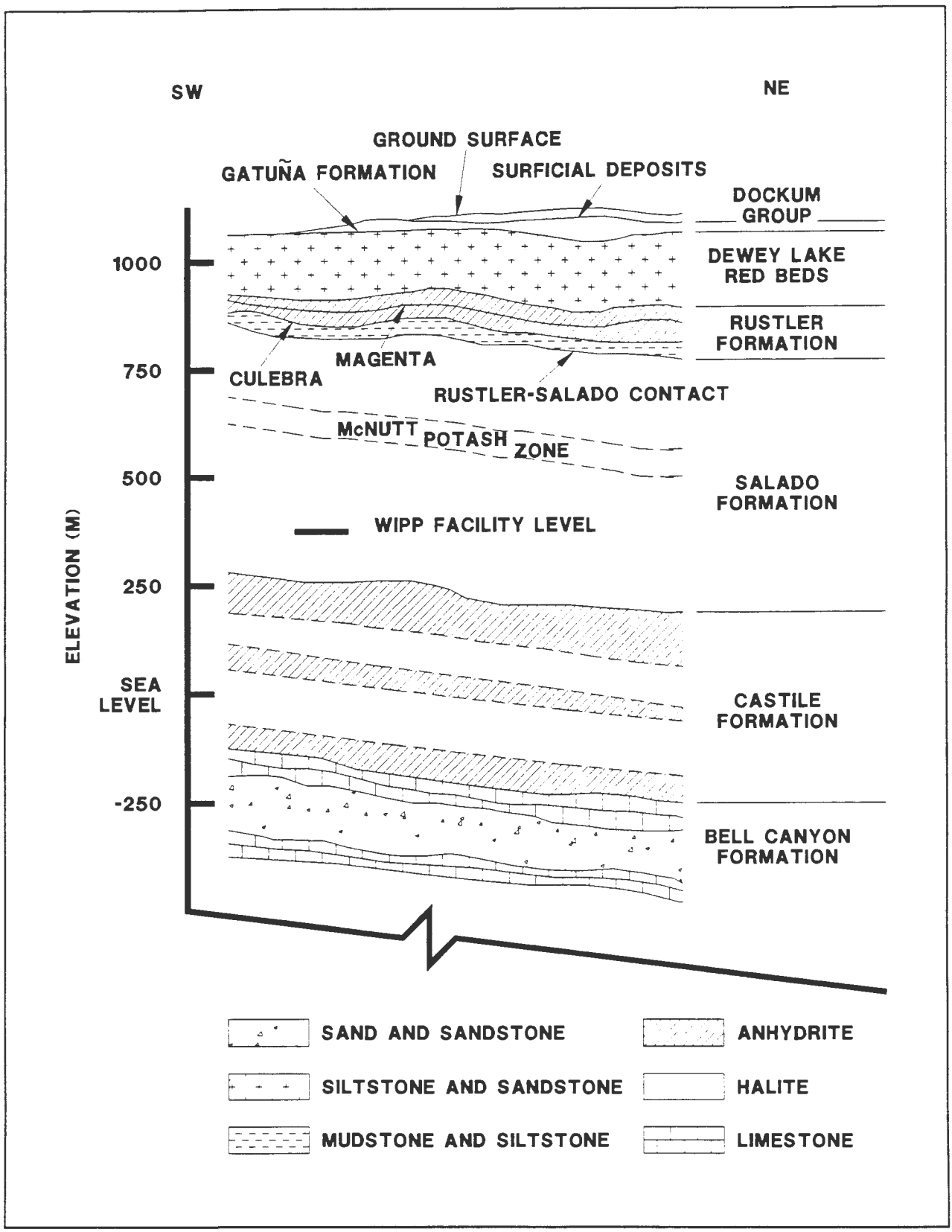


Figure D6-6
Generalized Stratigraphic Cross Section
Above Bell Canyon Formation at WIPP Site

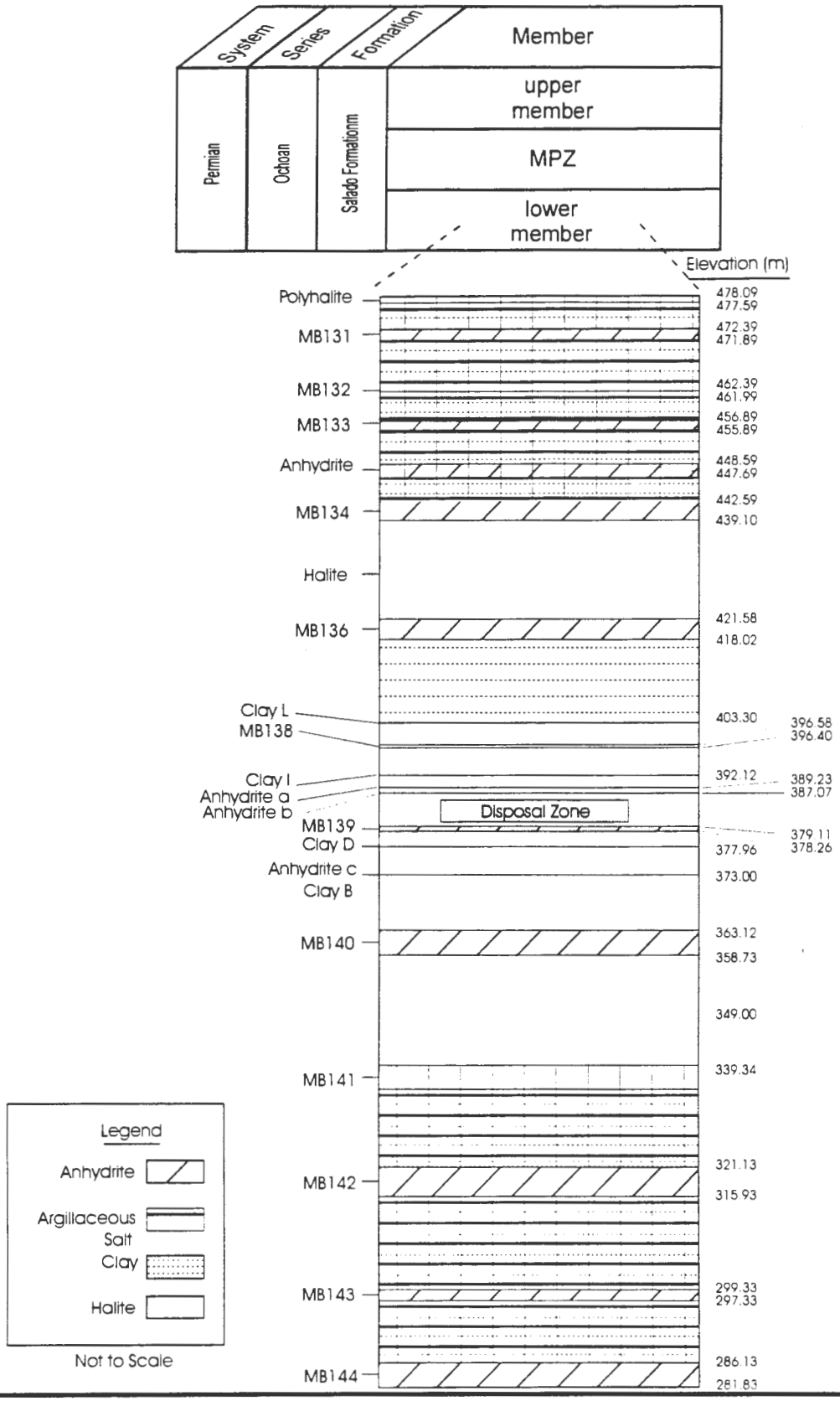
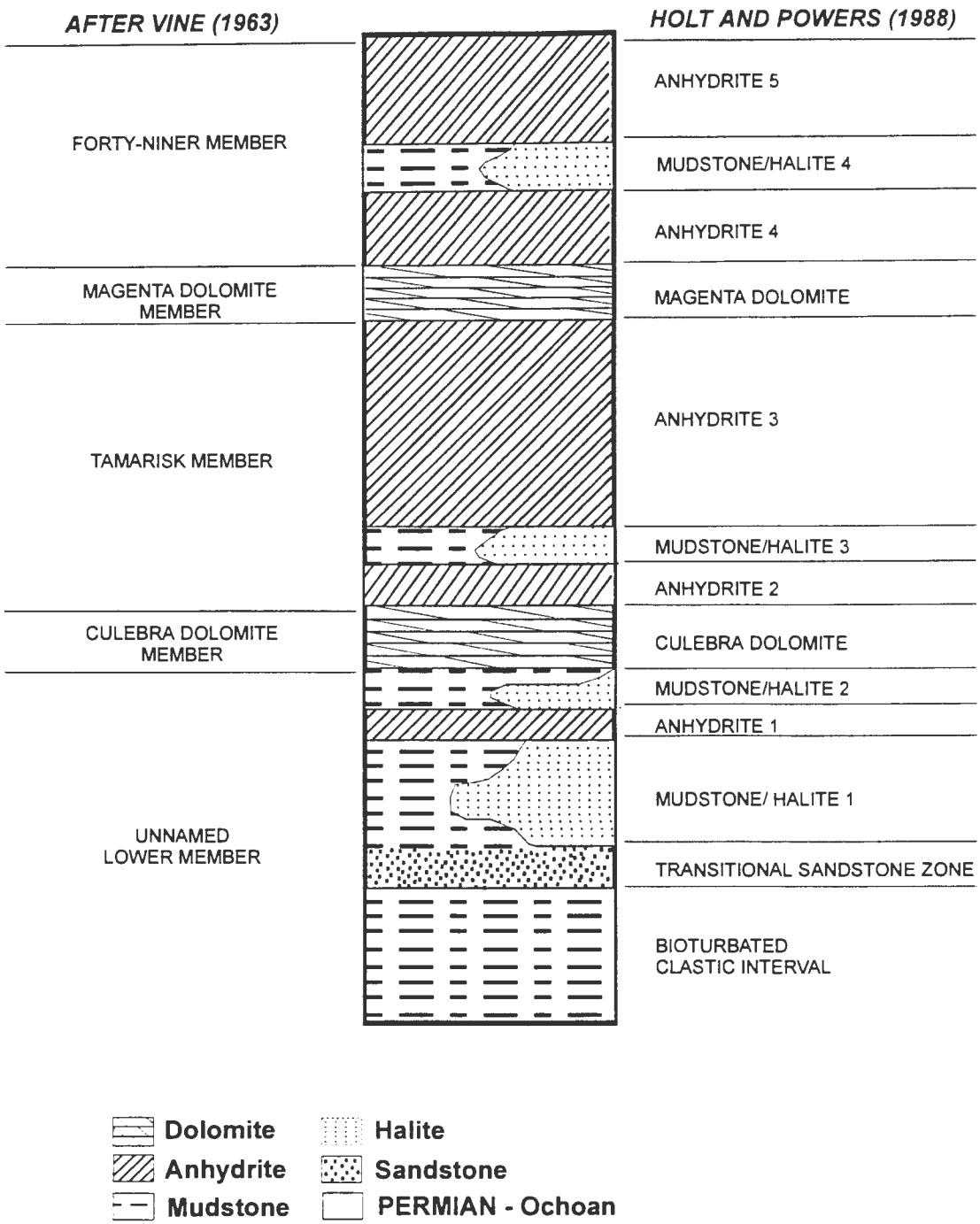


Figure D6-7

Salado Stratigraphy

RCRAD607



Modified from Holt & Powers, 1988

Figure D6-8

Rustler Stratigraphy

RCRAD608

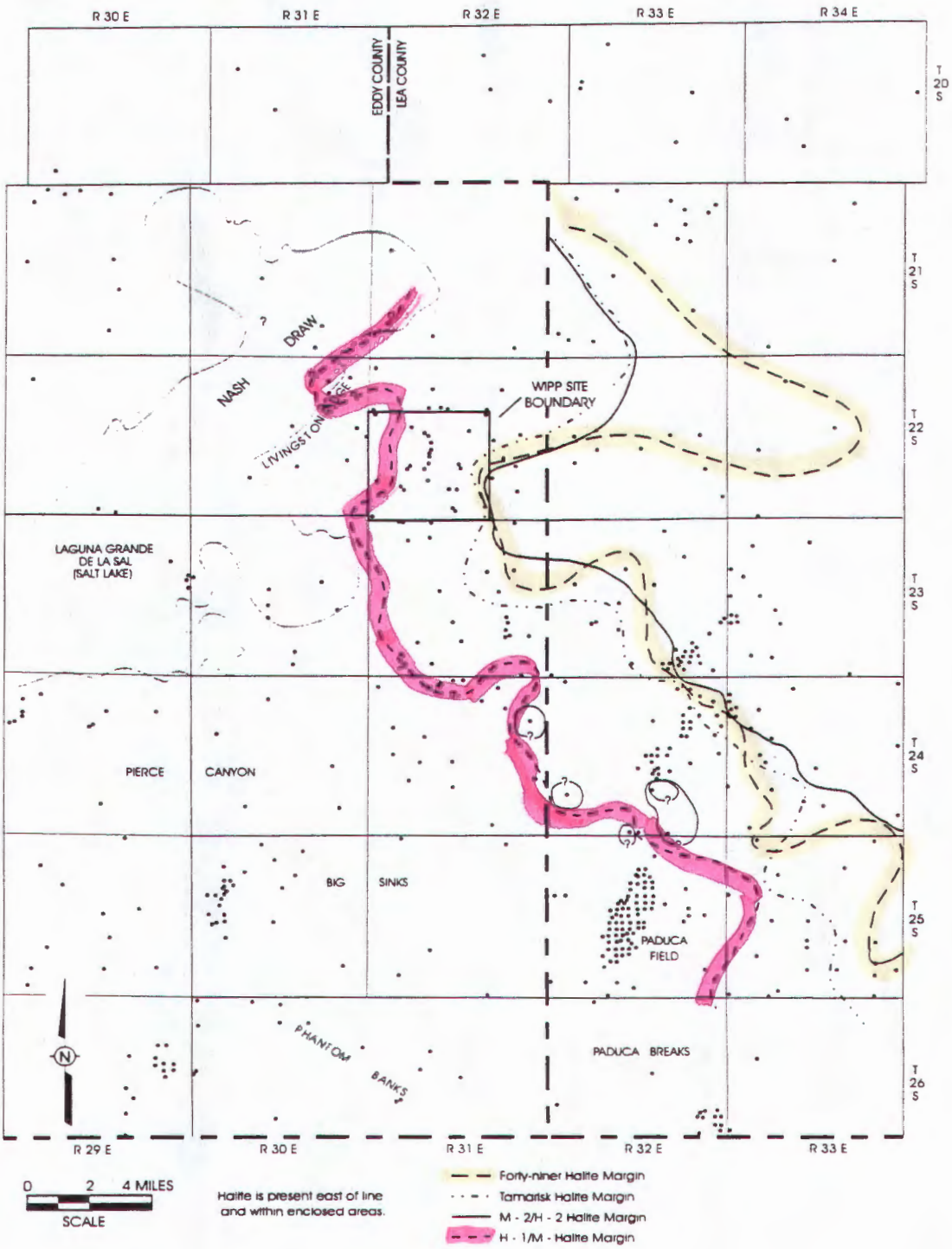


Figure D6-9

Halite Margins in Rustler

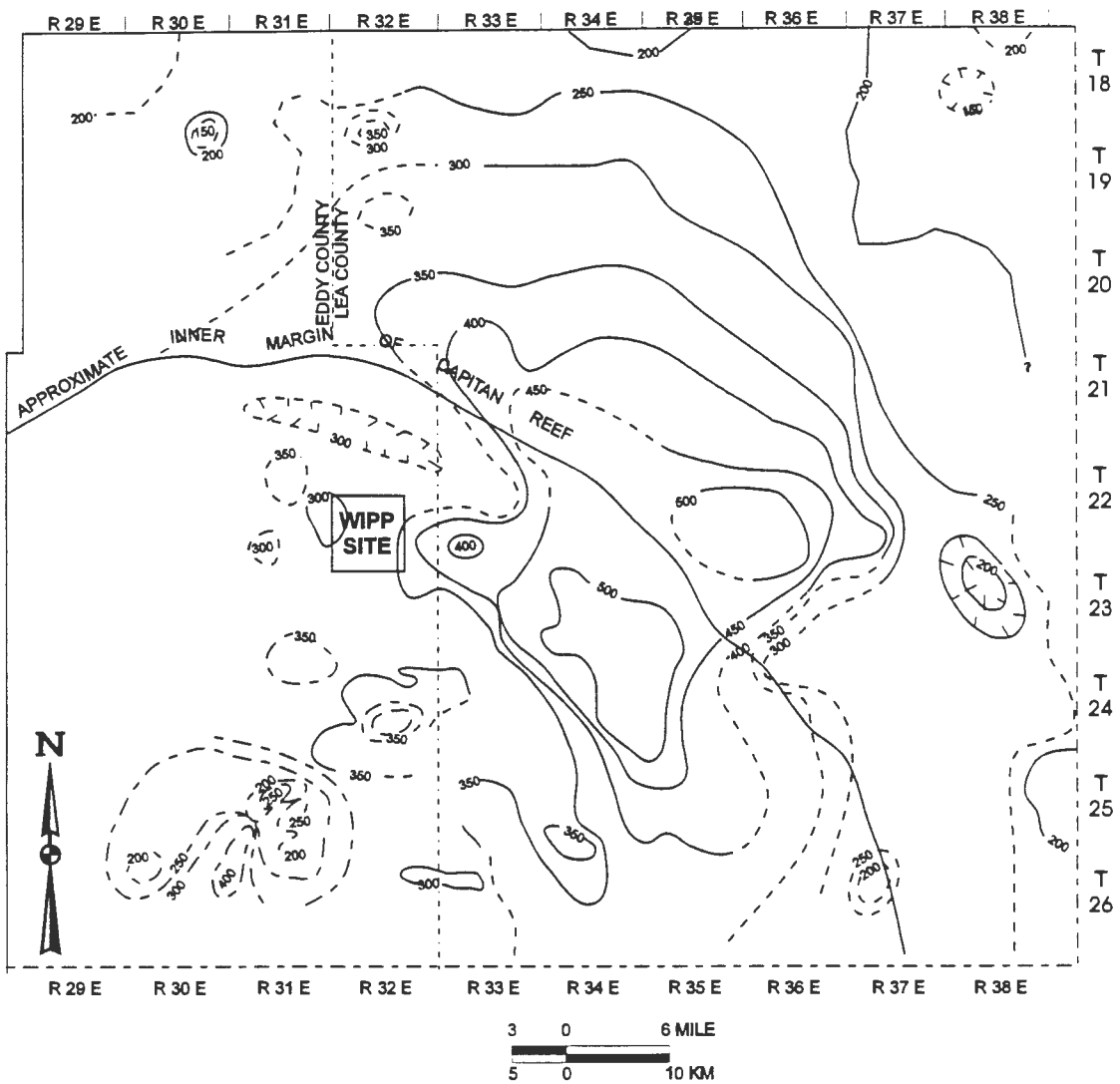


Figure D6-10

Isopach Map of the Entire Rustler

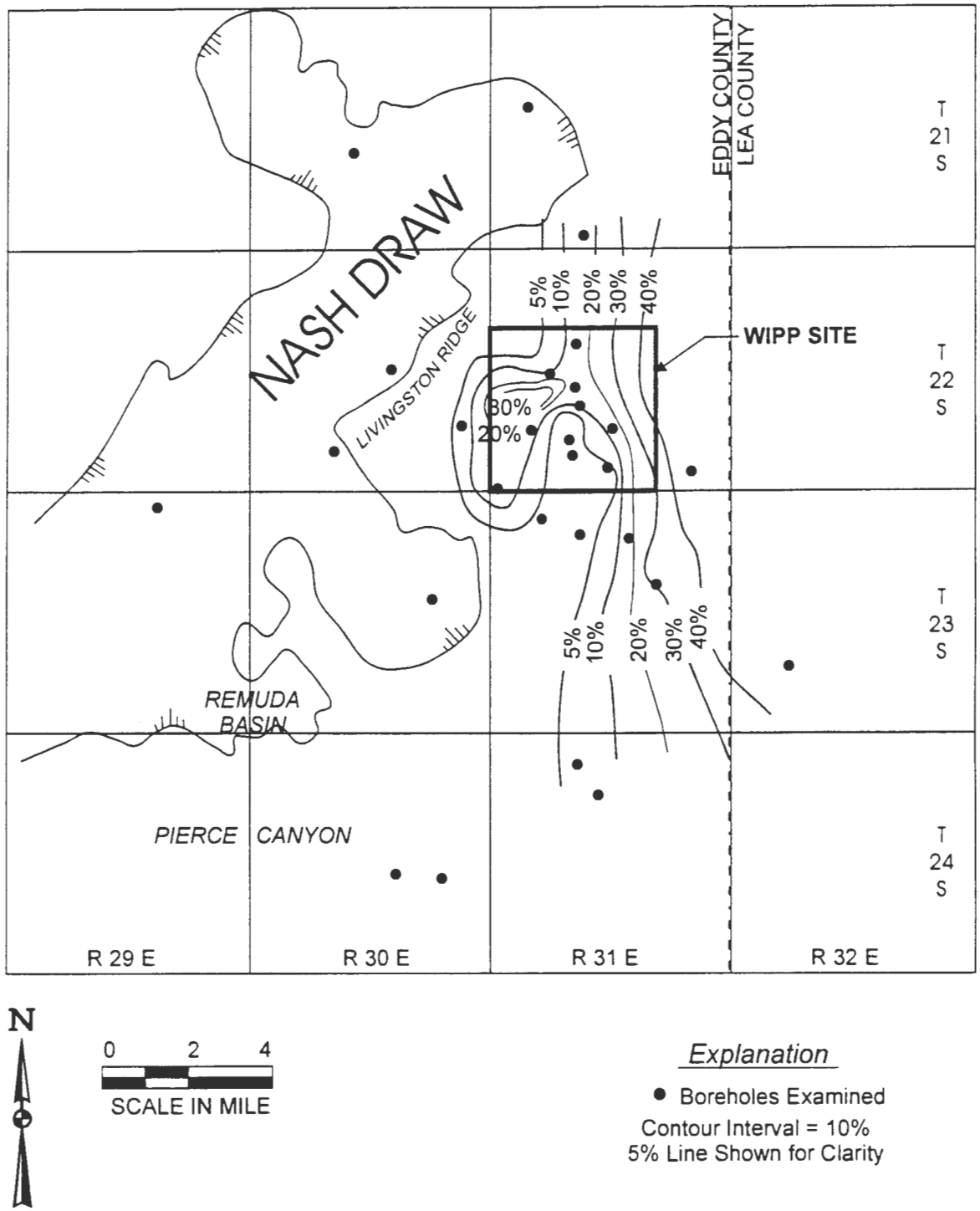


Figure D6-11

Percentage of Natural Fractures in the Culebra Filled with Gypsum

RCRAD611

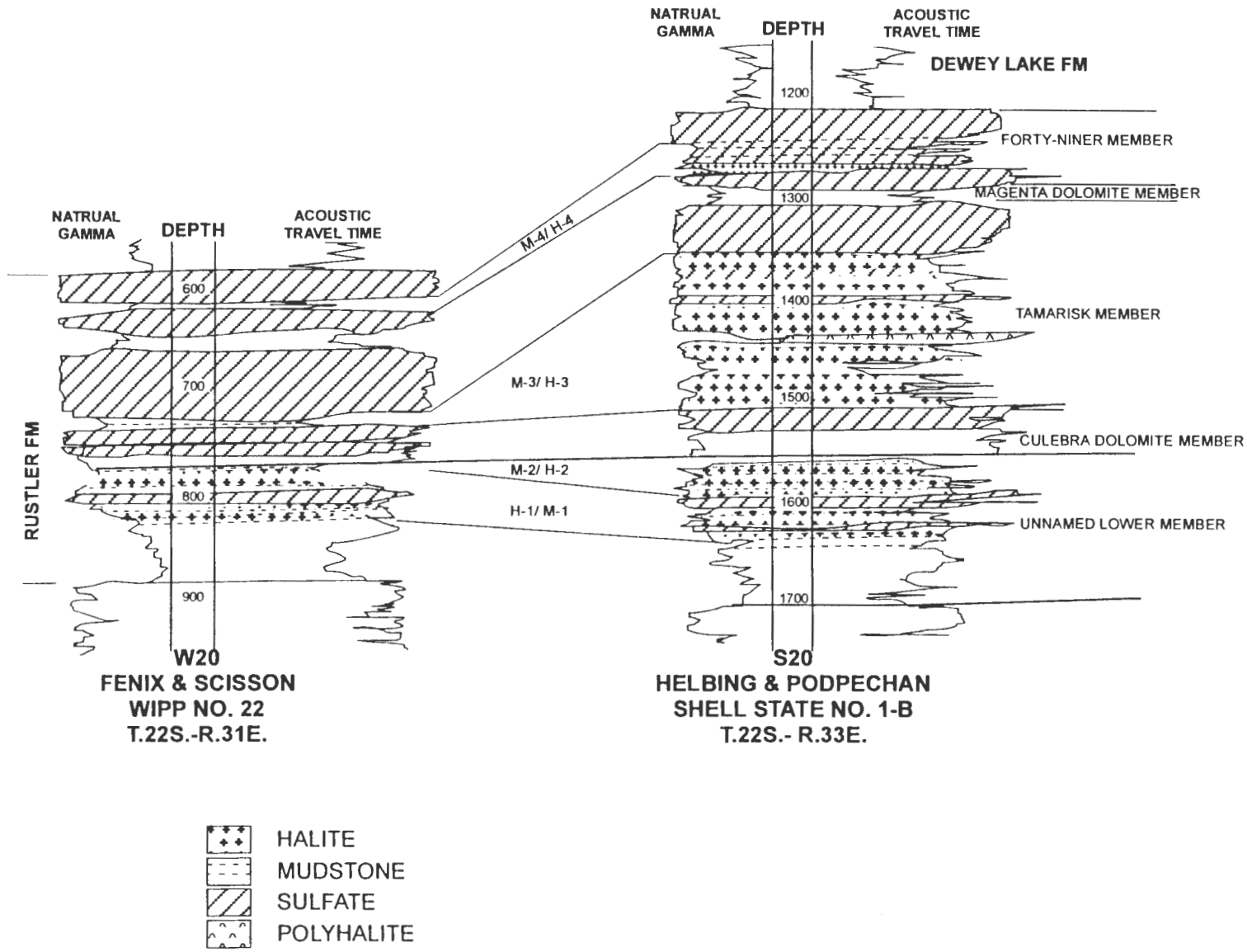


Figure D6-12

Log Character of the Rustler Showing Mudstone-Halite Lateral Relationships

RCRAD612

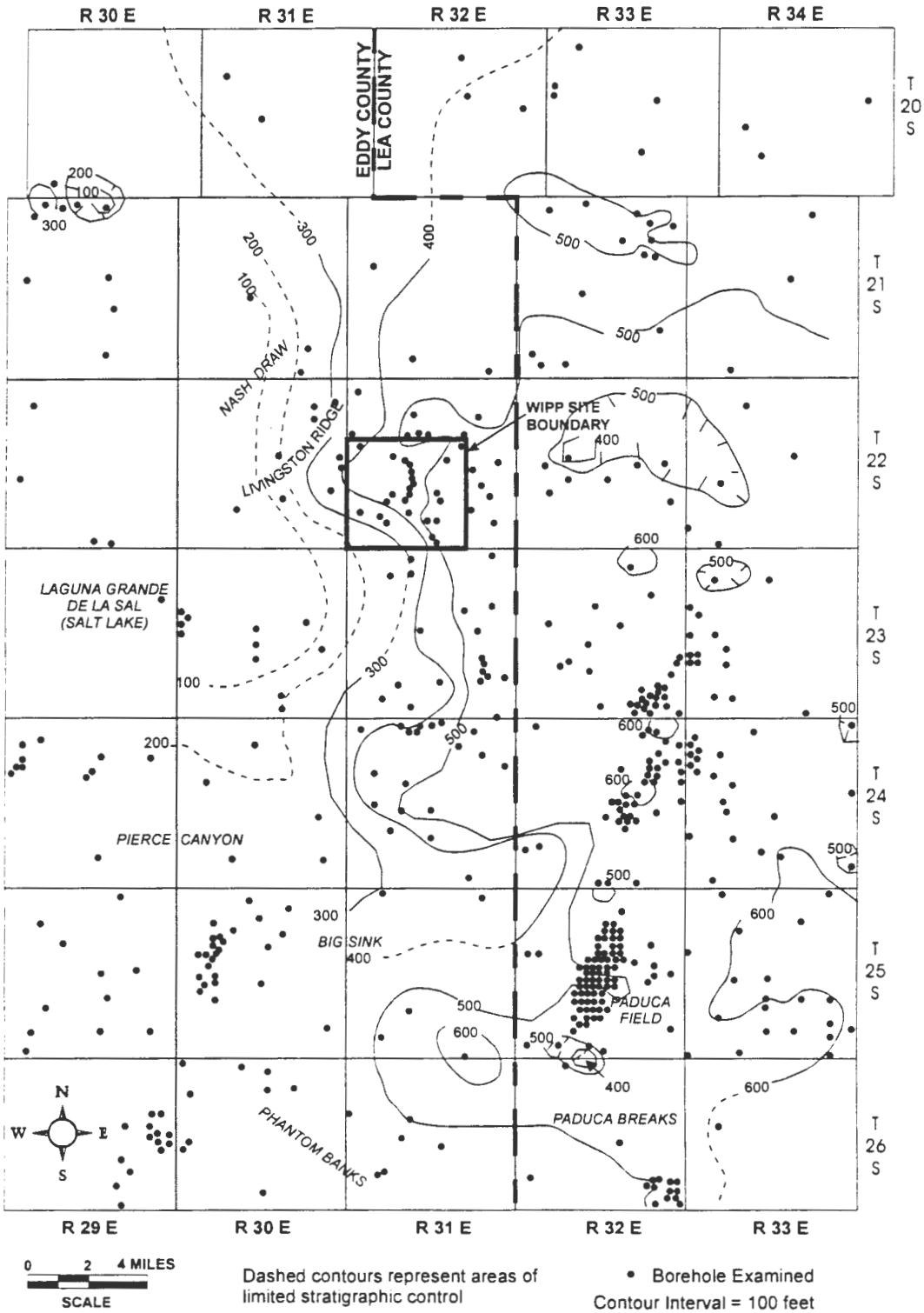


Figure D6-13

Isopach of the Dewey Lake

RCRAD613

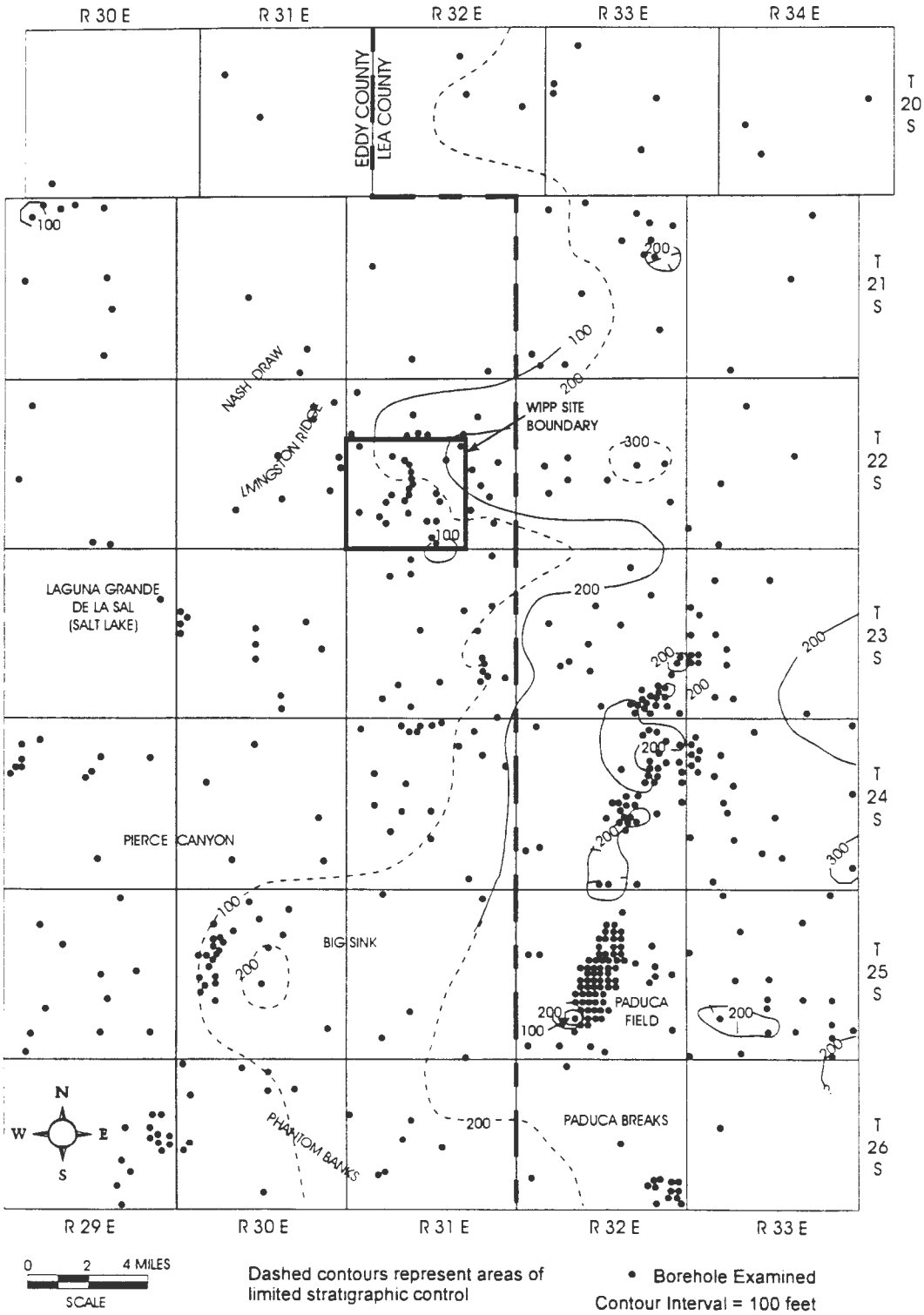


Figure D6-14

Isopach of the Santa Rosa

RCRAD614

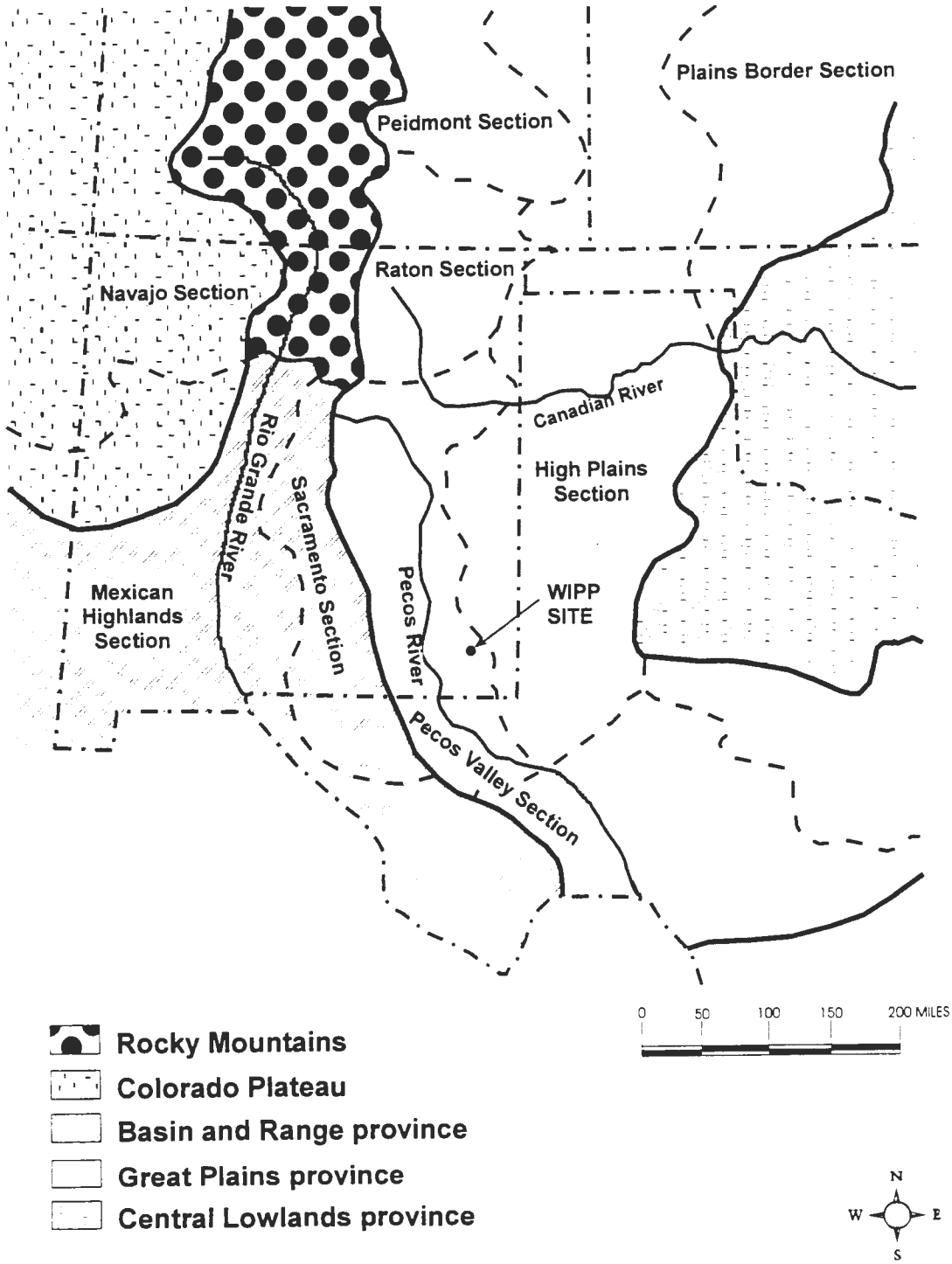


Figure D6-15

Physiographic Provinces and Sections

RCRAD615

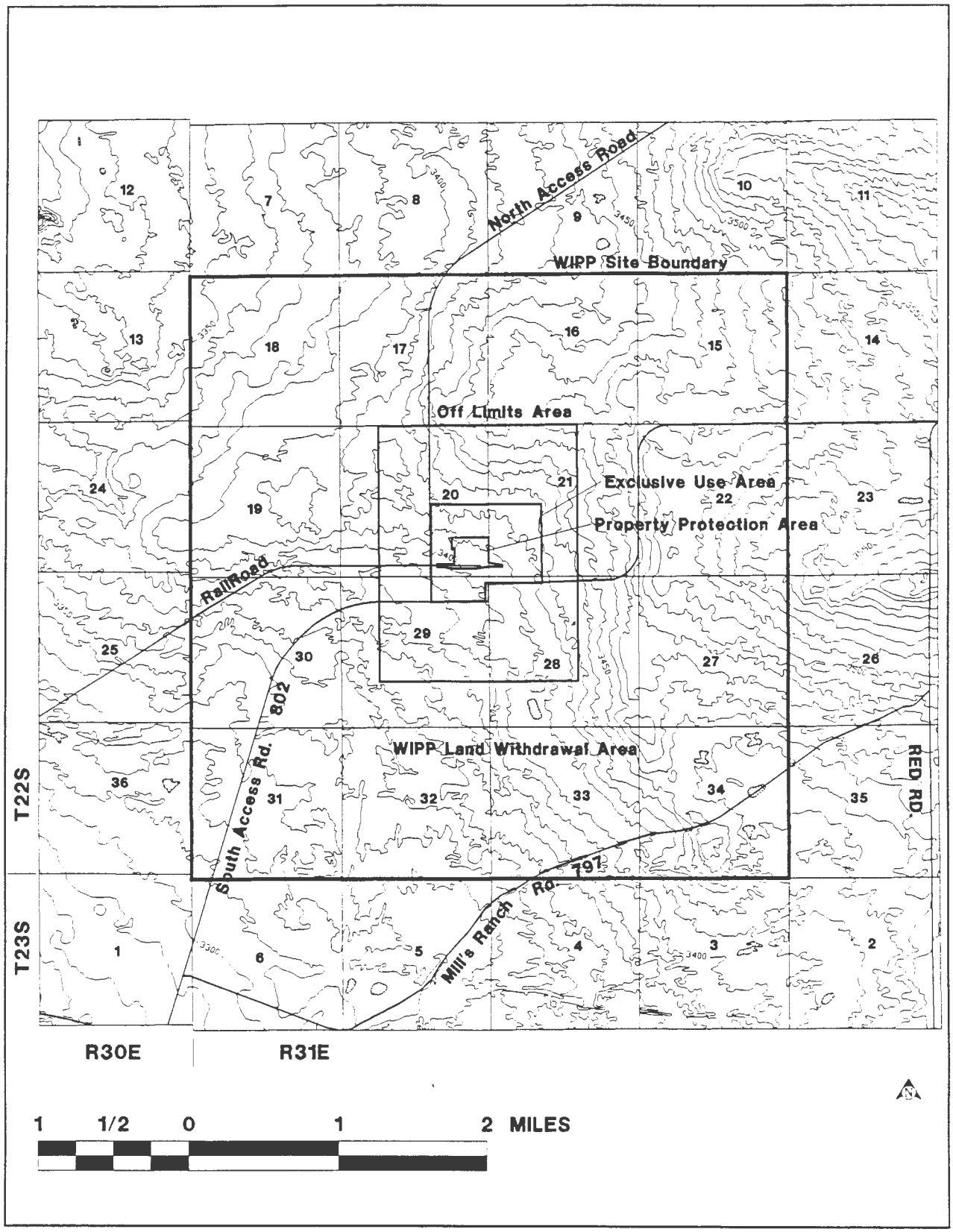


Figure D6-16
Site Topographic Map

P:CPAD616

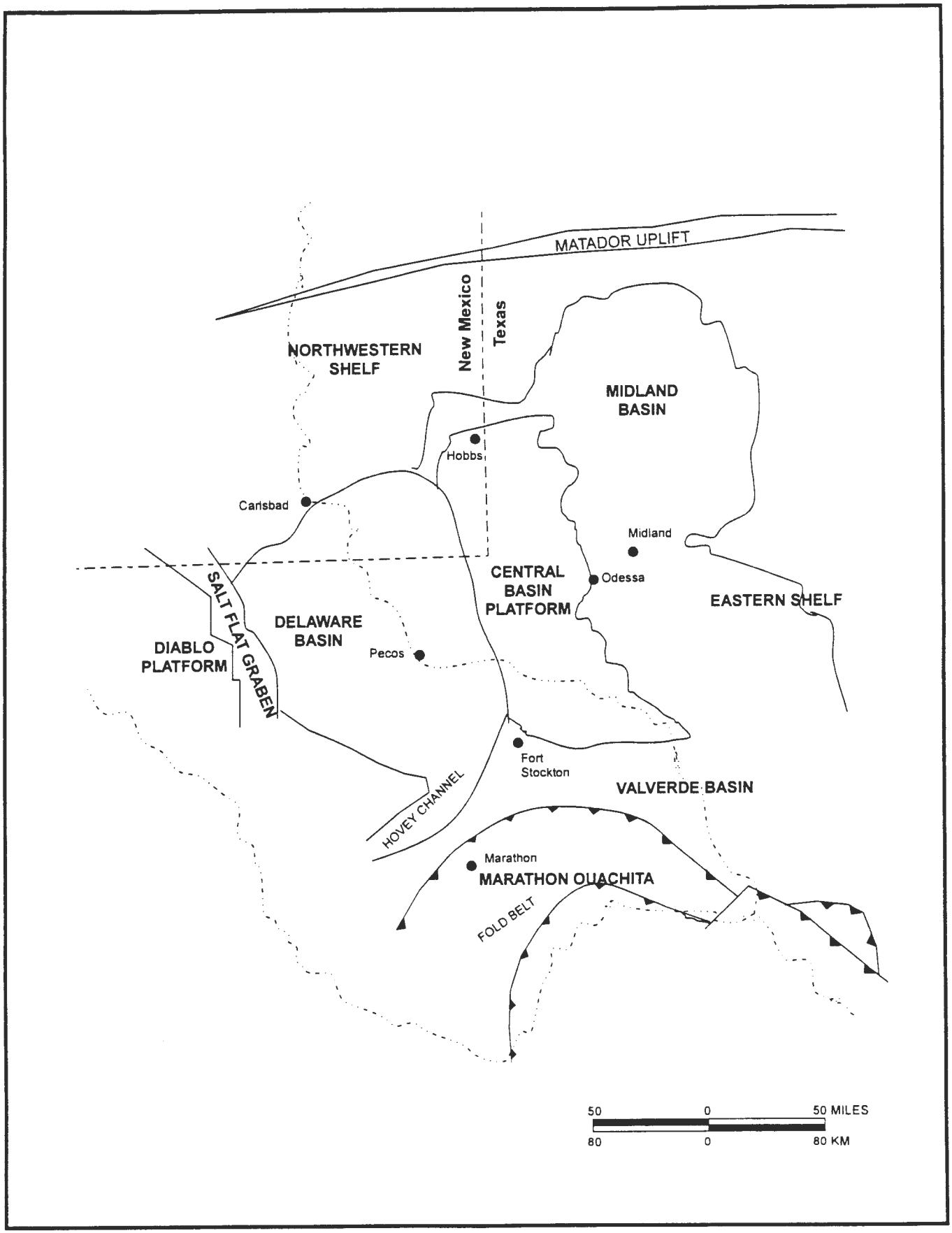
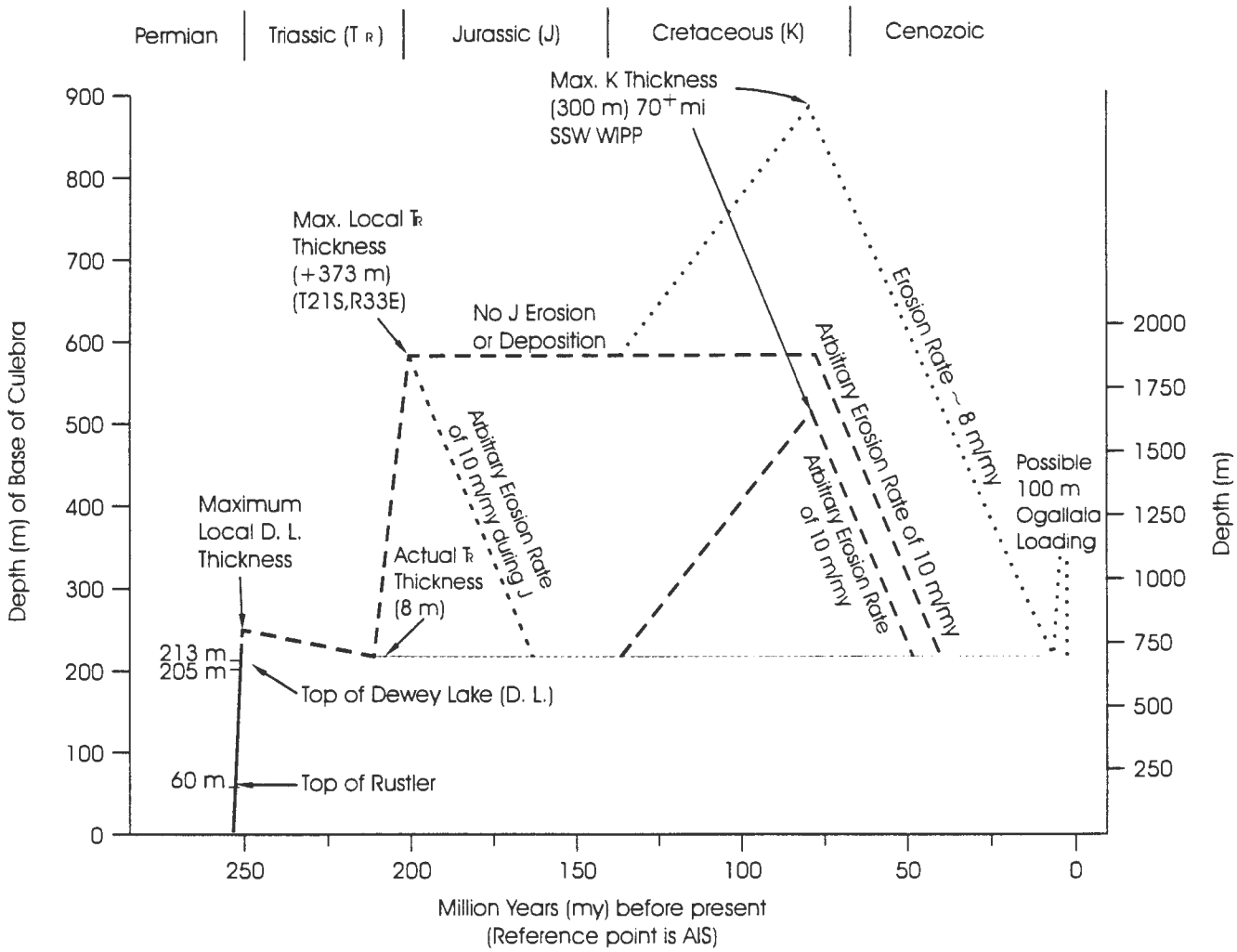


Figure D6-17

Structural Provinces of the Permian Basin Region

RCRAD617



Note: The estimates are made with a reference point and depth to the Culebra at the AIS. Source: Powers and Holt 1995.

Figure D6-18

Loading and Unloading History Estimated for Base of Culebra

RCRAD618

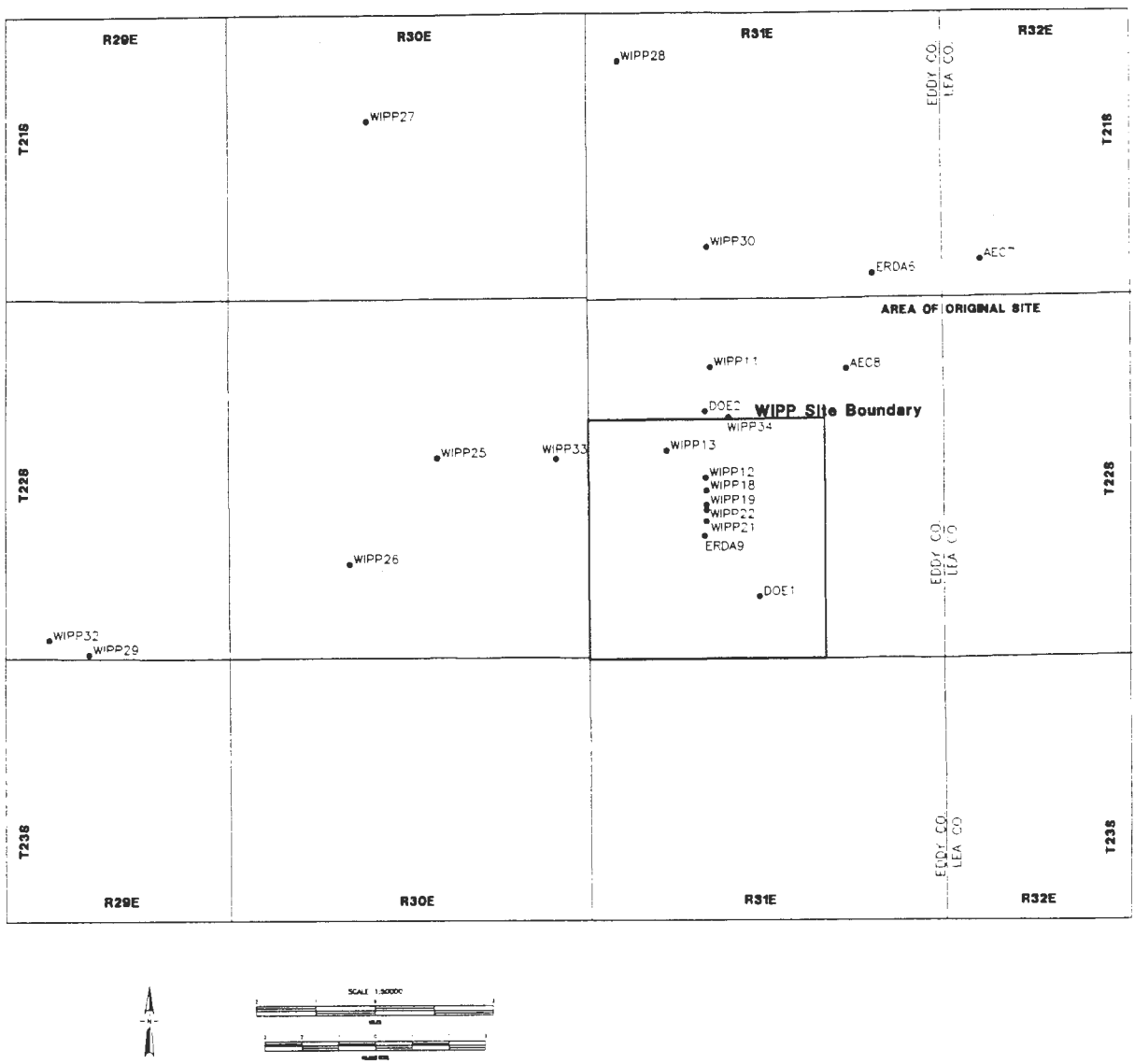
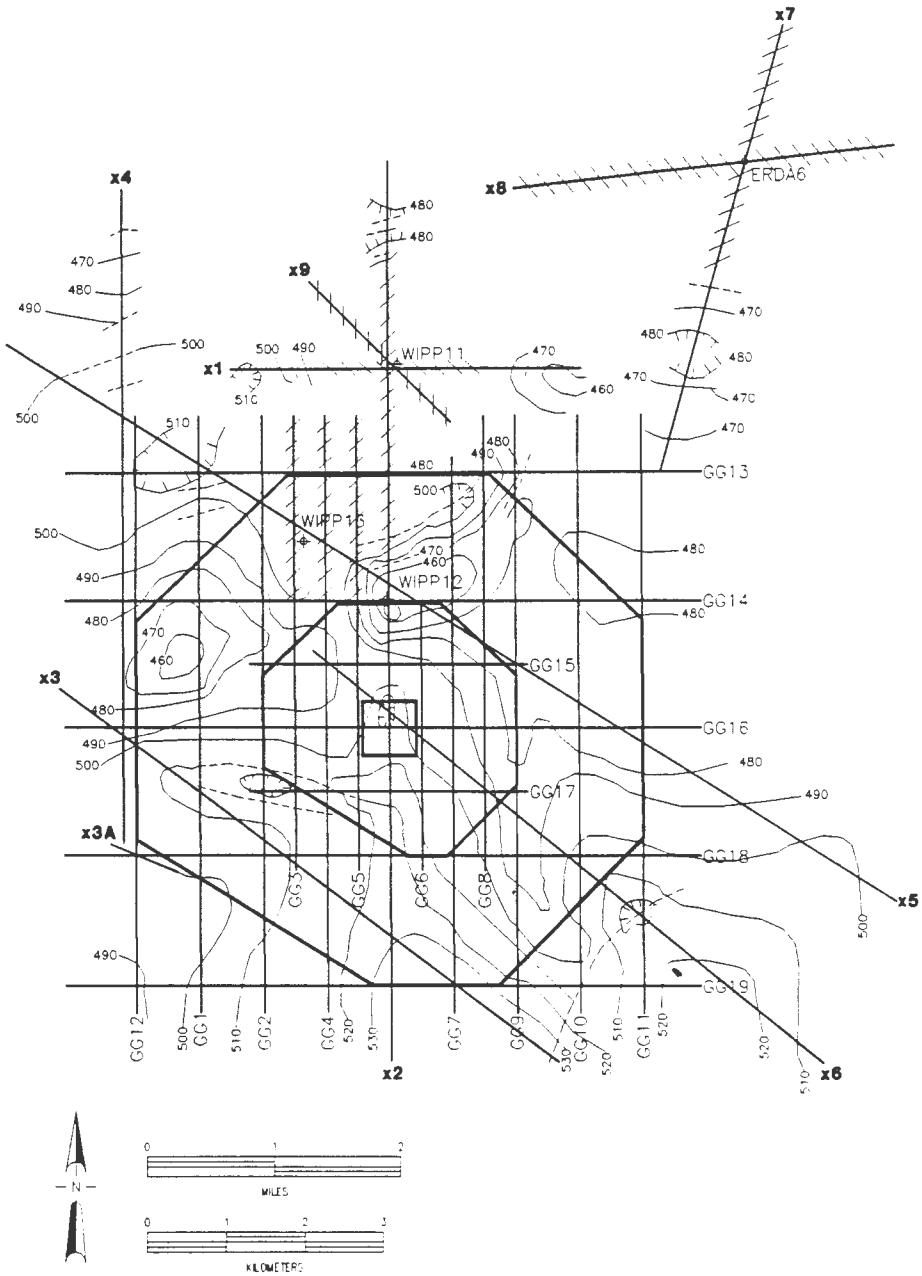


Figure D6-19
Location of Main Stratigraphic Drillholes



NOTES:

1. CONTOUR INTERVAL 10 MILLISECONDS, DATUM 3350 FEET ABOVE SEA LEVEL.
2. CONTOUR INTERVAL IN FEET WOULD BE APPROXIMATELY 75 FEET BASED ON AN AVERAGE SEISMIC VELOCITY OF 7620 FT./SEC. AVERAGED OVER THE ENTIRE STRATIGRAPHIC INTERVAL FROM GROUND SURFACE TO THE MIDDLE OF THE CASTILE FORMATION.

LEGEND

—530— MILLISECONDS TWO-WAY TIME

GG17 SEISMIC LINE (CROSSED WHERE AMBIGUOUS

AREA OF COMPLEX STRUCTURE

---- FAULT

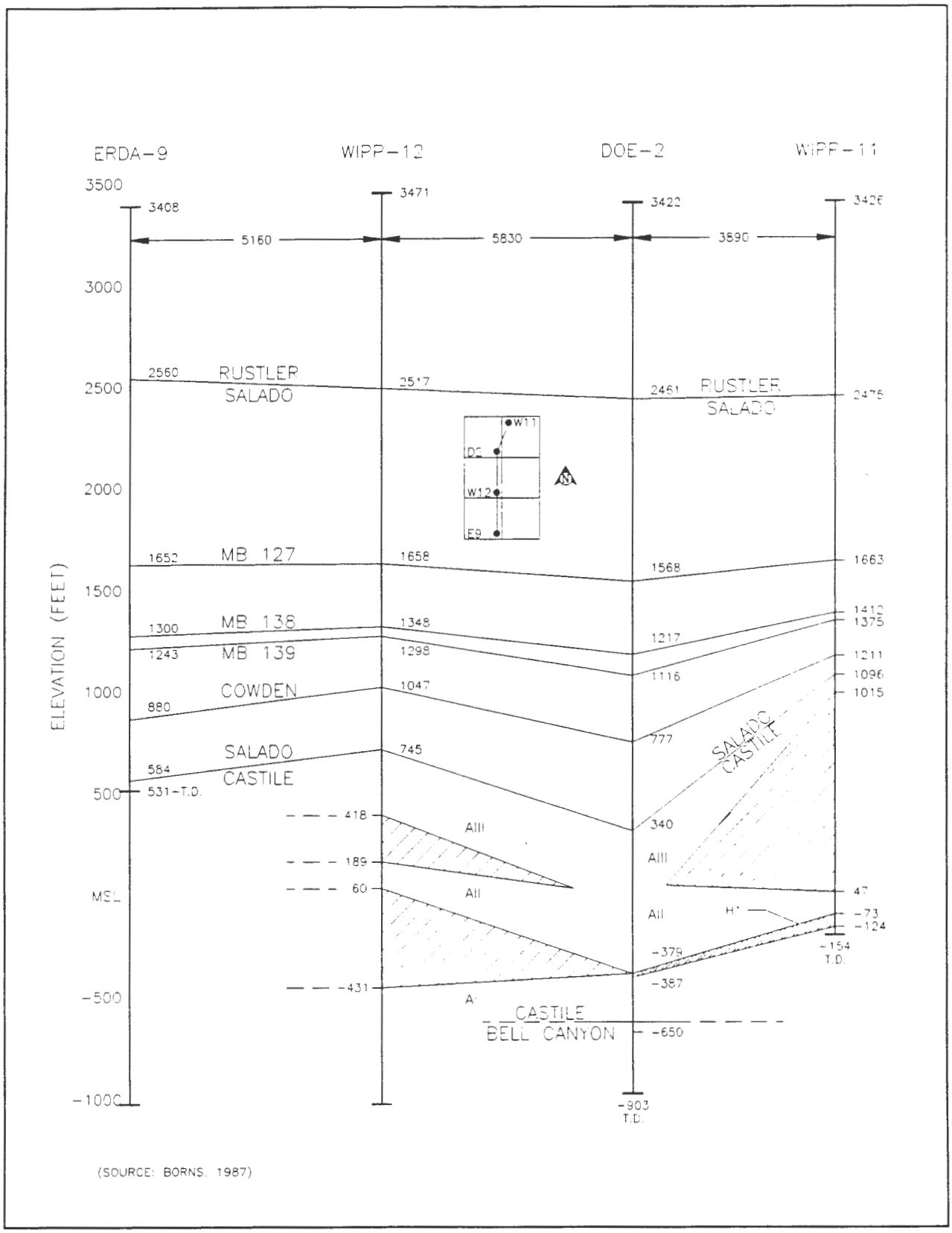
BOREHOLE TO HORIZON

SOURCE: POPIELAK ET AL., 1983

Figure D6-20

Seismic Time Structure Middle Castile Formation

RCRAD620



(SOURCE: BORNS, 1987)

Figure D6-21
Fence Diagram Using DOE-2 and Adjacent Holes

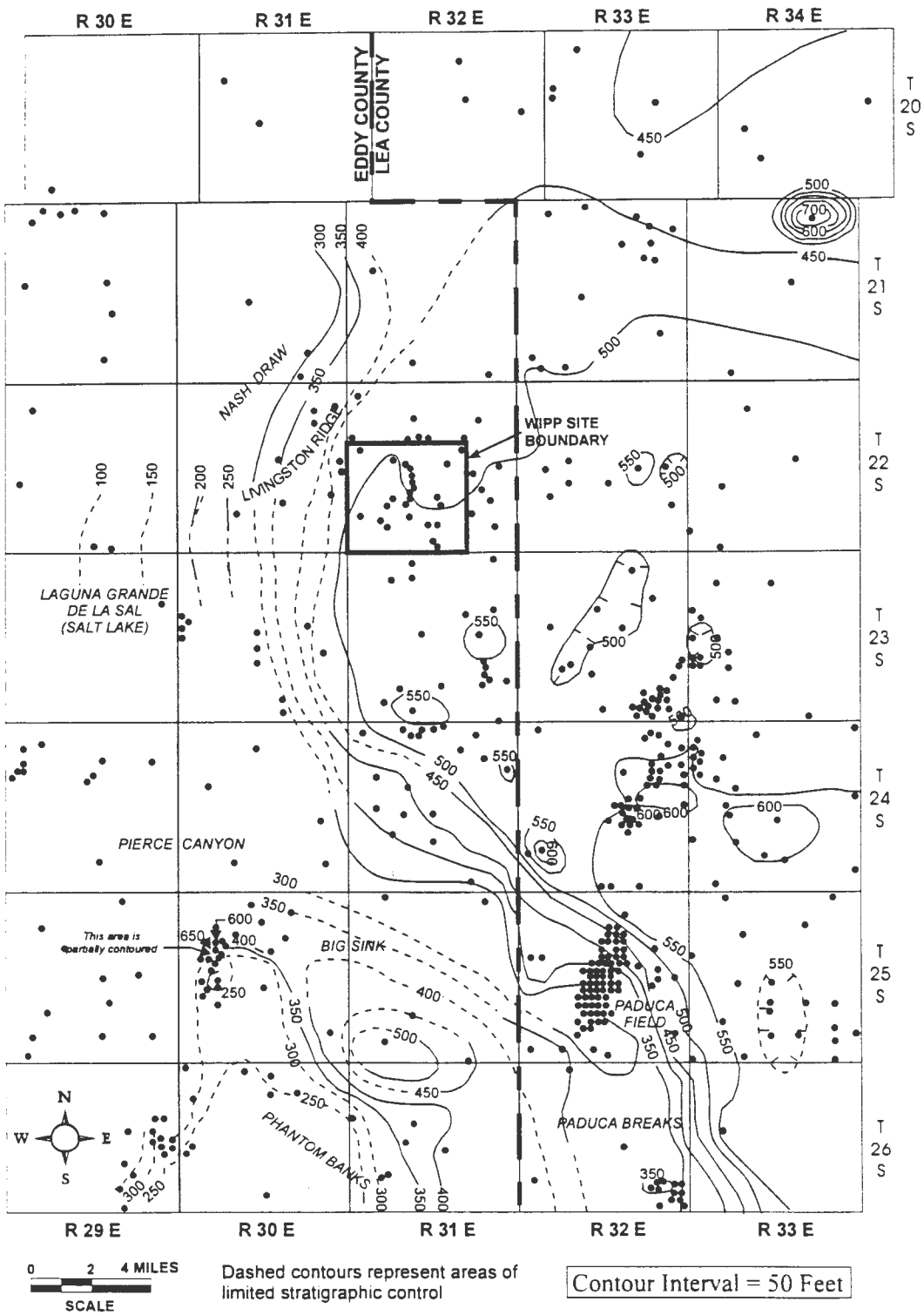


Figure D6-22

Isopach from the Top of the Vaca Triste to the Top of the Salado

RCRAD622

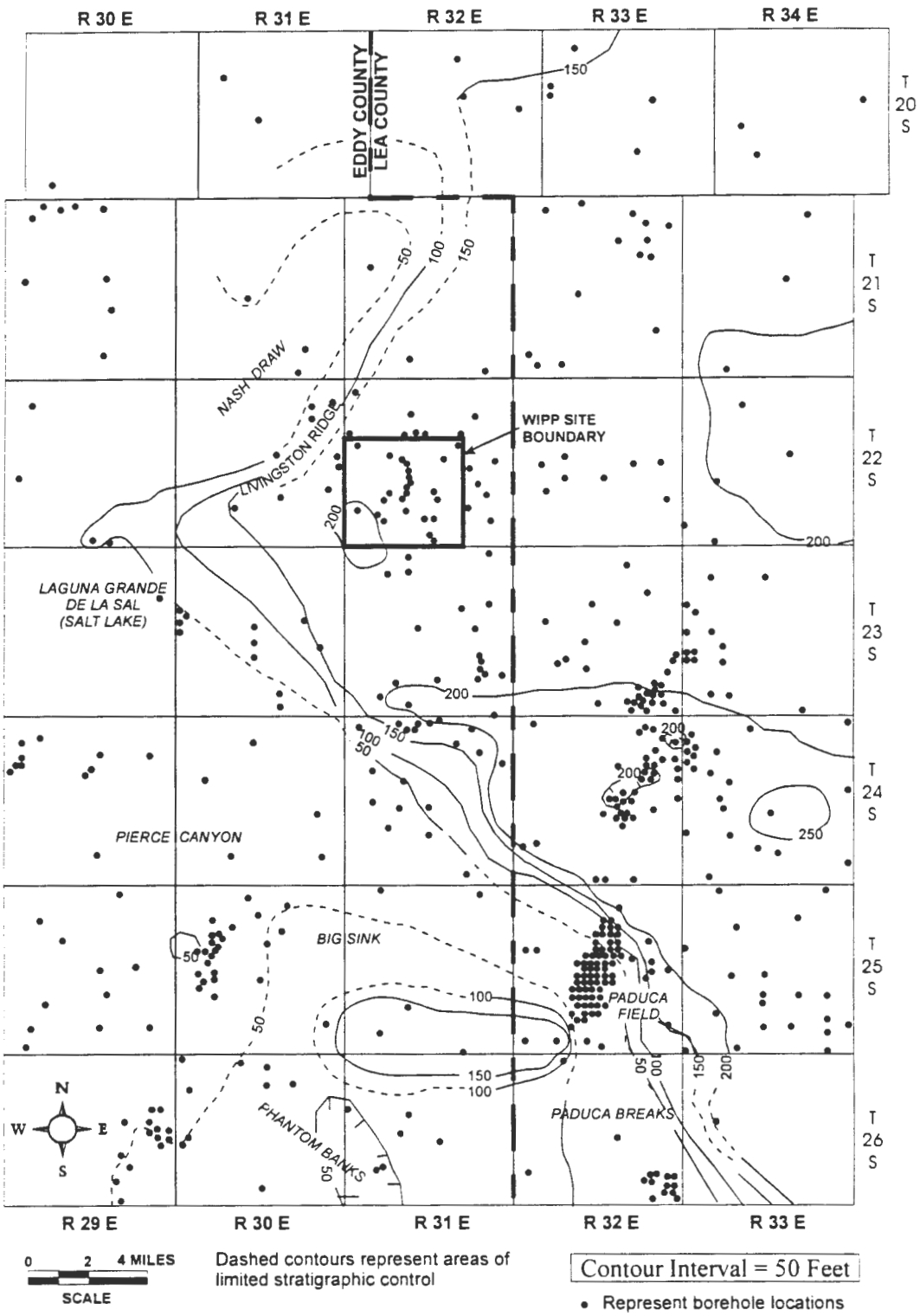


Figure D6-23

Isopach from the Base of MB 103 to the Top of the Salado

RCRAD623

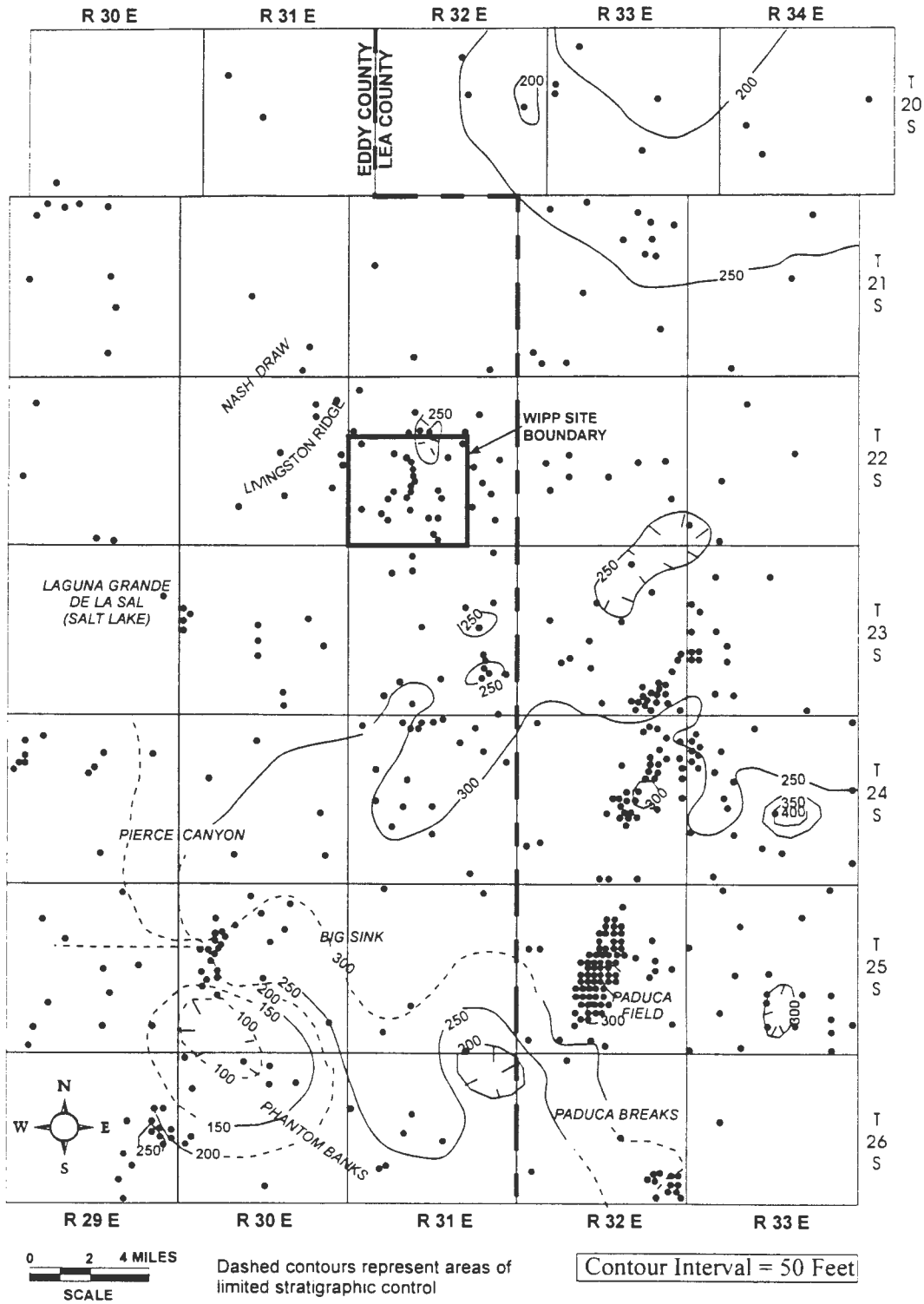


Figure D6-24

Isopach from the Base of MB 123/124 to the Base of the Vaca Triste

RCRAD624

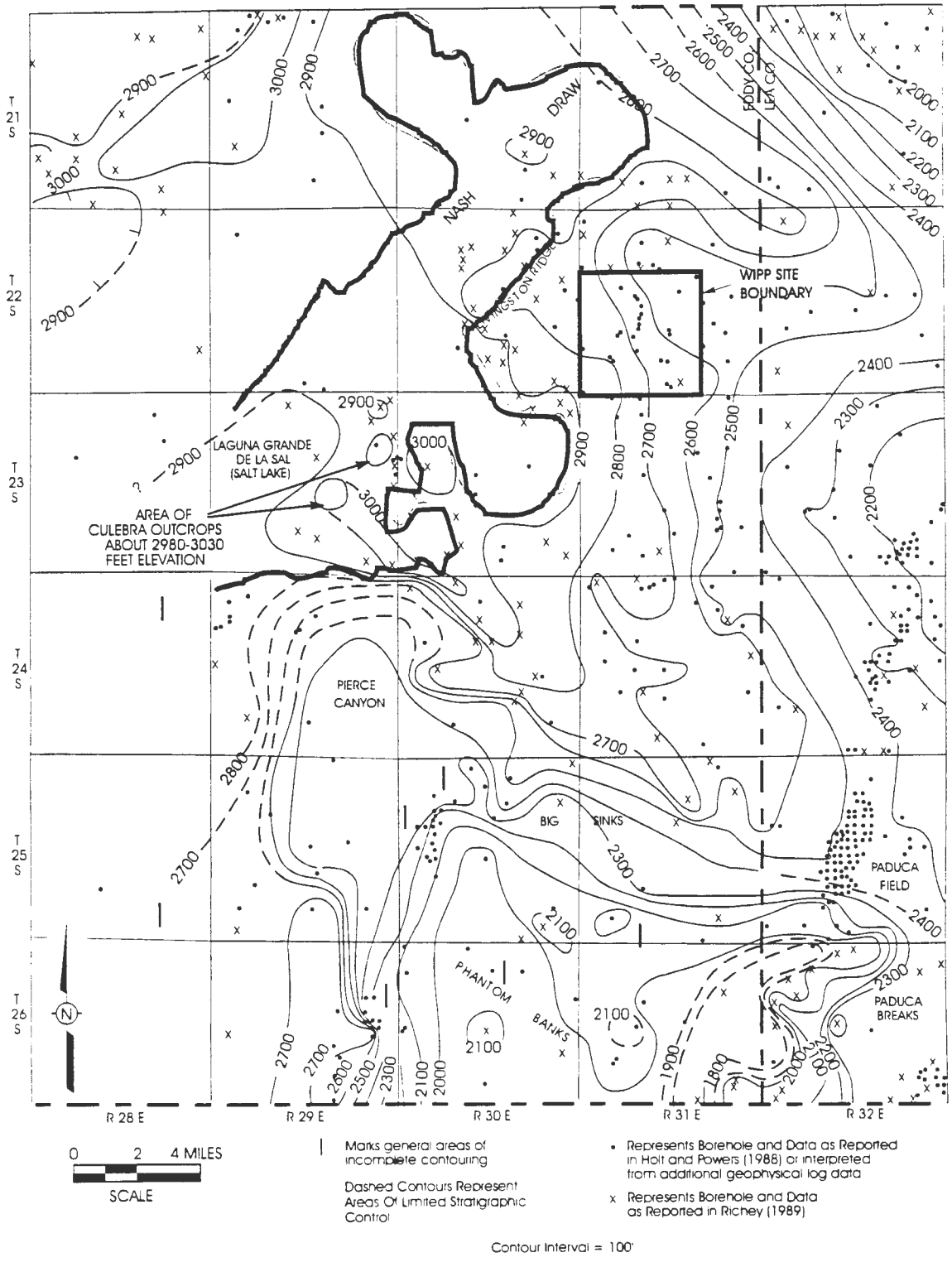


Figure D6-25

Structure Contour Map of Culebra Dolomite Base

RCRAD625

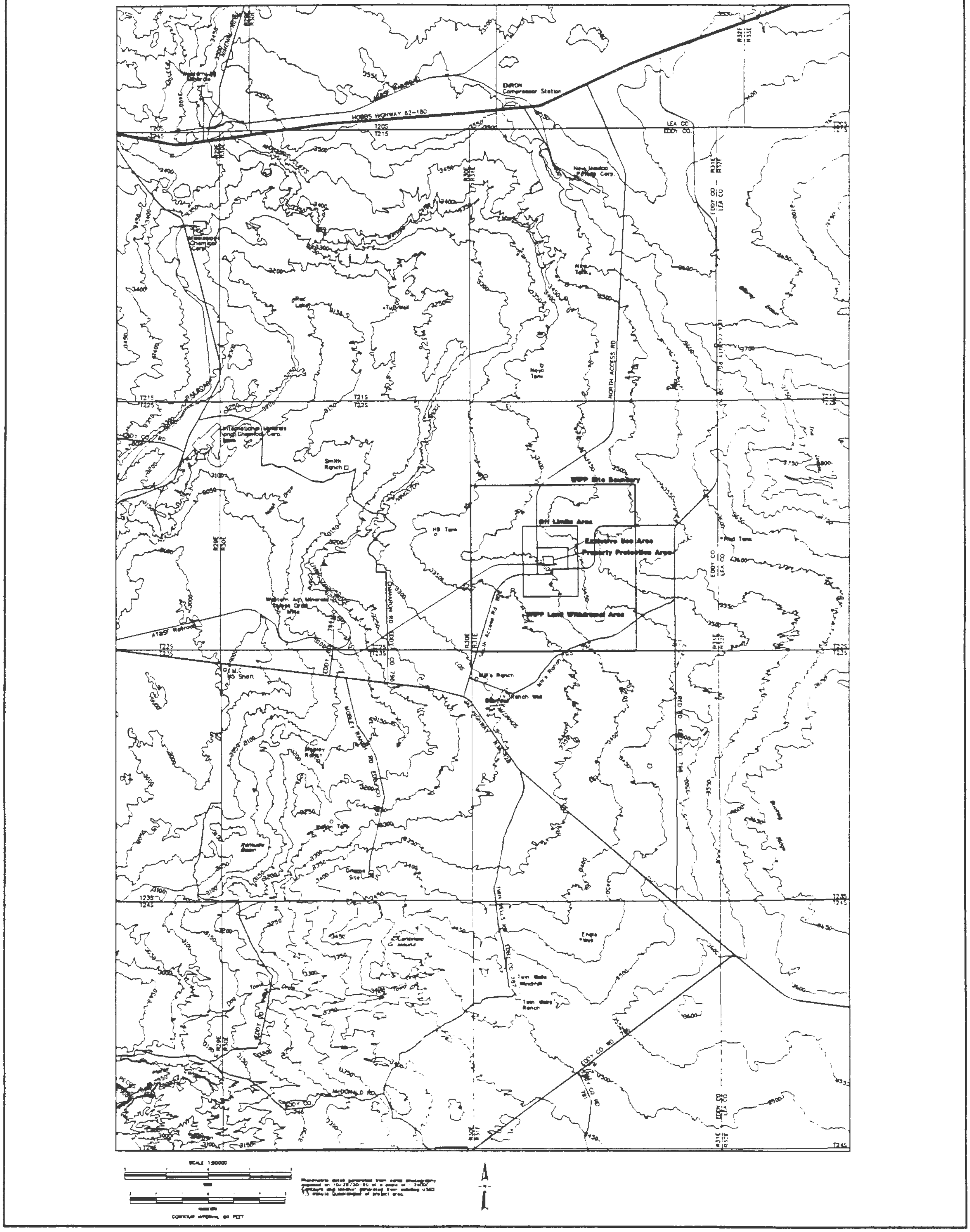
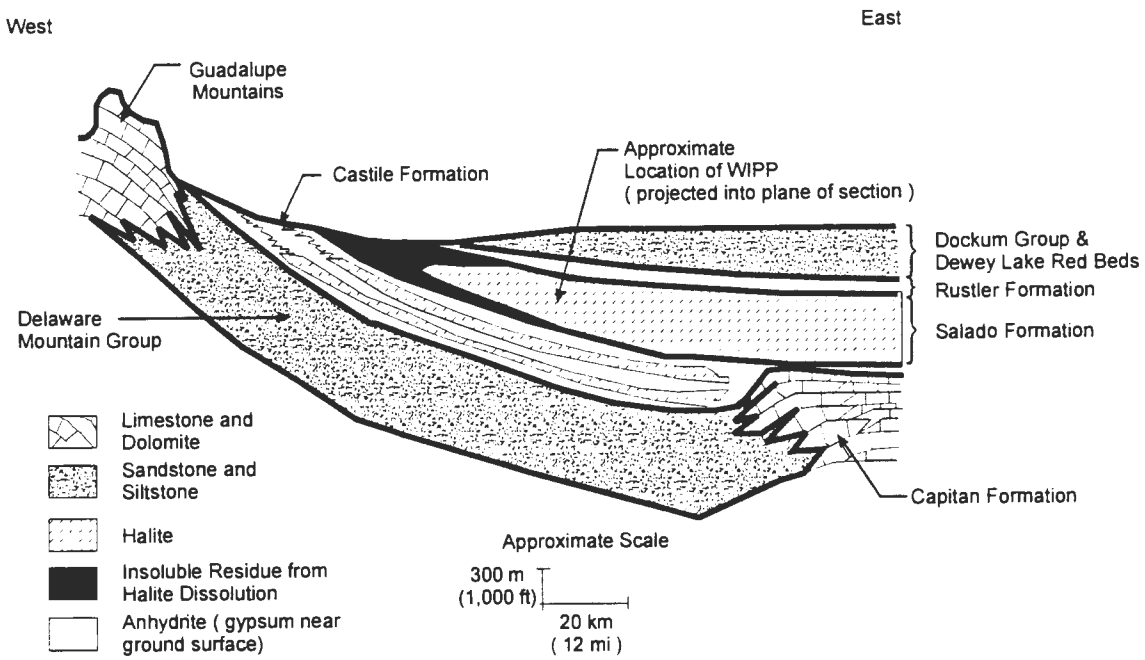


Figure D6-26
Drainage Pattern in the Vicinity of the WIPP Facility

PCRAD626

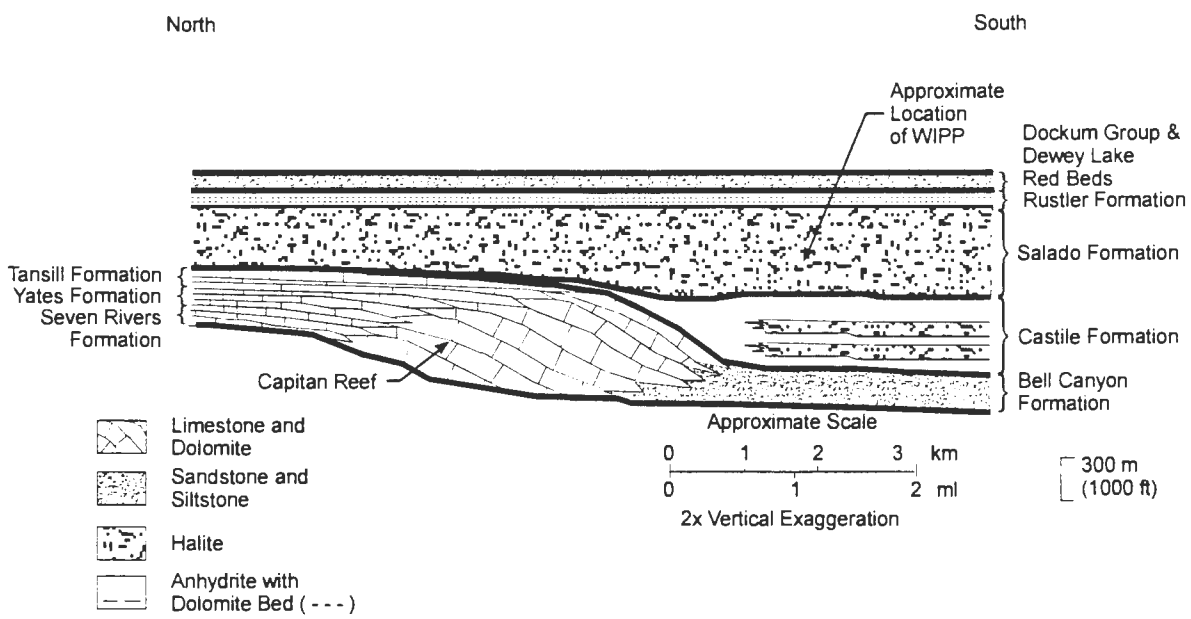


Source: Sandia, 1992, 2, 2-7.

Figure D6-27

Schematic West-East Cross-Section through the North Delaware Basin

RCRAD627



Source: Sandia, 1992, 2, 2-8.

Figure D6-28

Schematic North-South Cross-Section through the North Delaware Basin

RCRAD628

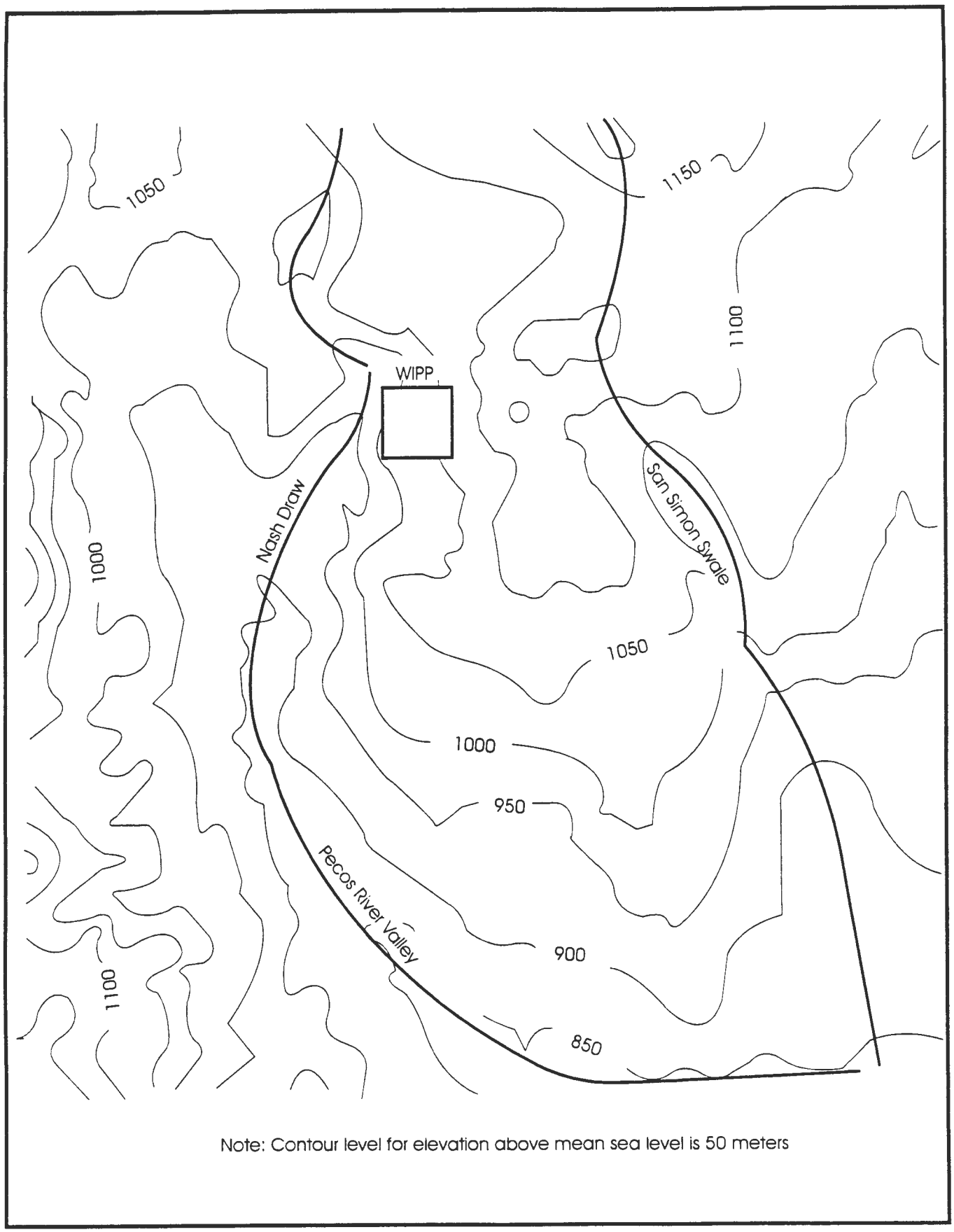
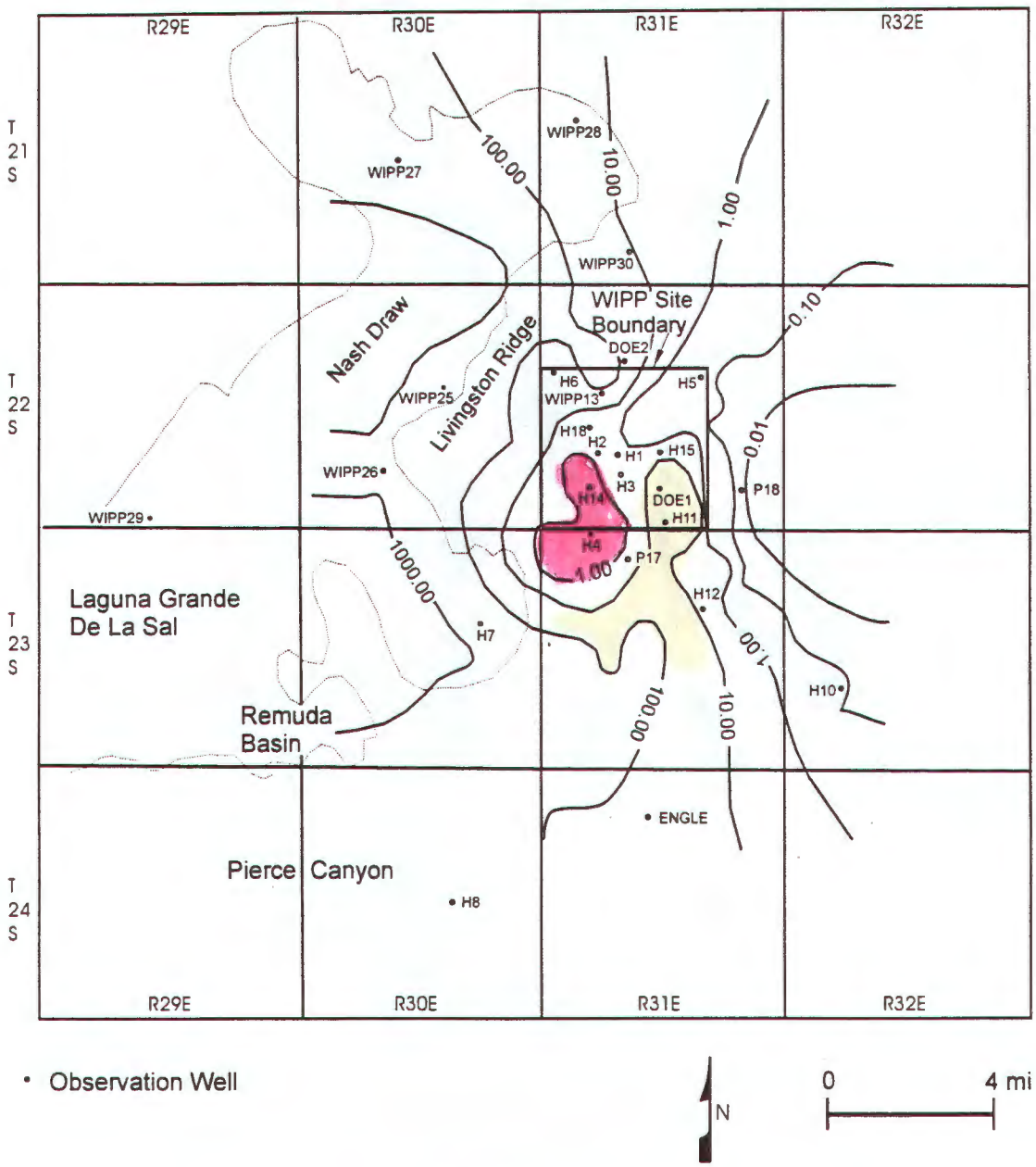


Figure D6-29

Outline of the Groundwater Basin Model Domain on a Topographic Map

RCRAD629



• Observation Well

N

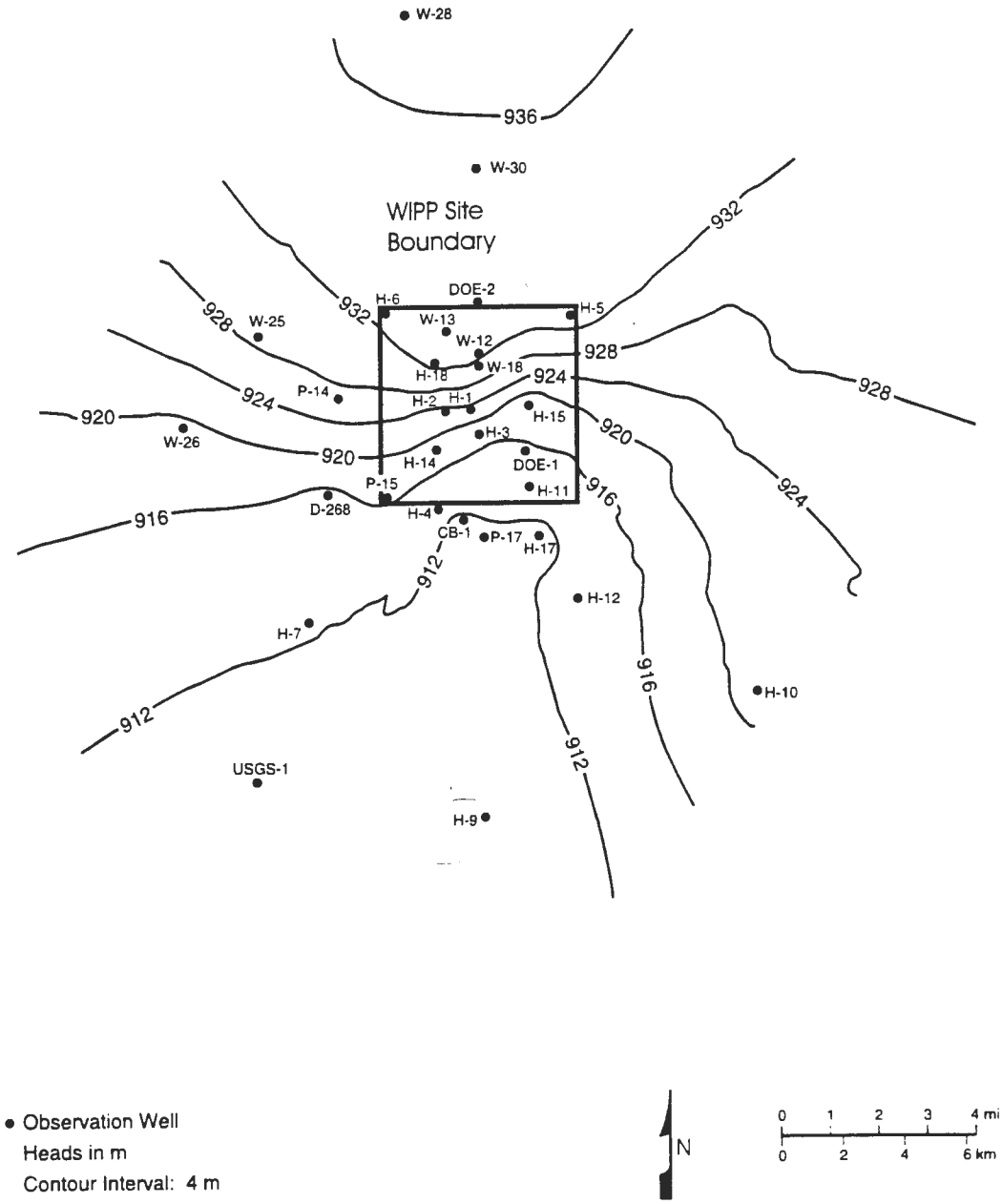
0 4 mi

Note: Transmissivities are given in square feet per day. Figure is modified from LaVenue et al. 1990 (Figure 2.22a).

Figure D6-30

Transmissivities of the Culebra

RCRAD630



• Observation Well
Heads in m
Contour Interval: 4 m

Note: Elevations in meters above the mean sea level adjusted to equivalent freshwater values.

Figure D6-31

Hydraulic Heads in the Culebra

RCRAD631

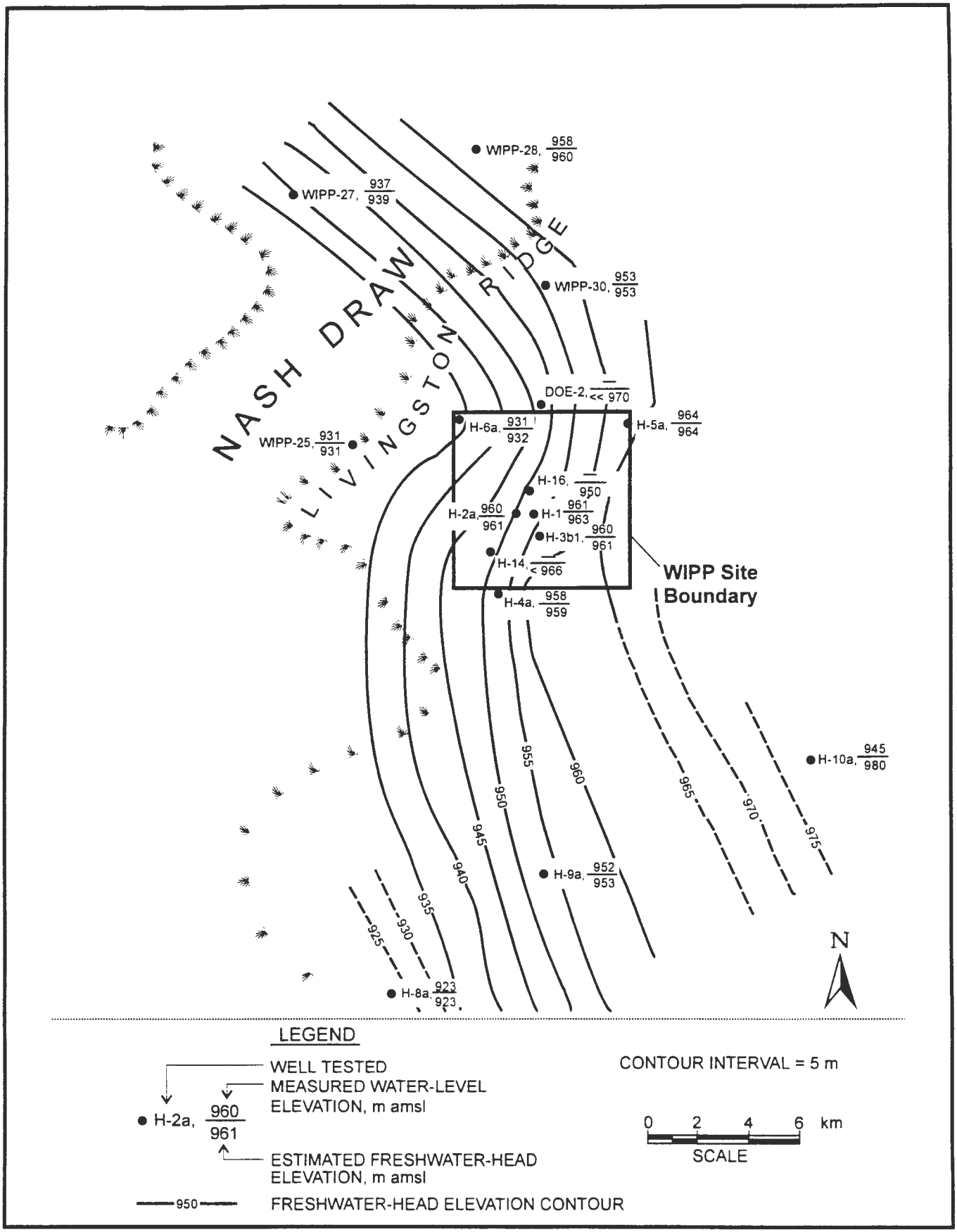


Figure D6-32

Hydraulic Heads in the Magenta

RCRAD632

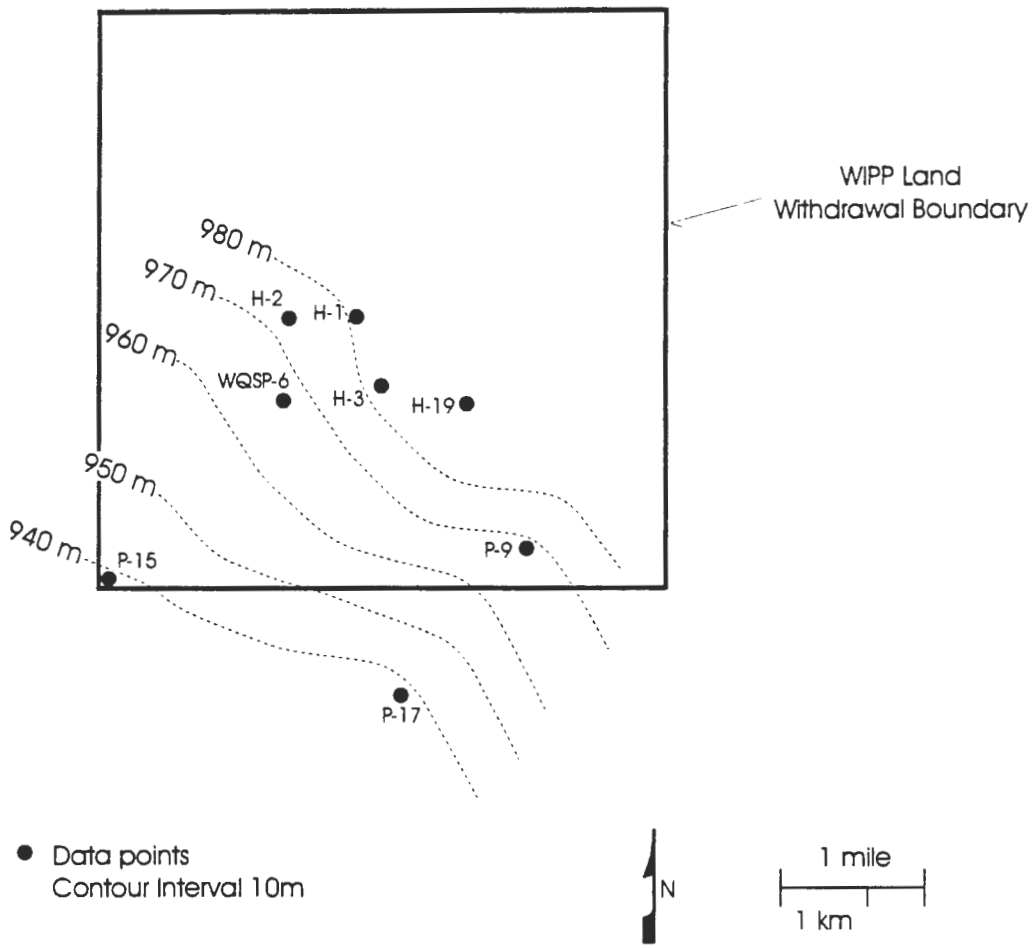


Figure D6-33

Interpreted Water Table Surface

RCRAD633

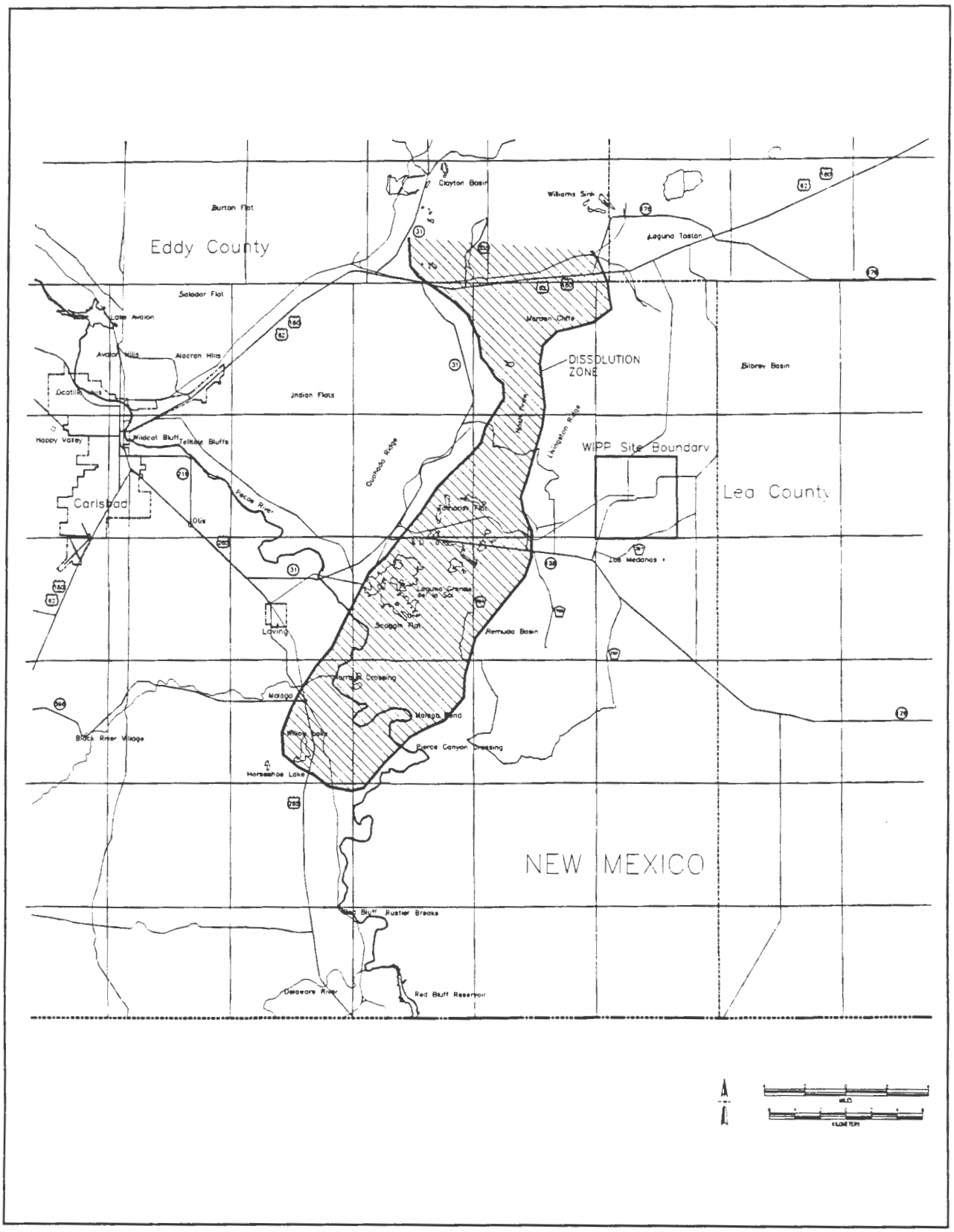


Figure D6-34
Brine Aquifer in the Nash Draw

RCRAD634

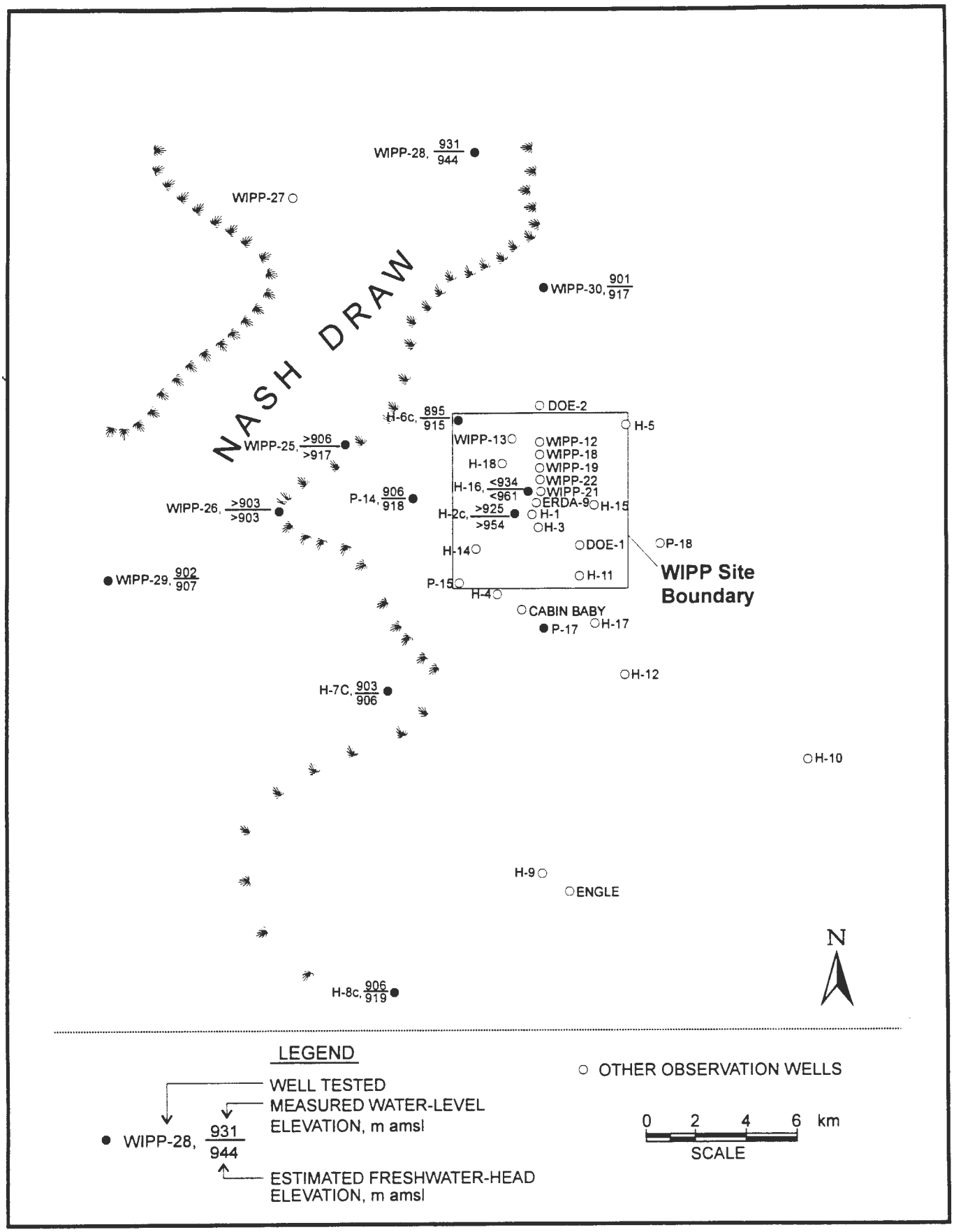


Figure D6-35

Measured Water Levels and Estimated Freshwater Heads of the Unnamed Lower Member and Rustler-Salado Contact Zone

RCRAD635

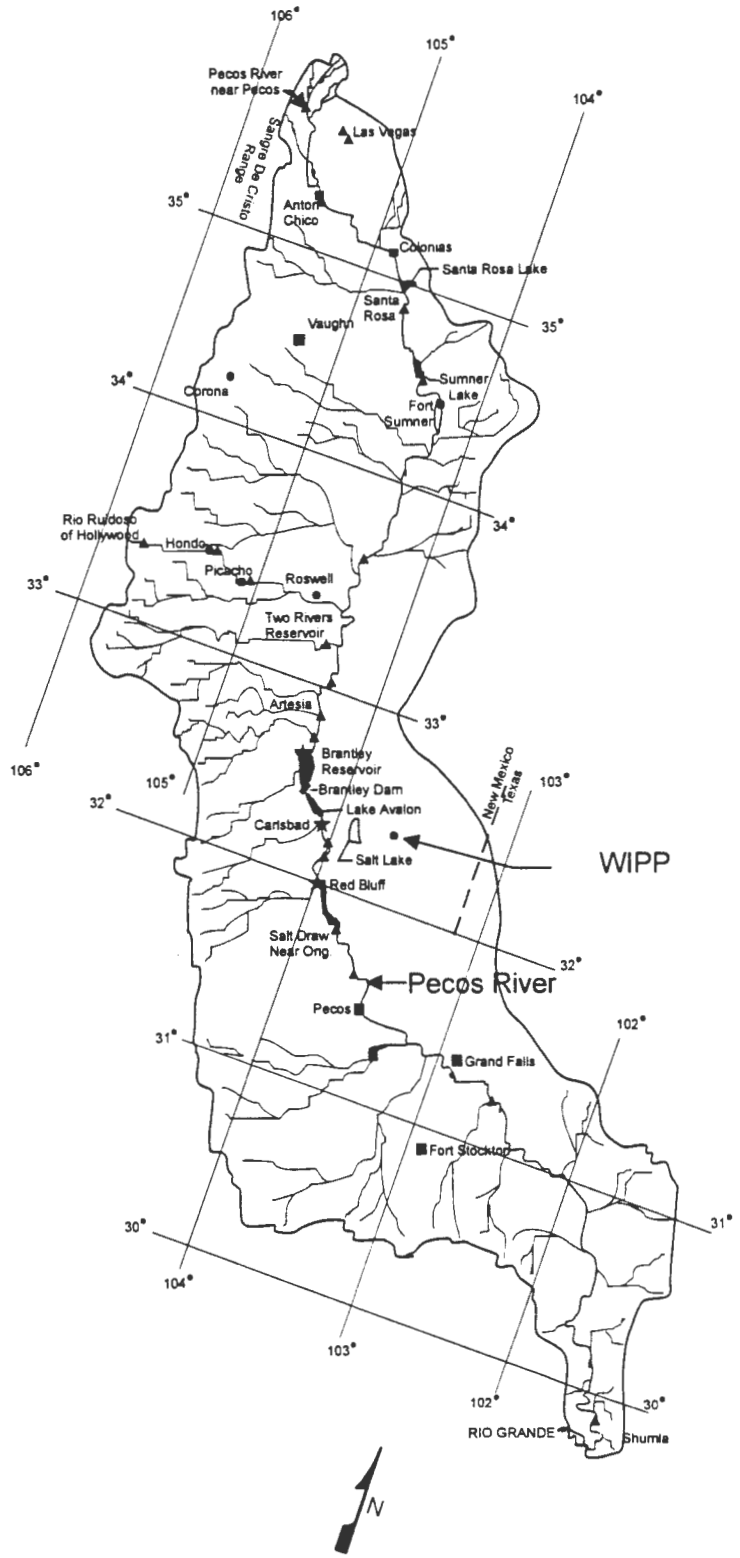


Figure D6-36

Location of Reservoirs and Gauging Stations in the Pecos River Basin

RCRAD636

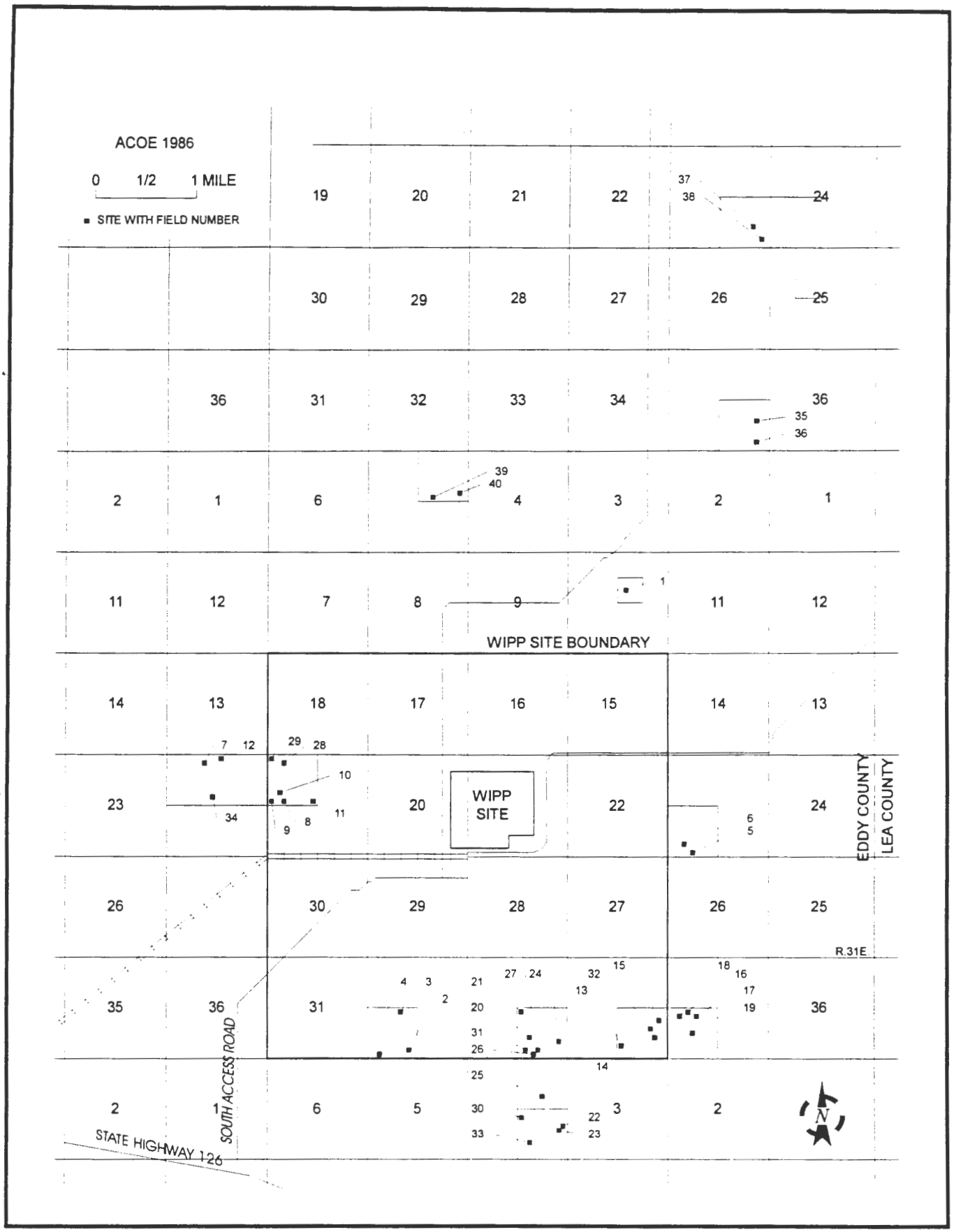


Figure D6-37

Mariah Study Archaeological Sites

RCRAD637

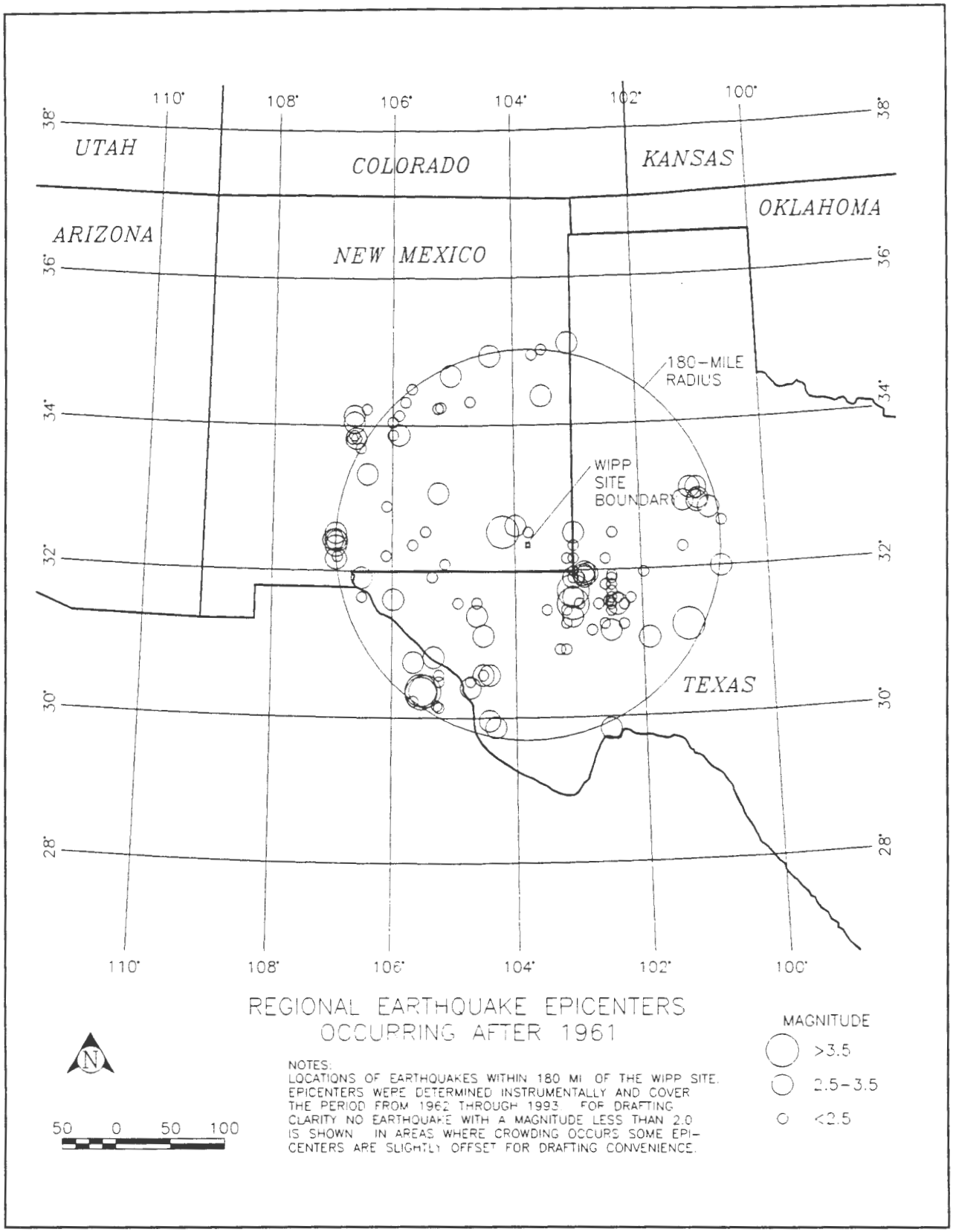


Figure D6-38
Regional Earthquake Epicenters Occurring After 1961

APPENDIX D6

WASTE ISOLATION PILOT PLANT
RCRA PART B PERMIT APPLICATION
Subappendix BH

APPENDIX D6

WASTE ISOLATION PILOT PLANT
RCRA PART B PERMIT APPLICATION
Subappendix BH

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BOREHOLE DATA

for

SOUTHEASTERN NEW MEXICO

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VALIDATION OF THE BOREHOLE DATA FOR SOUTHEASTERN NEW MEXICO

This data base was prepared by Stoller, Robin Strickland Robin Strickland

This data base was validated by Stoller, Jim Waters Jim Waters

This data base was validated by Merrick, James Ward James Ward

Dated: 02/28/95

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APPENDIX BH

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: AEC-7
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1323

LOCATION: 2036.97' FNL, 2033.23' FEL
Sec. 31, T 21 S, R 32 E

ELEVATION: 3657.25' (Top of Casing)
TOTAL DEPTH: 4734'
TYPE OF WELL: Geological Exploration
DRILLER: Verna Drilling Company

DRILLING RECORD: **Date Started:** 03/20/74 **Date Completed:** 04/19/80

CASING RECORD:
Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 40
Cement:

Diameter: 8 5/8
Grade: H-40
Wt/Ft: 28
From: 0
To: 1016
Cement:

PLUGGING SCHEDULE:
No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-7	Quaternary	
	Holocene-Eolian Sand	16.2-20.2
	Mescalero Caliche	20.2-24.2
	Triassic	
	Santa Rosa Sandstone	24.2-133.0
	Permian	
	Dewey Lake Red Beds	133.0-675.0
	Rustler Formation	675.0-1000.6
	Magenta Dolomite Member	733.5-767.0
	Culebra Dolomite Member	872.2-900.5
	Salado Formation	1000.6-3014.7
	Upper Member	1000.6-1505.1
	MB 101	1125.8
	MB 102	1158.5
	MB 103	1171.4-1186.5
	MB 104	1197.0
	MB 105	1211.5
	MB 106	1230.5
	MB 107	1269.0
	MB 108	1278.0
	MB 109	1303.8-1324.5
	MB 111	1378.0
	MB 112	1397.5
	MB 114	1450.5
	MB 116	1498.4
	McNutt Potash Zone	1505.1-1881.0
	Vaca Triste Sandstone	1505.1-1514.1
	MB 117	1578.9
	MB 118	1595.6
	MB 119	1619.8
	MB 121	1661.5
	MB 122	1668.5
	Union Anhydrite	1696.2-1705.0
	MB 123	1774.8-1781.2
	MB 124	1785.5-1795.5
	MB 126	1881.0
	Lower Member	1881.0-3104.7
	MB 128	1918.0
	MB 129	1943.9
	MB 131	2013.5
	MB 132	2039.0
	MB 133	2057.5
	MB 134	2097.0-2109.0
	MB 136	2161.0-2168.0
	MB 139	2267.5
	MB 140	2302.8-2314.2
	MB 141	2364.5
	MB 142	2400.2-2406.5
	MB 143	2453.0-2455.6
	Cowden Anhydrite	2520.0-2539.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-7	Castile Formation	3014.7-4535.3
	Anhydrite III	3014.7-3113.0
	Halite II	3113.0-3310.0
	Anhydrite II	3310.0-3506.9
	Halite II	3506.9-3588.2
	Anhydrite II	3588.2-4055.0
	Halite I	4055.0-4182.3
	Anhydrite I	4182.3-4535.5
	Bell Canyon Formation	4535.5-4731.9 (T.D.)
	Reef Talus	4535.5-4584.7
	Lamar Limestone	4584.7-4633.3
	Ramsey Sandstone	4633.3-4678.5
	Ford Shale	4678.5-4714.9
	Olds Sandstone	4714.9-4731.9

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: AEC-8
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 935' FNL, 1979' FWL
Sec. 11, T 22 S, R 31 E

ELEVATION: 3532' (Top of Casing)
TOTAL DEPTH: 4922'
TYPE OF WELL: Geological Exploration
DRILLER: Sonora Drilling Company

DRILLING RECORD: **Date Started:** 06/28/76 **Date Completed:** 08/05/76

CASING RECORD:
Diameter: 13 3/8
Grade:
Wt/Ft: 54.5
From: 0
To: 42
Cement:

Diameter: 8 5/8
Grade:
Wt/Ft: 28
From: 0
To: 885
Cement: 660 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 4919
Cement: 2481 Cu. Ft.

Note: Completed logging. Ran 7 7/8" bit in the hole and conditioned mud to run casing. Corrected total depth to 4922'. Laid down drill pipe. Ran 123 joints (4933.72') of 5 1/2" O.D., 15.50#, J-55, range 3, ST&C casing in the hole and landed at 4918.77' (4907.22' GL). A Halliburton guide shoe was on bottom with a float shoe at 4859.52' GL. Centralizers were placed at 4905' GL, 4827' GL, 800' GL and 50' GL. 38 joints (1533.25') of casing were sand blasted for better bond from 2374' to 4907' KB.

Completed running casing. Cemented annulus using Halliburton with 1500 sacks (2085 cu ft) of 50-50 Pozmix "C" with 9.7 #/sk of salt and 2% bentonite followed by 300 sacks (396 cu ft) of Class "C" cement. Displaced cement with 117 barrels of water. Casing was reciprocated during displacement. After displacing 90 barrels approximately 2 barrels of cement circulated to the surface, circulation was lost at this point. Bumped plug with 2000 psi and held. Cement in place at 0220 hours. Ran Dresser Atlas temperature log, top of cement at 880'. Ran Sperry-Sun gyroscopic multishot survey in the hole on 25' stations and 100' stations out of the hole.

All depths are measured from Kelly Bushing 11.5' above ground level.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-8	Quaternary: Holocene-Eolian Sand	9.0-29.0
	Mescalero Caliche	29.0-35.0
	Triassic	
	Santa Rosa Sandstone	35.0-177.4
	Permian	
	Dewey Lake Red Beds	177.4-668.0
	Rustler Formation	668.0-990.0
	Magenta Dolomite Mem	727.3-749.5
	Culebra Dolomite Mem	848.3-873.3
	Salado Formation	990.0-2979.6
	Upper Member	990.0-1469.3
	MB 101	1101.0-1116.5
	MB 102	1146.7
	MB 103	1157.7-1173.7
	MB 104	1184.4
	MB 105	1197.6
	MB 106	1215.3
	MB 107	1240.5
	MB 108	1261.3
	MB 109	1286.1-1304.7
	MB 111	1351.9
	MB 112	1370.4
	MB 113	1398.7
	MB 114	1418.2
	MB 115	1451.3
	MB 116	1462.5
	McNutt Potash Zone	1469.3-1826.5
	Vaca Triste Sands	1469.3-1484.1
	MB 117	1535.4
	MB 118	1557.0
	MB 119	1580.5
	MB 120	1603.2
	MB 121	1622.0
	MB 122	1628.6
	Union Anhydrite	1648.0-1657.9
	MB 123	1733.5
	MB 124	1746.8
	MB 126	1826.5
	Lower Member	1826.5-2979.6
	MB 127	1849.5
	MB 128	1861.5
	MB 129	1885.3
	MB 130	1894.7
	MB 131	1959.6
	MB 132	1989.0
	MB 133	2005.5
	MB 134	2047.9-2060.5
	MB 135	2076.0
	MB 136	2114.0-2128.3
	MB 137	2138.5

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
AEC-8	MB 138	2187.4
	MB 139	2247.8
	MB 140	2309.1-2316.5
	MB 141	2369.1
	MB 142	2411.8-2419.6
	MB 143	2465.2-2472.7
	MB 144	2498.8-2510.9
	Cowden Anhydrite	2539.5-2561.6
	Castile Formation	2979.6-4315.0
	Anhydrite III	2979.6-3290.0
	Halite II	3290.0-3555.0
	Anhydrite II	3555.0-3695.5
	Halite I	3695.5-4038.0
	Anhydrite I	4038.0-4315.0
	Bell Canyon Formation	4315.0-4918.0 (T.D.)
	Lamar Limestone	4344.5-4374.0
	Ramsey Sand	4374.0-4436.0
	Ford Shale	4436.0-?

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **ERDA-6**
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 2152' FSL, 910' FEL
Sec. 35, T 21 S, R 31 E

ELEVATION: 3540.2' (Top of Casing)
TOTAL DEPTH: 2775'
TYPE OF WELL: Geologic Exploration
DRILLER: Boyles Bros. Drilling Company: 06/11/75 to 08/15/75 - Pan AM E

DRILLING RECORD: **Date Started:** 06/13/75 **Date Completed:** 09/23/75

CASING RECORD:
Diameter: 13 3/8
Grade:
Wt/Ft: 54.5
From: 0
To: 30
Cement: Ready Mix

Diameter: 8 5/8
Grade: K-55
Wt/Ft: 24
From: 0
To: 880
Cement: 575 SX.

Note: Plugged back 2773' to 2560' with 225 cement. Hole filled with brine.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-6	Quaternary	
	Holocene-Eolian Sand	0-9
	Mescalero Caliche	9-17
	Triassic	
	Santa Rosa Sandstone	17-72
	Permian	
	Dewey Lake Red Beds	72-538
	Rustler Formation	538-811
	Dissolution Residue	570-581
	Magenta Dolomite Member	598-623
	Dissolution Residue	696-707
	Culebra Dolomite Member	713-739
	Dissolution Residue	742-762
	Salado Formation	811-2396.5
	Upper Unit	811-1276.6
	MB 100	NR
	MB 101	923.5-929.9
	MB 102	956.8-958.2
	MB 103	970.3-984.3
	MB 104	992.1-992.4
	MB 105	NR
	MB 106	NR
	MB 107	1060.0-1060.9
	MB 108	1069.1-1069.9
	MB 109	1090.9-1113.5
	MB 110	NP
	MB 111	1161.5-1161.8
	MB 112	1178.9-1180.2
	MB 113	NP
	MB 114	1224.9-1226.9
	MB 115	1256.1-1257.2
	MB 116	1268.7-1271.4
	McNutt Potash Zone	1276.6-1612.9
	Vaca Triste Sandstone	1276.6-1287.3
	11th Ore Zone	1324.7-1329.8
	MB 117	1340.7-1342.7
		1346-1349.0
	MB 118	1359.0-1366.2
	MB 119	1378.4-1379.4
	10th Ore Zone	1386.1-1395.5
	MB 120	1401.0-1402.3
	9th Ore Zone	1403.2-1410.3
	MB 121	1413.3-1415.5
	MB 122	1422.3-1424.3
	8th Ore Zone	1424.9-1437.0
	Union Anhydrite	1444.6-1453.8
	7th Ore Zone	1464.0-1468.5
	6th Ore Zone	1479.7-1482.2
	5th Ore Zone	1487.8-1494.9
	MB 123	1517.7-1524.9

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-6	MB 124	1529.4-1537.5
	4th Ore Zone	1541.9-1549.1
		1549.7-1553.0
	3rd Ore Zone	1555.5-1567.2
	2nd Ore Zone	1571.0-1574.3
	MB 125	NP
	1st Ore Zone	1587.0-1603.3
	MB 126	NP
	Lower Member	1612.9-2396.5
	MB 127	1635.0-1635.7
	MB 128	1647.7-1648.5
	MB 129	1670.0-1671.5
	MB 130	NP
	MB 131	1743.0-1743.7
	MB 132	1770.6-1771.4
	MB 133	1785.6-1789.2
	MB 134	1833.2-1843.4
	MB 135	1860.4-1861.5
	MB 136	1900.5-1910.5
	MB 137	NP
	MB 138	1967.5-1967.7
	MB 139	2019.5-2022.4
	MB 140	2060.4-2075.6
	MB 141	2124.5-2126.6
	MB 142	2163.8-2169.5
	MB 143	2212.7-2215.6
	MB 144	2237.0-2237.7
	Cowden Anhydrite	2269.5-2291.0
	Castile Formation	2400.5-2775.0
	Halite II	2400.5-2555.1
	Anhydrite II	2555.1-2732.5 (Fault or Rupture Zone)
	Halite I	2732.5-2775.0
	Cowden Anhydrite	2540.0-2653.0
	Castile Formation	2836.0-2889.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: ERDA-9
OPERATOR: Sandia National Labs
PERMIT NO.: Unknown

LOCATION: 267.17' FSL, 176.74' FEL
Sec. 20, T 22 S, R 31 E

ELEVATION: 3410.10' (Top of Casing)
TOTAL DEPTH: 2886'
TYPE OF WELL: Geologic Exploration
DRILLER: Sonora Drilling Company

DRILLING RECORD: **Date Started:** 04/28/76 **Date Completed:** 06/26/76

CASING RECORD:
Diameter: 16
Grade:
Wt/Ft:
From: 0
To: 40
Cement: 95 Cu. Ft.

Diameter: 10 3/4
Grade: J-55
Wt/Ft: 40.5
From: 0
To: 1045
Cement: 1159 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 2883
Cement: Mud Pack

Note: Ran Dresser Atlas caliper log. Ran 79 joints (2889.66') of 7" O.D., 23# casing with a Dowell swirl type shoe on bottom and a Dowell orifice fill collar on top of the bottom joint. Set casing at 2882.66' with centralizers at 2868', 2520', and 1030'. Rigged up Dowell and pumped in 140 barrels of Baroid casing pack mud. Cemented annulus with 10 barrels of water, 12 barrels of chemical wash, 12 barrels of oil base slurry ahead of 122 cu. ft. (115 sacks) of Class "H" cement + 3% calcium chloride. Seated plug with 1000 psi, plug holding. Cement in place at 1445 hours.

All depths are measured from Kelly Bushing 11.5' above ground level.

PLUGGING SCHEDULE:
See Casing Record.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-9	Kelly Bushing (KB) to Land Surface (LS)	0-12.0
	Holocene Deposits	12.0-22.0
	Pleistocene Rocks	
	Mescalero Caliche	22.0-27.0
	Gatuna Formation	27.0-54.0
	Triassic	
	Santa Rosa Sandstone	54.0-63.0
	Permian	
	Dewey Lake Red Beds	63.0-550.0
	Ruslter Formation	550.0-860.0
	Dissolution Residue	580.0-592.0
	Magenta Dolomite Member	608.0-632.0
	Dissolution Residue	691.0-710.0
	Culebra Dolomite Member	716.0-739.0
	Dissolution Residue	742.0-748.0
	Salado Formation	860.0-2836.0
	Upper Member	860.0-1362.0
	MB 100	939.0
	MB 101	984.0
	MB 102	1026.0
	MB 103	1040.0-1050.0
	MB 104	1061.0
	MB 105	1075.0
	MB 106	1093.0-1094.0
	MB 107	1132.0
	MB 108	1142.0
	MB 109	1165.0-1188.0
	MB 110	NP
	MB 111	1238.0
	MB 112	1256.0-1258.0
	MB 113	1282.0-1284.0
	MB 114	1306.0
	MB 115	1340.0-1344.0
	MB 116	1354.0-1356.0
	McNutt Potash Zone	1362.0-1742.0
	Vaca Triste Sands	1365.0-1367.0
	11th Ore Zone	1420.0-1422.0
	MB 117	1431.0-1433.0
	MB 118	1455.0-1463.0
	MB 119	1482.0
	10th Ore Zone	1487.0-1493.0
	MB 120	1501.0-1502.0
	9th Ore Zone	1507.0-1512.0
	MB 121	1515.0-1517.0
	MB 122	1524.0
	8th Ore Zone	1531.0-1542.0
	Union Anhydrite	1549.0-1557.0
	7th Ore Zone	1572.0-1576.0
	6th Ore Zone	1590.0-1593.0
	5th Ore Zone	1597.0-1603.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-9	MB 123	1630.0-1637.0
	MB 124	1645.0-1653.0
	4th Ore Zone	1659.0-1669.0
	3rd Ore Zone	1676.0-1688.0
	2nd Ore Zone	1696.0-1698.0
	MB 125	NP
	1st Ore Zone	1712.0-1723.0
	MB 126	1742.0
	Lower Member	1742.0-2836.0
	MB 127	1768.0-1770.0
	MB 128	1778.0-1781.0
	MB 129	1803.0-1805.0
	MB 130	1815.0
	MB 131	1884.0
	MB 132	1914.0-1915.0
	MB 133	1933.0-1935.0
	MB 134	1976.0-1989.0
	MB 135	2006.0
	MB 136	2043.0-2058.0
	MB 137	2075.0
	MB 138	2120.0-2121.0
	MB 139	2177.0-2180.0
	MB 140	2241.0-2251.0
	MB 141	2320.0-2330.0
	MB 142	2377.0-2391.0
	MB 143	2450.0-2456.0
	MB 144	2493.0-2506.0
	Cowden Anhydrite	2540.0-2653.0
	Castile Formation	2836.0-2889.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **ERDA-10**
OPERATOR: Sandia National Labs
PERMIT NO.: Unkown

LOCATION: 200' FNL, 2327' FEL
Sec. 34, T 23 S, R 30 E

ELEVATION: 3371.2' (Top of Casing)
TOTAL DEPTH: 4418.5'
TYPE OF WELL: Geologic Exploration
DRILLER: Corel Drilling Company

DRILLING RECORD: **Date Started:** 08/18/77 **Date Completed:** 10/14/77

CASING RECORD:
Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 50
Cement: 81 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 805
Cement: 554 Cu. Ft.

Note: Hole plugged to surface.
All depths are measured from Kelly Bushing 13' above ground level.

PLUGGING SCHEDULE:
10/01/77 - Made trip with 7 7/8" bit and conditioned hole. Ran 2 3/8" O.D. tubing in the hole and plugged back hole using Dowell with 10 barrels of water ahead of 48 barrels of mud wash followed by 414 cu. ft. of class "C" cement with 2% calcuim chloride. Displace cement with 12.5 barrels of water. Cement in place at 1300 hours. Pulled tubing and waited on cement.

10/03/77 - Made trip with 7 7/8" bit and tagged cement at 3556', conditioned hole. Made up 7 13/16" core bit and cut core #32 from 3556' to 3595', recovered 10' of cement. Cut core #33 from 3595' to 3623', recovered 20' of cement. Cut core #34 from 3623' to 3630'.

10/04/77 - Completed core #34 from 3630' to 3673', recovered 27' of cement. Ran 2 7/8" O.D. tubing in the hole to 3673'. Cemented plug #2 using Dowell with 10 barrels of water ahead of 84 barrels of mud flush followed by 10 barrels of water ahead of 1040 cu. ft. of 70% class "C" cement and 30% Litepoz. Cement in place at 1140 hours. Pulled tubing to 2300' and curculated hole. Waited on cement. Laid down drill pipe.

10/05/77 - Waited on cement to 0900 hours. Tagged top of plug #2 at 2335' with tubing. Cemented plug #3 with 10 barrels of water, 60 barrels of mud flush and 10 barrels of water, ahead of 1039 cu. ft. of cement slurry. Cement in place at 1420 hours. Pulled tubing to 803' and circulated out mud flush and cement. Waited on cement.

10/06/77 - Tagged top of plug #3 at 827'. Cemented plug #4 to surface with 10 barrels of water, 1000 gallons of mud flush and 10 barrels of water ahead of 417 cu. ft. of cement slurry. Cement in place at 0050 hours. Rigged down government furnished equipment and released rig at 1600 hours.

10/14/77 - Cement had dropped to 11.5' inside the 9 5/8" O.D. casing. Cemented to surface with 6 sacks of cement. Hole plugged

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-10	Quaternary	
	Holocene-Eolian Sand	
	Mescalero Caliche	13.0-17.0
	Triassic	
	Gatuna Formation	17.0-164.0
	Permian	
	Dewey Lake Red Beds	164.0-378.0
	Rustler Formation	378.0-640.0
	Magenta Dolomite Member	378.0-379.0
	Culebra Dolomite Member	489.0-517.0
	Salado Formation	640.0-2350.0
	Upper Member	640.0-1078.0
	MB 101	696.0
	MB 102	743.0
	MB 103	775.0-783.5
	MB 104	794.5
	MB 105	807.0
	MB 106	817.0
	MB 107	829.0
	MB 108	852.5
	MB 109	879.5-904.5
	MB 111	960.0
	MB 112	978.0
	MB 113	1018.0
	MB 114	1035.0
	MB 115	1068.0
	MB 116	1076.0
	McNutt Postash Zone	1087.0-1521.5
	Vaca Triste Sands	1087.0-1092.5
	MB 117	1162.0
	MB 118	1189.0
	MB 119	1225.0
	MB 121	1264.0
	MB 122	1279.5
	Union Anhydrite	1310.0-1330.0
	MB 123	1380.5-1387.0
	MB 124	1399.5-1407.5
	MB 125	1482.5
	MB 126	1521.5
	Lower Member	1521.5-2350.0
	MB 128	1556.0
	MB 129	1590.0
	MB 130	1604.0
	MB 131	1674.5
	MB 132	1704.5
	MB 133	1722.0
	MB 134	1771.5-1781.0
	MB 135	1807.0
	MB 136	1855.0-1864.5
	MB 138	1930.0

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
ERDA-10	MB 139	1993.0
	MB 140	2053.0-2062.5
	MB 141	2150.9-2155.4
	MB 142	2220.6-2237.4
	MB 143	2302.6-2313.6
	Castile Formation	2350.0-3842.9
	Anhydrite IV	2350.0-2398.2
	Cowden Anhydrite	2398.2-2424.0
	Anhydrite III	2424.0-3097.2
	Halite II	3097.2-3283.7
	Anhydrite II	3283.7-3377.4
	Halite I	3377.4-3616.4
	Anhydrite I	3616.4-3842.9
	Bell Canyon Formation	3842.9-4430.0 (T.D.)
	Lamar Limestone	3842.9-3870.0
	Ramsey Sandstone	3870.0-3918.0
	Ford Shale	3918.0-3928.0
	Old Sandstone	3928.0-3956.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **BABY-1**
OPERATOR: U.S. Department of Energy
PERMIT NO.:

LOCATION: 1989.5' FNL, 2017.1' FEL
Sec 5, T 23 S, R 31 E

ELEVATION: 3328.38' (Top of Casing)
TOTAL DEPTH: 4298.6'
TYPE OF WELL: Oil and Gas Well (Exploratory)
DRILLER: Michel P. Grace - 1974 and Salazar Bros.- 1983

DRILLING RECORD: **Date Started:** 08/12/83 **Date Completed:** 02/08/75

Deepened to 4298.6'
Date Started: 17/18/83
Date Completed: 08/19/83

CASING RECORD:
13 3/8" O.D. casing set in cement to surface 650'
9 7/8" O.D. 650 - 4159'
7 27/32" O.D. 4159 - 4298.6'

PLUGGING SCHEDULE:
Ran 20 joints of 13 3/8 71# casing set at 650'. Cemented with 275 sacks of Trin. Lt. Wt. and 125 sacks Cl. C. and 300# CaCl and 69# celloflake.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
BABY-1	Quaternary	15.5
	Triassic	
	Santa Rosa Sandstone	15.5-142.8
	Permian	
	Dewey Lake Red Beds	142.8-362.9
	Rustler Formation	362.9-653.0
	Magenta Dolomite Member	375.0-414.1
	Culebra Dolomite Member	469.0-487.2
	Salado Formation	653.0-2703.5
	Upper Member	781.3
	MB 101	818.0
	MB 102	845.0-851.0
	MB 103	884.2
	MB 105	922.1
	MB 106	946.8
	MB 107	962.1
	MB 108	977.0-993.9
	MB 109	1036.9
	MB 111	1065.8
	MB 112	1097.0
	MB 113	1117.1
	MB 114	1157.1
	MB 115	1169.8
	MB 116	1182.0-1585.1
	McNutt Potash Zone	1251.0
	MB 117	1277.6
	MB 118	1299.9
	MB 119	1328.9
	MB 120	1346.1
	MB 121	1353.2
	MB 122	1381.8-1395.2
	Union Anhydrite	1454.5-1463.1
	MB 123	1470.0-1481.0
	MB 124	1585.1
	MB 126	1585.1-2703.5
	Lower Member	1610.2
	MB 127	1621.8
	MB 128	1650.1
	MB 129	1663.2
	MB 130	1732.9
	MB 131	1763.7
	MB 132	1784.2
	MB 133	1837.7-1848.9
	MB 134	1871.9
	MB 135	1871.9
	MB 136	1905.2-1912.0
	MB 137	1930.5
	MB 138	1990.4
	MB 139	2040.7
	MB 140	2104.0-2110.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
BABY-1	MB 141	2188.8-2196.9
	MB 142	2239.8-2259.0
	MB 143	2314.1-2321.0
	MB 144	2356.0-2370.0
	Cowden Anhydrite	2407.7-2434.7
	Castile Formation	2703.5-4045.0
	Anhydrite III	2703.5-3154.8
	Halite II	3154.8-3373.1
	Anhydrite II	3373.1-3480.0
	Halite I	3480.0-3810.0
	Anhydrite I	3810.0-4045.0
	Bell Canyon Formation	4045.0-T.D.
	Lamar Limestone	4045.0-4086.0
	Ramsey Sandstone	4086.0-4132.0
	Ford Shale	4132.0-4140.0
	Olds Sandstone	4140.0-4171.0
	Hays Sandstone	4171.0-4298.6

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: D-268
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unkown

LOCATION: 720.4 FSL, 762.7 FEL, Sec. 35, T 22 S, R 30 E

ELEVATION: 3280.70 (Top of Casing)
TOTAL DEPTH: 1411'
TYPE OF WELL: Old Potash Drillhole
DRILLER: Pennsylvania Drilling Co.

DRILLING RECORD: **Date Started:** 11/15/89 **Date Completed:**

CASING RECORD:
Diameter: 4 1/2
Grade:
Wt/Ft:
From: 0
To: 528'
Cement: Cement in place

PLUGGING SCHEDULE:
From: 1411'
To: 528'
Int:
Material: Concrete Plug

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
D-268	Quaternary	
	Holocene-Eolian Sand	0-15.0
	Mescalero Caliche	
	Triassic	
	Santa Rosa Sandstone	15.0-30.0
	Permian	
	Dewey Lake Red Beds	30.0-187.0
	Rustler Formation	187.0-494.0
	Megenta Dolomite Member	255.0-275.0
	Culebra Dolomite Member	369.0-392.0
	Salado Formation	469.0
	Upper Member	
	MB 101	
	MB 102	
	MB 103	
	MB 104	
	MB 105	
	MB 106	
	MB 107	
	MB 108	
	MB 109	
	MB 111	
	MB 112	
	MB 114	
	MB 116	
	McNutt Potash Zone	
	Vaca Triste Sandstone	
	MB 117	
	MB 118	
	MB 119	
	MB 121	
	MB 122	
	Union Anhydrite	
	MB 123	
	MB 124	
	MB 126	
	Lower Member	
	MB 128	
	MB 129	
	MB 131	
	MB 132	1411.0

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: DOE-1
OPERATOR: Westinghouse
PERMIT NO.: Unknown

LOCATION: 182.4' FSL, 607.8' FEL
Sec. 28, T 22 S, R 31 E

ELEVATION: 3465.22' (Top of Casing)
TOTAL DEPTH: 4057.3'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Salazar Bros. Drilling Co.

DRILLING RECORD: **Date Started:** 07/14/82 **Date Completed:** 07/28/82

CASING RECORD:
Diameter: 10 3/4 O.D.
Grade:
Wt/Ft:
From: 0
To: 41
Cement: Set and cemented

Diameter: 10 3/4 O.D.
Grade: J-55
Wt/Ft: 40.5
From: 49
To: 1126.2
Cement:

Diameter: 7 7/8
Grade:
Wt/Ft:
From: 1126.2
To: 4057
Cement: Uncased

PLUGGING SCHEDULE:
No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-1	Quaternary	
	Eolian Sand	Not Described
	Gatuna Formation	Not Described
	Triassic	
	Santa Rosa Sandstone	46.0-133.0
	Permian	
	Dewey Lake Red Beds	133.0-667.5
	Rustler Formation	667.5-976.5
	Magenta Dolomite Member	722.0-745.0
	Culebra Dolomite Member	828.6-850.5
	Salado Formation	976.5-2936.5
	Upper Member	976.5-1486.0
	MB 101	1102.0
	MB 102	1138.5
	MB 103	1159.0-1169.0
	MB 105	1199.0
	MB 106	1216.0
	MB 107	1254.0
	MB 108	1263.0
	MB 109	1286.0-1309.5
	MB 111	1361.3
	MB 112	1379.8
	MB 113	1406.9
	MB 114	1429.3
	MB 115	1465.8
	MB 116	1477.6
	McNutt Potash Zone	1486.0-1880.3
	Vaca Triste Sandstone	1486.0-1489.8
	MB 117	1557.2
	MB 118	1582.6
	MB 119	1608.0
	MB 120	1632.0
	MB 121	1646.5
	MB 122	1656.0
	Union Anhydrite	1681.4-1694.0
	MB 123	1762.0-1769.9
	MB 124	1773.0-1783.8
	MB 126	1880.3
	Lower Member	1880.3-2936.5
	MB 127	1907.4
	MB 128	1919.7
	MB 129	1944.3
	MB 130	1956.7
	MB 131	2025.8
	MB 132	2056.6
	MB 133	2076.0
	MB 134	2117.0-2130.0
	MB 135	2149.4
	MB 136	2192.1-2197.1
	MB 137	2209.2

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-1	MB 138	2264.0
	MB 139	2323.7
	MB 140	2374.5-2389.0
	MB 141	2457.0
	MB 142	2497.0-2512.0
	MB 143	2563.5-2570.5
	MB 144	2606.0-2621.5
	Cowden Anhydrite	2647.8-2677.0
	Castile Formation	2936.5 (T.D.)
	Anhydrite III	2936.5-3374.8
	Halite II	3374.8-3600.0
	Anhydrite II	3600.0-3708.3
	Halite I	3708.3-4032.3
	Anhydrite I	4032.3-(T.D.)

ENERGY DEPARTMENT WELLS DATA BASE

BOREHOLE: **DOE-2**
OPERATOR: U.S. Department of Energy
PERMIT NO.: 0.08.1467(State Engineer's Office)

LOCATION: 704.07' FSL, 128.19' FEL
Sec. 8, T 22 S, R 31 E

ELEVATION: 3419.09' (Top of Casing)
TOTAL DEPTH: 4325'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Unkown

DRILLING RECORD: **Date Started:** 09/08/84 **Date Completed:** 09/18/84

CASING RECORD:
Diameter: 9.625
Grade: J-55
Wt/Ft: 36
From: 0
To: 1009
Cement:

Diameter: 13 3/8 O.D.
Grade: H-40
Wt/Ft: 48#
From: 0
To: 39
Cement: Cemented with 81 Cu. Ft.

PLUGGING SCHEDULE:
No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-2	Quaternary	
	Holocene-Dune Sand	0-8
	Pleistocene-Mescalero Caliche	8-13
	Triassic	
	Santa Rosa Sandstone	13-133.3
	Permian	
	Dewey Lake Red Beds	133.3-639.1
	Rustler Formation	639.1-698.6
	Forty-Niner Member	698.6-722.4
	Magenta Dolomite Member	722.4-823.7
	Tamarisk Member	823.7-846.0
	Culebra Dolomite Member	846.0-960.9
	Unnamed Lower Member	
	Salado Formation	960.9-3082.8
	Upper Member	960.9-1448.7
	MB 101	1080.3-1084.2
	MB 102	1116.6-1117.7
	MB 103	1130.4-1143.5
	MB 104	1154.7-1155.1
	MB 105	1170.8-1171.8
	MB 106	Not Present
	MB 107	1228.0-1228.4
	MB 108	1237.5-1238.1
	MB 109	1260.0-1283.5
	MB 110	Not Present
	MB 111	1330.8-1331.0
	MB 112	1347.0-1349.2
	MB 113	1372.4-1372.9
	MB 114	1394.3-1394.8
	MB 115	1427.7-1430.6
	MB 116	1439.3-1441.4
	McNutt Potash Zone	1448.7-1827.4
	Vaca Triste Sandstone	1448.7-1456.1
	MB 117	1510.0-1511.9
	MB 118	1533.6-1534.7
	MB 119	1556.8-1557.9
	10th Ore Zone	1574.0-1580.0
	MB 120	1581.4-1581.8
	9th Ore Zone	1580-1584(EST.)
	MB 121	1598.5-1599.8
	MB 122	1606.6-1607.5
	8th Ore Zone	1611.1-1619.3
	Union Anhydrite	1630.1-1637.9
	MB 123	1716.5-1721.9
	MB 124	1728.8-1738.4
	4th Ore Zone	1746.0-1748.5
	3rd Ore Zone	1766-1774(EST.)
	2nd Ore Zone	1780-1782.5(EST.)
	MB 125	Not Present
	MB 126	1825.9-1827.4

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
DOE-2	Lower Member	1827.4-3082.8
	MB 127	1852.7-1853.8
	MB 128	1864.5-1865.5
	MB 129	1889.9-1891.9
	MB 130	1901.8-1902.0
	MB 131	1971.2-1971.7
	MB 132	1999.7-2001.2
	MB 133	2018.8-2021.7
	MB 134	2069.3-2081.0
	MB 135	2099.8-2100.5
	MB 136	2144.9-2157.3
	MB 137	Not Present
	MB 138	2203.1
	MB 139	2303.3-2306.3
	MB 140	2372.1-2388.0
	MB 141	2450.1-2454.5
	MB 142	2503.6-2517.9
	MB 143	2566.4-2571.6
	MB 144	2603.6-2615.7
	Cowden Anhydrite	2644.5-2669.5
	Castile Formation	3082.8-4071.4
	Anhydrite III	3082.8-3801.1
	Halite II	Not Present
	Anhydrite II	?
	Halite I	3801.1-3809.2
	Anhydrite I	3809.2-4071.4
	Delaware Mountain Group	
	Bell Canyon Formation	4071.4-4325+
	Lamar Limestone Member	4071.4-4103.4
	Ramsey Sand	4103.4-4174.0
	Ford Shale	4174.0-4182.8
	Olds Sand	4182.8-4218.2(?)
	Hays Sand	4218.2(?)-4248+

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-11
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.994 (State Engineer's Office)

LOCATION: 711.80' FNL, 294.08' FWL
Sec. 9, T 22 S, R 31 E

ELEVATION: 3426.07'
TOTAL DEPTH: 3580'
TYPE OF WELL: Geologic Exploration
DRILLER: Verna Drilling Compa

DRILLING RECORD: **Date Started:** 02/06/78 **Date Completed:** 03/14/78

CASING RECORD:

Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 40
Cement: 81 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 985
Cement: 656 Cu. Ft.

Note: Hole loaded with brine based mud, hole temporarily capped pending further testing and/or plugging, all depths are measured from Kelly Bushing 13 ft. above ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-11	MB 136-T	1978.5
	MB 136-B	1978.5-1986.0
	MB 138-T	1986-2025.0
	MB 138-B	2025-2027
	Anhydrite A	Not Encountered
	Anhydrite B	Not Encountered
	MB 139-T	2061.0
	MB 139-B	2061-2064
	MB 140-T	2064-2092
	MB 140-B	2092-2105

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-12
OPERATOR: Westinghouse
PERMIT NO.: Unknown

LOCATION: 149.4' FSL, 80.4' FEL
Sec. 17, T 22 S, R 31 E

ELEVATION: 3472.06 (Top of Casing)
TOTAL DEPTH: 3927.5'
TYPE OF WELL: Geologic Exploration
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 11/17/81 **Date Completed:** 12/07/78

CASING RECORD:

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 32.3
From: 39
To: 1001.8
Cement: 475 Cu. Ft.

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 39
Cement: 475 Cu. Ft.

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 32
From: 39
To: 1013
Cement: 475 Cu. Ft.

Note: Hole loaded with brine based mud pending further tests. All depths are measured from Kelly Bushing 12.2 ft. above ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-12	Quaternary Deposits	
	Sand (Holocene-eolian)	0-16.2
	Mescalero Caliche	16.2-19.2
	Gatuna Formation	19.2-28.8
	Triassic Rocks	
	Santa Rosa Sandstone	28.8-167.0
	Permian Rocks	
	Dewey Lake Red Beds	167.0-640.0
	Rustler Formation	640.0-966.0
	Magenta Dolomite Member	703.9-727.0
	Culebra Dolomite Member	822.0-846.8
	Salado Formation	966.0-2737.5
	Upper Member	966.0-1444.0
	MB 101	1084.5
	MB 102	1116.0
	MB 103	1130.0-1141.0
	MB 104	1150.0
	MB 105	1167.6
	MB 106	1183.5
	MB 107	1223.5
	MB 108	1232.5
	MB 109	1254.0-1278.0
	MB 111	1324.0
	MB 112	1338.0-1342.0
	MB 113	1367.0
	MB 114	1389.0
	MB 115	1424.5
	MB 116	1436.0
	McNutt Member	1444.0-1798.0
	Vaca Triste Sandstone Member	1444.0-1447.0
	MB 117	1507.5
	MB 118	1531.0
	MB 119	1552.0-1556.5
	MB 120	1575.0
	MB 121	1588.0
	MB 122	1596.0
	Union Anhydrite	1617.0-1625.0
	MB 123	1695.0-1700.8
	MB 124	1708.0-1715.4
	MB 126	1798.0
	Lower Member	1798.0-2737.5
	MB 127	1825.0
	MB 128	1834.0
	MB 129	1856.0
	MB 130	1867.0
	MB 131	1928.0
	MB 132	1957.5

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-12	MB 133	1976.0
	MB 134	2015.0-2025.0
	MB 135	2040.0
	MB 136	2071.6-2083.1
	MB 138	2135.1
	MB 139	2184.9
	MB 140	2226.1-2238.1
	MB 141	2290.0-2296.0
	MB 142	2332.0-2344.0
	MB 143	2381.5-2387.6
	MB 144	2413.5-2423.9
	Cowden Anhydrite	2445.5-2471.0
	Castile Formation	2337.5-T.D.
	DEEPENED PORTION OF WIPP-12	
	Castile Formation	2776.0-T.D.
	Anhydrite III Member	2776.0-3053.9
	Halite II Member	3053.9-3281.8
	Anhydrite II Member	3281.8-3391.0
	Halite I Member	3391.0-3901.6
	Anhydrite I Member	3901.6-T.D.

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-13
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.09.1182 (State Engineer's Office)

LOCATION: 2565.68' FSL, 1730.59' FWL
Sec. 17, T 22 S, R 31 E

ELEVATION: 2565.68' (Top of Casing)
TOTAL DEPTH: 3856'
TYPE OF WELL: Geologic Exploration
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/26/78 **Date Completed:** 10/05/79 (Recompletion)

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 35.5
Cement: 108 Cu. Ft.

Diameter: 9 5/8
Grade:
Wt/Ft: 36
From: 0
To: 1023
Cement: 665 Cu. Ft.

Note: Hole loaded with brine based mud pending further test and/or plugging. All depths are measured from Kelly Bushing 12.2 ft. above ground except cores between 570 and 878 ft. and Schlumberger logs which were measured from ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-13	Quaternary Deposits	0-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-66
	Permian Rocks	
	Dewey Lake Red Beds	66-517
	Rustler Formation	517-846
	Dissolution Residue	543-550
	Magenta Dolomite Member	565-583
	Dissolution Residue	679-686
	Culebra Dolomite Member	703-726
	Dissolution Residue	730-735
	Top of Highest Salt in Section	745
	Salado Formation	846-1025
	Upper Member	846-1025
	MB 101	967
	MB 102	1003
	MB 103	1018
	DEEPENED PORTION OF WIPP-13 (Distance below K.B.)	
	Permian Rocks	
	Salado Formation	858.0-2971.6
	Upper Member	858.0-1356.7
	MB 103	1030.0-1042.3
	MB 104	1069.8
	MB 105	1091.0
	MB 106	1111.0
	MB 107	1128.0
	MB 108	1136.1
	MB 109	1161.0-1185.0
	MB 111	1232.8
	MB 112	1250.0
	MB 113	1277.9
	MB 114	1300.9
	MB 115	1338.3
	MB 116	1350.0
	McNutt Member	1356.7-1730.4
	Vaca Triste Sandstone Member	1356.7-1359.0
	MB 117	1426.5
	MB 118	1451.5
	MB 119	1478.2
	MB 120	1497.0
	MB 121	1513.8
	MB 122	1522.0
	Union Anhydrite	1542.0-1550.0
	MB 123	1628.0
	MB 124	1644.7
	MB 126	1730.4
	Lower Member	1730.4-2971.6

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-13	MB 127	1757.8
	MB 128	1770.0
	MB 129	1794.0
	MB 130	1804.5
	MB 131	1873.6
	MB 132	1902.0
	MB 133	1924.0
	MB 134	1968.9-1980.6
	MB 135	1996.8
	MB 136	2033.0-2048.0
	MB 137	2063.0
	MB 138	2110.2
	MB 139	2168.3
	MB 140	2221.0-2232.9
	MB 141	2294.6
	MB 142	2341.5-2355.0
	MB 143	2409.0-2417.0
	MB 144	2460.4
	Cowden Anhydrite	2493.9-2521.6
	Castile Formation	2971.6-3861.6+ (T.D.)
	Anhydrite III	2971.6-3518.7
	Halite II	3518.7-3638.0
	Anhydrite II	3638.0-3727.5
	Halite I	3727.5-3821.0
	Anhydrite I	3821.0-3861.6+ (T.D.)

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-14**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1458 (State Engineer's Office)
LOCATION:	98.57' FSL, 2112.08' FEL Sec. 9, T 22 S, R 31 E
ELEVATION:	3429' (G.L.)
TOTAL DEPTH:	1000'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 05/02/81 **Date Completed:** 06/08/81
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 111 Cement: Note: Hole loaded with brine based mud and temporarily abandoned pending further tests and/or plugging.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-14	Quaternary Rocks	
	Sand (Holocene-eolian)	0-15.4
	Triassic Rocks	
	Santa Rosa Sandstone	15.4-141.0
	Permian Rocks	
	Dewey Lake Red Beds	141.0-638.7
	Rustler Formation	638.7-951
	Magenta Dolomite Member	706.5-730.0
	Culebra Dolomite Member	817.2-836.2
	Salado Formation (Upper Member)	951.6

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-15
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.13.00 (State Engineer's Office)

LOCATION: 2426' FNL, 1973' FWL
Sec. 18, T 23 S, R 35 E

ELEVATION: 3269.34' (G.L.l)
TOTAL DEPTH: 810'
TYPE OF WELL: Geologic Exploration
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 03/08/78 **Date Completed:** 04/04/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 13
Cement:

Diameter: 6 1/8
Grade: HW
Wt/Ft: 11.3
From: 13
To: 592
Cement:

Diameter: 4
Grade: Core
Wt/Ft:
From: 592
To: 810
Cement:

Diameter: 4 1/2
Grade: HW
Wt/Ft: 11.3
From: 0
To: 555
Cement:

Note: Hole loaded with mud and temporarily capped pending further testing and/or plugging. Hole was relinquished to land owner for use as water well to relieve liability for plugging.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-15	Quaternary Deposits	
	Clay	0-34
	Marl	34-99
	Sand	99-153.3
	Clay	153.3-226
	Sand	226-547.2
	Triassic Rocks	
	Chinle	547.2-790.5
	Santa Rosa Sandstone	790.5-812

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-16
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1290 (State Engineer's Office) 0.08.1182 (reentry)

LOCATION: 2356.6' FSL, 138.8' FWL
Sec. 5, T 21 S, R 30 E

ELEVATION: 3383.40' (Top of Casing)
TOTAL DEPTH: 1300'
TYPE OF WELL: Geologic Exploration
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 01/11/80 **Date Completed:** 02/08/80

CASING RECORD:

Diameter: 13 3/8
Grade: H-40
Wt/Ft: 48
From: 0
To: 38
Cement:

Diameter: 4 1/2
Grade: J-55
Wt/Ft: 10.5
From: 0
To: 459
Cement:

Note: Hole filled with brine based mud and temporarily abandoned.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-18**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1123 (State Engineer's Office)
LOCATION:	983.58' FNL, 11.85' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3458.7' (Top of Casing)
TOTAL DEPTH:	1060'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 03/14/78 **Date Completed:** 04/03/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 16 Cement: Note: Hole loaded with mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-18	Quaternary Deposits	
	Holocene Deposits	0-5
	Mescalero Caliche	5-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-138
	Permian Rocks	
	Dewey Lake Red Beds	138-613
	Rustler Formation	613-928
	Dissolution Residue	643-655
	Magenta Dolomite Member	672-696
	Dissolution Residue	757-769
	Culebra Dolomite Member	787-808
	Dissolution Residue	812-822
	Salt-bearing Interval	822-928
	Salado Formation	928-1060
	Upper Member	928-1060
	MB 101	1049
	Maximum Depth Recorded	1060

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-19**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1124 (State Engineer's Office)
LOCATION:	2286.5' FNL, 12.7' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3435.14' (Top of Casing)
TOTAL DEPTH:	1038'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 04/06/78 **Date Completed:** 05/08/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 8 Cement:
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-19	Quaternary Deposits	
	Holocene Deposits	0-7
	Mescalero Caliche	7-14
	Triassic Rocks	
	Santa Rosa Sandstone	14-96
	Permian Rocks	
	Dewey Lake Red Beds	96-590
	Rustler Formation	590-895
	Dissolution Residue	619-629
	Magenta Dolomite Member	647-672
	Dissolution Residue	730-756
	Culebra Dolomite Member	756-779
	Dissolution Residue	781-795
	Salt-bearing Interval	795-895
	Salado Formation	895-1038.2
	Upper Member	895-1038.2
	MB 101	1010-1012
	Maximum Depth Recorded	1034

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-21**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1126 (State Engineer's Office)
LOCATION:	1450.6' FSL, 11.7' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3418.96' (Top of Casing)
TOTAL DEPTH:	1045'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brothers Drilling
DRILLING RECORD:	**Date Started:** 05/24/78 **Date Completed:** 05/26/78
CASING RECORD:	Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 20 Cement: Note: Hole loaded with brine mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-21	Quaternary Deposits	
	Holocene Deposits	0-6
	Mescalero Caliche	6-12
	Gatuna Formation	12-39
	Triassic Rocks	
	Santa Rosa Sandstone	39-73
	Permian Rocks	
	Dewey Lake Red Beds	73-560
	Rustler Formation	560-868
	Dissolution Residue	588-601
	Magenta Dolomite Member	618-642
	Dissolution Residue	706-715
	Culebra Dolomite Member	729-753
	Dissolution Residue	755-759
	Salt-bearing Interval	770-868
	Salado Formation	868-1046
	Upper Member	868-1046
	MB 101	986-989
	MB 102	1025-1026
	MB 103	1039
	Maximum Depth Recorded	1046

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-22**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1127 (State Engineer's Office)
LOCATION:	2544.9' FSL, 10.82' FEL Sec. 20, T 22 S, R 31 E
ELEVATION:	3428.12' (Top of Casing)
TOTAL DEPTH:	1450'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Boyles Brother Drilling
DRILLING RECORD:	**Date Started:** 05/08/78 **Date Completed:** 05/24/78
CASING RECORD:	Diameter: 7 Grade: Used Wt/Ft: 20 From: 0 To: 20 Cement: Note: Hole loaded with mud pending further testing and/or plugging.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-22	Quaternary Deposits	
	Holocene Deposits	0-6
	Mescalero Caliche	6-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-81
	Permian	
	Dewey Lake Red Beds	81-574
	Rustler Formation	574-885
	Dissolution Residue	603-614
	Magenta Dolomite Member	630-654
	Dissolution Residue	717-728
	Culebra Dolomite Member	742-764
	Dissolution Residue	767-773
	Salt Interval	777-885
	Salado Formation	885-1450
	Upper Member	883-1363
	MB 101	1000-1003
	MB 102	1036-1037
	MB 103	1049-1063
	MB 104	1071-1072
	MB 105	1086-1087
	MB 106	1102-1103
	MB 107	1142-1143
	MB 108	1150-1151
	MB 109	1172-1196
	MB 111	1242-1243
	MB 112	1259-1261
	MB 113	1285-1286
	MB 114	1307-1308
	MB 115	1342-1344
	MB 116	1353-1355
	McNutt Potash Unit	1363-1450
	Vaca Triste Sandstone Member	1363-1367
	MB 117	1426-1427
	Maximum Depth Recorded	1448

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-25
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1172 (State Engineer's Office)

LOCATION: 1852.77' FSL, 2838.10' FEL
Sec. 15, T 22 S, R 30 E

ELEVATION: 3214.39' (Top of Casing)
TOTAL DEPTH: 650'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 08/28/78 **Date Completed:** 09/12/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 21
Cement:

Diameter: 5 1/2
Grade: K-55
Wt/Ft: 15.5
From: 0
To: 649
Cement: 269 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 445-475 with 120 holes spaced at 4 holes per foot. Magenta perforated from 300-330 with 120 holes spaced at 4 holes per foot. Rustler perforated from 579-608 with 116 holes spaced at 4 holes per foot. Top of Pip Packers set at 572.7 and 365.1.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-25	Pleistocene Deposits	0-17
	Permian Rocks	
	Dewey Lake Red Beds	17-232
	Rustler Formation	232-565
	Dissolution Residue	270-287
	Magenta Dolomite Member	302-328
	Dissolution Residue	415-424
	Culebra Dolomite Member	447-472
	Dissolution Residue	475-512
	Salado Formation	565-655 (T.D.)
	Upper Member	565-600
	Dissolution Residue	565-600
	MB 101	589
	MB 102	599
	Salt Interval	600-655
	MB 103	615
	MB 104	628
	MB 105	640
	Maximum Depth Recorded on Geophysical Logs	651

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-26**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1173 (State Engineer's Office)

LOCATION: 2232.27' FNL, 12.20' FEL
Sec. 29, T 22 S, R 30 E

ELEVATION: 3153.20' (Top of Casing)
TOTAL DEPTH: 503'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/28/78 **Date Completed:** 09/11/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 268
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 502
Cement: 510 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 185-210 with 100 holes spaced at 4 holes per foot. Magenta perforated from 70-100 wih 120 holes spaced at 4 holes per foot, and from 50-70 with 80 holes spaced at 4 holes per foot. Rustler perforated from 288-329 with 164 holes spaced at 4 holes per foot. Top of Pip Packers set at 269 and 139.1.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-26	Holocene Deposits	0-10
	Permian Rocks	
	Rustler Formation	10-309
	Dissolution Residue	34-50
	Magenta Dolomite Member	70-99
	Dissolution Residue	152-174
	Culebra Dolomite Member	186-209
	Dissolution Residue	213-234
	Salado Formation	309-503
	Upper Member	309-503
	Dissolution Residue	309-320
	Salt Interval	320-503
	MB 101	387
	MB 102	423
	MB 103	460
	MB 104	469
	MB 105	481
	MB 106	495
	Maximum Depth Recorded	503

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-27**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1174 (State Engineer's Office)

LOCATION: 89.79' FNL, 1485.03' FWL
Sec. 21, T 21 S, R 30 E

ELEVATION: 3178.98' (Top of Casing)
TOTAL DEPTH: 592'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Boyles Brothers Drilling

DRILLING RECORD: **Date Started:** 09/12/78 **Date Completed:** 10/09/78

CASING RECORD:
Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 588
Cement: 440 Cu. Ft.

Note: Culebra perforated from 290-320 with 120 holes spaced at 4 holes per foot. Magenta perforated from 175-195 with 80 holes spaced at 4 holes per foot. Rustler perforated from 425-460 with 135 holes and from 483-513 with 120 holes spaced at 4 holes per foot. Top of Pip Packers set at 399.4 and 267.4.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-27	Quaternary Deposits	
	Holocene Deposits	0-74
	Mescalero Caliche	74-79
	Permian Rocks	
	Dewey Lake Red Beds	79-152
	Rustler Formation	152-421
	Dissolution Residue	152-193
	Magenta Dolomite Member	175-193
	Dissolution Residue	270-281
	Culebra Dolomite Member	292-318
	Dissolution Residue	321-421
	Salado Formation	421-592
	Upper Member	421-592
	Dissolution Residue	421-509
	MB 101	442-447
	MB 102	449-451
	MB 103	456-468
	MB 107-108	481-484
	MB 109	487-494
	Salt Interval	509-592
	MB 113	548-550
	Maximum Depth Recorded	592

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **WIPP-28**
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1175 (State Engineer's Office)

LOCATION: 98.72' FNL, 2400.99' FEL
Sec. 18, T 21 S, R 31 E

ELEVATION: 3349.21' (Top of Casing)
TOTAL DEPTH: 801'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/07/78 **Date Completed:** 08/28/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 21
Cement: Ready Mix

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 223
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 800
Cement: 314 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 420-446 with 104 holes spaced at 4 holes per foot. Magenta perforated from 285-310 with 100 holes spaced at 4 holes per foot. Rustler perforated from 549-589 with 160 holes spaced at 4 holes per foot. Top of Pip Packers set at 526.7 and 365.1.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-28	Holocene Deposits	0-12
	Permian Rocks	
	Dewey Lake Red Beds	12-215
	Rustler Formation	215-531
	Magenta Dolomite Member	285-310
	Culebra Dolomite Member	420-446
	Salado Formation	531-801 (T.D)
	Upper Member	531-801
	Dissolution Residue	531-589
	MB 101	567
	MB 103	585
	Salt Interval	589-801
	MB 105	598
	MB 106	612
	MB 107	656
	MB 108	664
	MB 109	694
	MB 111	731
	MB 112	743
	MB 113	769
	MB 114	791
	Maximum Depth Recorded	802

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-29**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	0.08.1176 (State Engineer's Office)
LOCATION:	406.62' FSL, 1827.54' FEL Sec. 34, T 22 S, R 29 E
ELEVATION:	2978.26' (Top of Casing)
TOTAL DEPTH:	377'
TYPE OF WELL:	Geologic Exploration/Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 10/03/78 **Date Completed:** 10/10/78
CASING RECORD:	Diameter: 5 1/2 Grade: J-55 Wt/Ft: 15.5 From: 0 To: 376 Cement: 135 Cu. Ft. Note: Top joint of 5.5 casing is 14 lb. Culebra perforated from 10-45 with 140 holes spaced at 4 holes per foot. Rustler perforated from 216-250 with 136 holes spaced at 4 holes per foot. Top of Pip Packers set at 203.7.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-29	Holocene Deposits	0-12
	Permian Rocks	
	Rustler Formation	12-143
	Culebra Dolomite Member	12-42
	Salado Formation	143-377 (T.D.)
	Upper Member	143-248
	Dissolution Residue	143-248
	MB 101	175
	MB 102	181
	MB 103	199
	MB 109	228
	McNutt Potash Zone	248-377 (T.D.)
	Dissolution Residue	248-251
	Vaca Triste Sandstone Member	248-251
	Salt Interval	251-377
	MB 117	319
	MB 118	346
	Maximum Depth Recorded	358

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-30
OPERATOR: Sandia National Laboratories
PERMIT NO.: 0.08.1177 (State Engineer's Office)

LOCATION: 667.5' FNL, 177.41' FWL
Sec. 33, T 21 S, R 30 E

ELEVATION: 3429.05' (Top of Casing)
TOTAL DEPTH: 913'
TYPE OF WELL: Geologic Exploration/Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/08/78 **Date Completed:** 10/02/78

CASING RECORD:

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 246
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 912
Cement: 463 Cu. Ft.

Note: 7" casing pulled. Culebra perforated from 631-654 with 92 holes spaced at 4 holes per foot. Magenta perforated from 510-540 with 120 holes spaced at 4 holes per foot. Rustler perforated from 731-753 with 88 holes spaced at 4 holes per foot. Top of Pip Packers set at 701.1 and 585.4.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-30	Permian Rocks	
	Dewey Lake Red Beds	0-449
	Rustler Formation	449-748
	Magenta Dolomite Member	513-537
	Culebra Dolomite Member	631-653
	Salado Formation	748-912 (T.D.)
	Upper Member	748-912
	Salt Interval	748-912
	MB 101	862
	MB 102	894
	MB 103	In Bed at Total Depth
	Maximum Depth Recorded	908

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE: WIPP-31
OPERATOR: Sandia National Laboratories
PERMIT NO.: Unknown

LOCATION: 422.54' FSL, 1762.24' FWL
Sec. 35, T 20 S, R 30 E

ELEVATION: 3401.43' (Top of Casing)
TOTAL DEPTH: 1981.7'
TYPE OF WELL: Geologic Exploration
DRILLER: Chortes Drilling Company

DRILLING RECORD: **Date Started:** 07/18/80 **Date Completed:** 09/29/80 (Recompletion)

CASING RECORD:

Diameter:
Grade: 6' x 6' CEL
Wt/Ft:
From: 0
To: 5
Cement: Dirt

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 3
To: 37
Cement: 81 Cu. Ft.

Diameter: 7 5/8
Grade: J-55
Wt/Ft: 26.4
From: 2.5
To: 808
Cement: 414 Cu. Ft.

Note: Hole loaded with brine based mud pending further testing and/or plugging.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-31	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-32**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	SEO: 04/25/79; USGS: 10/15/79
LOCATION:	1673.22' FSL, 29.14' FEL Sec. 33, T 22 S, R 29 E
ELEVATION:	3023.26' (Top of Casing)
TOTAL DEPTH:	390'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/07/79 **Date Completed:** 08/23/79
CASING RECORD:	No casing used.
PLUGGING SCHEDULE:	Note: Hole plugged to surface with 500 Cu. Ft. cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-32	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-33**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	SEO: 04/25/79
LOCATION:	1762.48' FSL, 2426.65' FWL Sec. 13, T 22 S, R 30 E
ELEVATION:	3323.23' (Top of Casing)
TOTAL DEPTH:	840'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 07/13/79 **Date Completed:** 07/26/79
CASING RECORD:	Diameter: 9 5/8 Grade: J-55 Wt/Ft: 36 From: 0 To: 38 Cement: 192 Cu. Ft. Note: Hole filled with brine based mud. Fluid level at 27 ft.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-33	Quaternary Deposits	
	Triassic Rocks	
	Santa Rosa Sandstone	
	Permian Rocks	
	Dewey Lake Red Beds	
	Rustler Formation	
	Dissolution Residue	
	Magenta Dolomite Member	
	Dissolution Residue	
	Culebra Dolomite Member	
	Dissolution Residue	
	Top of Highest Salt in Section	
	Salado Formation	
	Upper Member	
	MB 101	
	MB 102	
	MB 103	

GEOLOGIC EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**WIPP-34**
OPERATOR:	Sandia National Laboratories
PERMIT NO.:	08.08.1291 (State Engineer's Office) 08.08.1195 (reentry)
LOCATION:	201.78' FSL, 1999.73' FWL Sec. 9, T 22 S, R 31 E
ELEVATION:	3433' (Top of Casing)
TOTAL DEPTH:	1820'
TYPE OF WELL:	Geologic Exploration
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 08/16/79 **Date Completed:** 09/04/79
CASING RECORD:	Diameter: 13 3/8 Grade: Wt/Ft: 48 From: 0 To: 38 Cement: Note: Hole filled with brine based mud.
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
WIPP-34	Quaternary Deposits	0-11
	Triassic Rocks	
	Santa Rosa Sandstone	11-154
	Permian Rocks	
	Dewey Lake Red Beds	154-657
	Rustler Formation	657-973
	Magenta Dolomite Member	716-741
	Culebra Dolomite Member	834-861
	Salado Formation	973-1820+
	Upper Unit	973-1437
	MB 101	1092
	MB 102	1122
	MB 103	1148
	MB 104	1158
	MB 105	1173
	MB 106	1191
	MB 107	1228
	MB 108	1237
	MB 109	1280
	MB 110	1317
	MB 111	1326
	MB 112	1344
	MB 113	1366
	MB 114	1396
	MB 115	1420
	MB 116	1430
	McNutt Potash Unit	1437-1751
	Vaca Triste Sandstone Member	1437-1442
	MB 117	1498
	MB 118	1520
	MB 119	1540
	MB 120	1560
	MB 121	1573
	MB 122	1580
	Union Anhydrite	1599-1607
	MB 123	1676
	MB 124	1690
	MB 125	—
	MB 126	1751
	Lower Unit	1751-1820+
	MB 127	1768
	MB 128	1775
	MB 129	1785

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-1
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.979 (State Engineer's Office)

LOCATION: 623.2' FNL, 1083.1' FWL Sec. 29, T 22 S, R 31 E

ELEVATION: 3399.53' (Top of Casing)
TOTAL DEPTH: 856'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/20/76 **Date Completed:** 06/10/76

CASING RECORD:

Diameter: 10 1/8
Grade:
Wt/Ft: 40.5
From: 0
To: 48
Cement: 51 Cu. Ft.

Diameter: 7
Grade: K-55
Wt/Ft: 26
From: 0
To: 848
Cement: 192 Cu. Ft.

Note: Perforated from 803 to 827 with 72 holes, 703 to 683 with 3 holes per foot, 683 to 675 with 3 holes per foot, 562 to 590 with 3 holes per foot. All depths are measured from Kelly Bushing 8' above ground level except DST's which are measured from ground level.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-1	Holocene	
	Surficial Deposits	0-15
	Pleistocene	
	Gatuna Formation	15-35
	Ochoan	
	Dewey Lake Red Beds	35-502
	Rustler Formation	502-824
	Magenta Dolomite Member	563-589
	Culebra Dolomite Member	676-699
	Top of Salado	824
	Total Depth	856

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-2a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 726.96' FNL, 1697.64', FWL
Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.09' (Top of Casing)
TOTAL DEPTH: 672'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 02/14/77 **Date Completed:** 02/21/77

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft:
From: 0
To: 33
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 511
Cement: 260 Cu. Ft.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2a	Holocene	
	Surficial Deposit	0-14
	Pleistocene	
	Gatuna Formation	14-38
	Ochoan	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-672 (T.D.)
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-672 (T.D.)
	Total Depth	672

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-2b1**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 695.57' FNL, 1660.57' FWL,
Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.46 (Top of Casing)
TOTAL DEPTH: 661'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 02/07/77 **Date Completed:** 02/14/77

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft:
From: 0
To: 33
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 609
Cement: 282 Cu. Ft.

Note: Perforated from 510'-538' with 3 holes per foot.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2b1	Holocene	
	Surficial Deposit	0-14
	Pleistocene	
	Gatuna Formation	14-38
	Ochoan	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-661
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-661
	Total Depth	661

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-2b2
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 700.6' FNL, 1690.8' FWL, Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.31' (Top of Casing)
TOTAL DEPTH: 660'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/16/83 **Date Completed:** 05/03/84

CASING RECORD:

Diameter: 9.625 O.D.
Grade: J-55
Wt/Ft: 36
From: 0
To: 20
Cement:

Diameter: 5.5 O.D.
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 620
Cement:

Note: Open 613-650'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2b2	Holocene	
	Surficial Deposits	0-14
	Quaternary	
	Gatuna Formation	14-38
	Permian	
	Dewey Lake Red Beds	38-457
	Rustler Formation	457-660 (T.D.)
	Forty-Niner Member	457-515
	Magenta Dolomite Member	515-543
	Tamarisk Member	543-623
	Culebra Dolomite Member	623-645
	Unnamed Part	645-660 (T.D.)

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-2c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.990 (State Engineer's Office)

LOCATION: 637.15' FNL, 1708.62' FWL,
Sec. 29, T 22 S, R 31 E

ELEVATION: 3378.41' (Top of Casing)
TOTAL DEPTH: 795'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 01/28/77 **Date Completed:** 02/05/77

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft:
From: 0
To: 33
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 742
Cement: 339 Cu. Ft.

Note: Perforated from 618-655 with 3 holes per foot.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-2c	Holocene	
	Surficial Deposits	0-34
	Quaternary	
	Gatuna Formation	0-34
	Permian	
	Dewey Lake Red Beds	34-457
	Rustler Formation	
	Magenta Dolomite Member	515-540
	Culebra Dolomite Member	624-642
	Top of Rustler Salt	642
	Salado Formation	764-795 (T.D.)
	Maximum Depth	795

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-3b1
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08.991 (State Engineer's Office)

LOCATION: 2085.31' FSL, 138.10' FEL,
Sec. 29, T 22 S, R 31 E

ELEVATION: 3390.64' (Top of Casing)
TOTAL DEPTH: 902'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/25/76 **Date Completed:** 08/12/76

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft: 40.5
From: 0
To: 38
Cement: 54 Cu. Ft.

Diameter: 6 5/8
Grade: J-55
Wt/Ft: 24
From: 0
To: 891
Cement: 625 Sacks

Note: Perforated from 813 to 837 with 72 holes, 683 to 703 with 3 holes per ft, 675 to 683 with 3 holes per ft, 562 to 590 with 3 holes per ft.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b1	Holocene	
	Surficial Deposits	0-4
	Quaternary	
	Gatuna Formation	4-22
	Permian	
	Dewey Lake Red Beds	22-502
	Rustler Formation	502-821
	Magenta Dolomite Member	559-584
	Culebra Dolomite Member	672-694
	Top of Rustler Salt	Not Given
	Salado Formation	821- T.D.
	Maximum Depth	902

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3b2**	
OPERATOR:	Sandia National Labs	
PERMIT NO.:	0.08.991 (State Engineer's Office)	
LOCATION:	2122.15' FSL, 231.29' FEL, Sec. 29, T 22 S, R 31 E	
ELEVATION:	3390.03' (Top of Casing)	
TOTAL DEPTH:	725'	
TYPE OF WELL:	Hydrologic Test Hole	
DRILLER:	Pennsylvania Drilling Company	
DRILLING RECORD:	**Date Started:**	**Date Completed:**
CASING RECORD:	Diameter: 5 1/2 O.D. Grade: J-55 Wt/Ft: 15.5 From: 0 To: 672.7 Cement:	
PLUGGING SCHEDULE:	No plugging data.	
STRATIGRAPHIC SUMMARY:	Attached	

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b2	Surficial Deposits	0-11
	Gatuna Formation	
	Dockum Group	11-65
	Dewey Lake Red Beds	65-565.7
	Rustler Formation	565.7-788.7
	Magenta Dolomite Member	564-590
	Culebra Dolomite Member	676-700
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	725

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3b3**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.991 (State Engineer's Office)
LOCATION:	2022.35' FSL, 217.30' FEL, Sec. 29, T 22 S, R 31 E
ELEVATION:	3388.67' (Top of Casing)
TOTAL DEPTH:	730'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** **Date Completed:** 01/30/84
CASING RECORD:	Diameter: 5.5 Grade: J-55 Wt/Ft: 15.5 From: .50 To: 670.5 Cement: Casing cemented in place
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3b3	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	
	Rustler Formation	
	Magenta Dolomite Member	563-586
	Culebra Dolomite Member	673-696
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-3d (H-3b4)**	
OPERATOR:	Sandia National Labs	
PERMIT NO.:	0.08.991 (State Engineer's Office)	
LOCATION:	2067.3' FSL, 164.3' FEL, Sec. 29, T 22 S, R 31 E	
ELEVATION:	3390.01' (Top of Casing)	
TOTAL DEPTH:	554'	
TYPE OF WELL:	Hydrologic Test Hole	
DRILLER:	Pennsylvania Drilling Company	
DRILLING RECORD:	**Date Started:**	**Date Completed:**
CASING RECORD:	Diameter: 8 5/8 Grade: Wt/Ft: From: 0 To: 39 Cement:	
	Note: 7 7/8" uncased borehole 33-559'.	
PLUGGING SCHEDULE:	No plugging data.	
STRATIGRAPHIC SUMMARY:	Attached	

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-3d	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	420
	Rustler Formation	
	Forty-Niner Member	508-537
	Forty-Niner Claystone Member	537-547
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-4a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1153 (State Engineer's Office)

LOCATION: 545.89' FNL, 720.00' FWL,
Sec. 5, T 23 S, R 31 E

ELEVATION: 3333.29' (Top of Casing)
TOTAL DEPTH: 415'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/30/78 **Date Completed:** 05/23/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 32
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 364
Cement: 173 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests. 4 1/2" inflatable packer set at 485' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder set at 499' in the Culebra Dolomite. The hole is dual completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4a	Holocene	
	Surficial Deposits	0-13
	Pleistocene	
	Gatuna Formation	13-29
	Ochoan	
	Dewey Lake Red Beds	29-315
	Rustler Formation	315
	Magenta Dolomite Member	375-400
	Total Depth	415

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-4b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1154 (State Engineer's Office)

LOCATION: 498.47' FNL, 632.54' FWL,
Sec. 5, T 23 S, R 31 E

ELEVATION: 3333.35 (Top of Casing)
TOTAL DEPTH: 529'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/30/78 **Date Completed:** 05/15/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 33
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 476
Cement: 269 Cu. Ft.

Note: Hole is in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4b	Surficial Deposits	0-13
	Gatuna Formation	13-29
	Dockum Group	NP
	Dewey Lake Red Beds	29-315
	Rustler Formation	315-T.D.
	Magenta Dolomite Member	377-402
	Culebra Dolomite Member	498-522
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	529

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-4c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1152 (State Engineer's Office)

LOCATION: 446.36 FNL, 717.89 FWL,
Sec. 5, T 23 S, R 31 E

ELEVATION: 3334.04' (Top of Casing)
TOTAL DEPTH: 661'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/30/78 **Date Completed:** 05/09/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 33
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 610
Cement: 270 Cu. Ft.

Note: Bridge plug at 530'. Perforated from 494' to 520' with 104 holes spaced at 4 holes per foot. Hole in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-4c	Surficial Deposits	0-13
	Gatuna Formation	13-29
	Dockum Group	NP
	Dewey Lake Red Beds	29-315
	Rustler Formation	315-626
	Magenta Dolomite Member	377-403
	Culebra Dolomite Member	490-516
	Salado Formation	626-661

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-5a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1159 (State Engineer's Office)

LOCATION: 1091.98 FNL, 185.03 FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.19 (Top of Casing)
TOTAL DEPTH: 824'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/20/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 774
Cement: 192 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests. 4 1/2" inflatable packer set at 895' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder set at 905' in the Culebra Dolomite. The hole is dual-completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-5b
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08.1160 (State Engineer's Office)

LOCATION: 1008.30' FNL, 236.22' FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.04' (Top of Casing)
TOTAL DEPTH: 925'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/13/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 881
Cement: 336 Cu. Ft.

Note: Hole is in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-5b	Surficial Deposits	0-8
	Gatuna Formation	NP
	Dockum Group	8-225
	Dewey Lake Red Beds	225-732
	Rustler Formation	732-T.D.
	Magenta Dolomite Member	785-805
	Culebra Dolomite Member	897-920
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Castile Formation	

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-5c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1161 (State Engineer's Office)

LOCATION: 1005.55 FNL, 134.95 FEL,
Sec. 15, T 22 S, R 31 E

ELEVATION: 3506.04' (Top of Casing)
TOTAL DEPTH: 1076'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 05/22/78 **Date Completed:** 06/03/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 1024
Cement: 416 Cu. Ft.

Note: Bridge plug set at 935'. Perforated from 895' to 925' with 120 holes spaced at 4 holes per foot. Hole in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-5c	Surficial Deposits	0-8
	Gatuna Formation	NP
	Dockum Group	8-225
	Dewey Lake Red Beds	225-732
	Rustler Formation	732-1041
	Magenta Dolomite Member	788-812
	Culebra Dolomite Member	899-924
	Salado Formation	1041-T.D.
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	1076

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-6a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1162 (State Engineer's Office)

LOCATION: 283.30' FNL, 274.34' FWL,
Sec. 18, T 22 S, R 31 E

ELEVATION: 3347.83' (Top of Casing)
TOTAL DEPTH: 525'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/06/78 **Date Completed:** 07/11/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 475
Cement: 155 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests. 4 1/2" packer set at 594' on 1 1/2" galvanized pipe. 1 3/8" pump cylinder at 608' in the Culebra Dolomite. The hole is dual-completion across the Magenta and Culebra Dolomites.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-6b
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1163 (State Engineer's Office)

LOCATION: 196.34' FNL, 332.96' FWL,
Sec 18, T 22 S, R 31 E

ELEVATION: 3348.25' (Top of Casing)
TOTAL DEPTH: 640'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 06/19/78 **Date Completed:** 07/05/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 590
Cement: 210 Cu. Ft.

Note: Hole in standby condition for hydro tracer tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-6b	Surficial Deposits	0-12
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-T.D.
	Magenta Dolomite Member	492-511
	Culebra Dolomite Member	604-627
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	640

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-6c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1164 (State Engineer's Office)

LOCATION: 281.06' FNL, 374.47' FWL,
Sec. 18, T 22 S, R 31 E

ELEVATION: 3348.52' (Top of Casing)
TOTAL DEPTH: 741'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 06/19/78 **Date Completed:** 06/26/78

CASING RECORD:

Diameter: 9 5/8
Grade: J-55
Wt/Ft: 36
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: +1.29
To: 699
Cement: 335 Cu. Ft.

Note: Bridge plug set at 641'. Perforated from 604' to 631' with 108 holes spaced at 4 holes per foot.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-6c	Surficial Deposits	0-12
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-721
	Magenta Dolomite Member	490-514
	Culebra Dolomite Member	604-627
	Salado Formation	721-T.D.
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	741

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-7a
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08-1271 (State Engineer's Office)

LOCATION: 2495.04' FNL, 2492.35' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164'
TOTAL DEPTH: 154'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/18/79 **Date Completed:** 10/18/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From:0
To: 38
Cement: 81 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 109
Cement: 265 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-7b1**
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08-1272 (State Engineer's Office)

LOCATION: 2565.80' FNL, 2563.45' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164.17' (Top of Casing)
TOTAL DEPTH: 286'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/13/79 **Date Completed:** 09/18/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 54 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 230
Cement: 270 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7b1	Holocene	
	Surficial Deposits	0-5
	Pleistocene	
	Gatuna Formation	12-38
	Dockum Group	NP
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-T.D.
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	237-283
	Salado Formation	
	Upper Member	
	Lower Member	
	Castile Formation	
	Total Depth	286

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-7b2
OPERATOR: Sandia National Labs
PERMIT NO.: --- (State Engineer's Office)

LOCATION: 2662.16' FNL, 2537.98' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164.40' (Top of Casing)
TOTAL DEPTH: 295'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/27/83 **Date Completed:** 09/02/83

CASING RECORD:

Diameter: 9 7/8
Grade:
Wt/Ft:
From: 0
To: 20
Cement: Casing set in cement

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 230.19
Cement: Cemented in place

PLUGGING SCHEDULE: Hole was back filled with peu gravel from 295' to 268' and left open for testing.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7b2	Surficial Deposits	
	Gatuna Formation	57
	Dockum Group	NP
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-T.D.
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	232-280
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	295

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-7c
OPERATOR: Sandia National Labs
PERMIT NO.:

LOCATION: 2591.93' FNL, 2467.51' FWL,
Sec. 14, T 23 S, R 30 E

ELEVATION: 3164.13 (Top of Casing)
TOTAL DEPTH: 420'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/06/79 **Date Completed:** 11/02/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 68 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 356
Cement: 706 Cu. Ft.

Note: Hole in standby condition for testing. Slotted liner installed from 347' to 420'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-7c	Holocene	
	Unconsolidated Alluvium and Dune Sand	0-5
	Pleistocene	
	Gatuna Formation	5-57
	Permian	
	Dewey Lake Red Beds	57-87
	Rustler Formation	87-283
	Magenta Dolomite Member	117-140
	Culebra Dolomite Member	237-273.5
	Salado Formation	283-420
	Dissolution Residue	283-405
	Top of Salt Interval	405
	Total Depth	420

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-8a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1274 (State Engineer's Office)

LOCATION: 1962.61' FNL, 1486.59' FEL,
Sec. 23, T 24 S, R 30 E

ELEVATION: 3432.99' (Top of Casing)
TOTAL DEPTH: 505'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/07/79 **Date Completed:** 09/18/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 108 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 452
Cement: 393

Note: Hole in standby condition for testing

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-8b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1275 (State Engineer's Office)

LOCATION: 1994.76' FNL, 1405.41' FEL,
Sec. 23, T 24 S, R 30 E

ELEVATION: 3433.64' (Top of Casing)
TOTAL DEPTH: 624'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/06/79 **Date Completed:** 08/12/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 108 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 20
From: 0
To: 574
Cement: 378 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-8b	Surficial Deposits	0-10
	Gatuna Formation	10-153
	Dockum Group	NP
	Dewey Lake Red Beds	153-399
	Rustler Formation	399-T.D.
	Magenta Dolomite Member	466-490
	Culebra Dolomite Member	586-613
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	624

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-8c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1276 (State Engineer's Office)

LOCATION: 2059.36' FNL, 1470.14' FEL,
Sec. 23, T 24 S, R 30 E

ELEVATION: 3432.90' (Top of Casing)
TOTAL DEPTH: 808'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/27/79 **Date Completed:** 08/06/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 108 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 20
From: 0
To: 734
Cement: 314 Cu. Ft.

Note: Hole is standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-8c	Holocene	
	Unconsolidated Alluvium and Eolian Sand	0-4
	Pleistocene Rocks	
	Mescalero Caliche	4-10
	Gatuna Formation	10-153
	Permian	
	Dewey Lake Red Beds	153-399
	Rustler Formation	399-733
	Magenta Dolomite Member	466-488
	Culebra Dolomite Member	588-614
	Salado Formation	733-
	Dissolution Residue	733-774
	MB 103	774-786
	Top of Salt Interval	798
	Total Depth	808

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-9a
OPERATOR: Sandia National Lab
PERMIT NO.: 0.08.1277 (State Engineer's Office)

LOCATION: 2392.14' FNL, 138.92' FWL,
Sec. 4, T 24 S, R 31 E

ELEVATION: 3406.68' (Top of Casing)
TOTAL DEPTH: 692'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/09/79 **Date Completed:** 08/23/83

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 570
Cement: 266 Cu. Ft.

Diameter: 4.5" O.D.
Grade: J-55
Wt/Ft: 9.5
From: 0
To: 643
Cement:

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-9a	Holocene	
	Surficial Deposits	0-5
	Pleistocene	
	Gatuna Formation	5-25
	Ochoan	
	Dewey Lake Red Beds	25-455
	Rustler Formation	455-T.D.
	Forty-Niner Member	455-523
	Magenta Dolomite Member	523-554
	Tamarisk Member	554-647
	Culebra Dolomite Member	647-677
	Unnamed Part	677-T.D.
	Total Depth	692

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-9b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1278 (State Engineer's Office)

LOCATION: 2391.04' FNL, 238.63' FWL,
Sec. 4, T 24 S, R 31 E

ELEVATION: 3406.86' (Top of Casing)
TOTAL DEPTH: 708'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/14/79 **Date Completed:** 08/28/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 638
Cement: 295 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-9b	Surficial Deposits	0-5
	Gatuna Formation	5-25
	Dockum Group	NP
	Dewey Lake Red Beds	24-455
	Rustler Formation	455-T.D.
	Magenta Dolomite Member	523-554
	Culebra Dolomite Member	647-677
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	708

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-9c
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1279 (State Engineer's Office)

LOCATION: 2479.06' FNL, 188.02' FWL,
Sec. 4, T 24 S, R 31 E

ELEVATION: 3407.30' (Top of Casing)
TOTAL DEPTH: 816'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/01/79 **Date Completed:** 09/24/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 20
From: 0
To: 783
Cement: 320 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-10a**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1280 (State Engineer's Office)

LOCATION: 433.0' FSL, 2068.9' FEL, Sec. 20, T 23 S, R 32 E

ELEVATION: 3688.67' (Top of Casing)
TOTAL DEPTH: 1318'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/21/79 **Date Completed:** 08/26/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 1243
Cement: 519 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-10b**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1281 (State Engineer's Office)

LOCATION: 484.5' FSL, 1981.8' FEL, Sec. 20, T 23 S, R 32 E

ELEVATION: 3689.47' (Top of Casing)
TOTAL DEPTH: 1398'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/07/79 **Date Completed:** 10/13/79

CASING RECORD:

Diameter: 13 3/8
Grade:
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 1346
Cement: 480 Cu. Ft.

Note: Hole in standby condition for possible future tests.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-10c**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1282 (State Engineer's Office)

LOCATION: 384.5' FSL, 1981.8 FEL, Sec. 20, T 23 S, R 32 E

ELEVATION: 3687'
TOTAL DEPTH: 1550'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 08/11/79 **Date Completed:** 08/20/79

CASING RECORD:

Diameter: 13 3/8
Grade: K-55
Wt/Ft: 48
From: 0
To: 38
Cement: 72 Cu. Ft.

Diameter: 7
Grade:
Wt/Ft: 20
From: 0
To: 1483
Cement: 627 Cu. Ft.

Note: Hole in standby condition for testing.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-10c	Holocene	
	Unconsolidated Alluvium and Eolian Sand	0-5
	Pleistocene	
	Mescalero Caliche	5-9
	Gatuna Formation	9-90
	Triassic	
	Dockum Group	
	Chinle Formation	90-482
	Santa Rosa Sandstone	482-658
	Permian	
	Dewey Lake Red Beds	658-1204
	Rustler Formation	1204-1501
	Magenta Dolomite Member	1256-1280
	Culebra Dolomite Member	1360-1387
	Salado Formation	1501
	Top of Salt Interval	1501
	Total Depth	1538

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-11b2**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1462 (State Engineer's Office)

LOCATION: 1436.3' FSL, 168.7' FEL, Sec. 33, T 22 S, R 31 E

ELEVATION: 3411.64' (Top of Casing)
TOTAL DEPTH: 776'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/83 **Date Completed:** 11/28/83

CASING RECORD:

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 40
From: 0
To: 37
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 733.39
Cement: Cemented

Note: 4 3/4" open hole from 733.39' to the total depth of 776'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-11b2	Magenta Dolomite Member	618-644
	Culebra Dolomite Member	733-757
	Total Depth	776

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-11b3**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1462 (State Engineer's Office)

LOCATION: 1501.7' FSL, 105.2' FEL, Sec. 33, T 22 S, R 31 E

ELEVATION: 3412.42' (Top of Casing)
TOTAL DEPTH: 788.7' (Below Kelly Bushing)
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 12/01/83 **Date Completed:** 01/84

CASING RECORD:

Diameter: 9 5/8
Grade: H-30
Wt/Ft: 40
From: 0
To: 34
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 55
From: 0
To: 733
Cement:

Note: 4 3/4" open hole from 733' to the total depth of 788.7'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-11b3	Surficial Deposits	
	Gatuna Formation	
	Dockum Group	
	Dewey Lake Red Beds	
	Rustler Formation	
	Magenta Dolomite Member	616-644
	Culebra Dolomite Member	734-759
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	788.7

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-11b4**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1474 (State Engineer's Office)

LOCATION: 1514.7' FSL, 320.2' FEL, Sec. 33, T 22 S, R 31 E

ELEVATION: 3410.89' (Top of Casing)
TOTAL DEPTH: 765'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 02/23/88 **Date Completed:** 03/17/88

CASING RECORD:

Diameter: 8 5/8
Grade: H-40
Wt/Ft: 28
From: 0
To: 27
Cement:

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: 0
To: 714
Cement:

Note: 4 3/4 " open hole from 715' to total depth of 765'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-12
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1463 (State Engineer's Office)

LOCATION: 23.1' FNL, 91.9' FEL,
Sec. 15, T 23 S, R 31 E

ELEVATION: 3427.19' (Top of Casing)
TOTAL DEPTH: 1001'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/03/83 **Date Completed:** 10/18/83

CASING RECORD:

Diameter: 9 5/8
Grade: H-40
Wt/Ft: 36
From: 0
To: 37
Cement: 63 Cu. Ft.

Diameter: 5 1/2
Grade: J-55
Wt/Ft: 15.5
From: +1.45
To: 820
Cement:

Note: 4 3/4 " open hole from 820' to plugged back depth of 890'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-12	Quaternary Deposits	0-10+
	Dockum Group	10+-70
	Dewey Lake Red Beds	70-622
	Rustler Formation	622-976
	Forty-Niner Member	622-678
	Magenta Dolomite Member	678-703
	Tamarisk Member	703-823
	Culebra Dolomite Member	823-850
	Unnamed Lower Member	850-976
	Salado Formation	976-T.D.
	Unnamed Upper Member	976-T.D.
	Total Depth	1001

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-14
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1469 (State Engineer's Office)

LOCATION: 372.2' FSL, 562.4' FWL, Sec. 29, T 22 S, R 31 E

ELEVATION: 3347.11' (Top of Casing)
TOTAL DEPTH: 589'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/86 **Date Completed:** 10/86

CASING RECORD:

Diameter: 8.625
Grade:
Wt/Ft: 28
From: +1.6
To: 39
Cement:

Diameter: 5.5
Grade:
Wt/Ft: 15.5
From: 0
To: 532
Cement:

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-14	Surficial Deposits	0-13
	Gatuna Formation	13-40
	Dockum Group	NP
	Dewey Lake Red Beds	40-360
	Rustler Formation	360-T.D.
	Magenta Dolomite Member	424-448
	Culebra Dolomite Member	545-572
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	589

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-15**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1470 (State Engineer's Office)
LOCATION:	88.7' FNL, 174.3' FEL, Sec. 28, T 22 S, R 31 E
ELEVATION:	3481.63' (Top of Casing)
TOTAL DEPTH:	900'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 11/86 **Date Completed:** 11/86
CASING RECORD:	Diameter: 8.625 Grade: Wt/Ft: 28 From: 0 To: 39 Diameter: 5.5 Grade: Wt/Ft: 15.5 From: +1.4 To: 853
PLUGGING SCHEDULE:	No plugging data.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-15	Surficial Deposits	0-8
	Gatuna Formation	4-42
	Dockum Group	42-168
	Dewey Lake Red Beds	168-692
	Rustler Formation	692-T.D.
	Magenta Dolomite Member	748-773
	Culebra Dolomite Member	861-883
	Salado Formation	
	Upper Member	
	McNutt Member	
	Lower Member	
	Total Depth	900

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: **H-16**
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1471 (State Engineer's Office)

LOCATION: 1112.6 FSL, 1241.3 FEL, Sec. 20, T 22 S, R 31 E

ELEVATION: 3406.77' (Top of Casing)
TOTAL DEPTH: 850.9'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 07/13/87 **Date Completed:** 08/18/87

CASING RECORD:

Diameter: 10 3/4
Grade:
Wt/Ft: 40.5
From: 0
To: 36.5

Diameter: 7
Grade:
Wt/Ft: 23
From: 0
To: 469

Note: 6 1/8" inch open hole from 469' to total depth of 850.9'.

PLUGGING SCHEDULE: No plugging data.

STRATIGRAPHIC SUMMARY:

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE: H-17
OPERATOR: Sandia National Labs
PERMIT NO.: 0.08.1477 (State Engineer's Office)

LOCATION: 1465.5' FSL, 994.1' FWL, Sec. 3, T 23 S, R 31 E

ELEVATION: 3385.31' (Top of Casing)
TOTAL DEPTH: 880'
TYPE OF WELL: Hydrologic Test Hole
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/21/87 **Date Completed:** 11/04/87

CASING RECORD:

Diameter: 10 3/4
Grade: H-40
Wt/Ft: 40.5
From: 0
To: 38

Diameter: 7
Grade: J-55
Wt/Ft: 23
From: 0
To: 692

Note: 6 1/8" inch open hole from 693' to the plugged back depth of 773'.

PLUGGING SCHEDULE: The borehole was plugged back with cement grout to a total depth of 773' on 11/06/87.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-17	Quaternary Deposits	
	Holocene	0-15
	Pleistocene	
	Mescalero Caliche	15-21.5
	Upper Triassic	
	Dockum Group	21.5-55
	Upper Permian	
	Dewey Lake Red Beds	55-509
	Rustler Formation	509-855.7
	Forty-Niner Member	509-564
	Magenta Dolomite Member	564-590.8
	Tamarisk Member	590.8-705.8
	Culebra Dolomite Member	705.8-731.4
	Unnamed Lower Member	731.4-855.7
	Salado Formation	855.7-870.3+

HYDROLOGIC TEST BOREHOLE DATA BASE

BOREHOLE:	**H-18**
OPERATOR:	Sandia National Labs
PERMIT NO.:	0.08.1473 (State Engineer's Office)
LOCATION:	964.8' FNL, 445.6' FWL, Sec. 20, T 22 S, R 31 E
ELEVATION:	3414.21' (Top of Casing)
TOTAL DEPTH:	840'
TYPE OF WELL:	Hydrologic Test Hole
DRILLER:	Pennsylvania Drilling Company
DRILLING RECORD:	**Date Started:** 09/29/87 **Date Completed:** 11/16/87
CASING RECORD:	Diameter: 10 3/4 Grade: H-40 Wt/Ft: 40.5 From: 0 To: 39 Diameter: 7 Grade: J-55 Wt/Ft: 23 From: 0 To: 673 Note: 6 1/8" inch open hole from 673' to the plugged back depth of 766'.
PLUGGING SCHEDULE:	The borehole was plugged back with cement grout to a total depth of 766' on 11/19/87.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
H-18	Quaternary Deposits	
	Holocene	
	Drill Pad Material & Unconsolidated Sand	0-5
	Pleistocene	
	Mescalero Caliche	5-8
	Upper Triassic	
	Dockum Group	8-20
	Upper Permian	
	Dewey Lake Red Beds	20-506.1
	Rustler Formation	506.1-820.9
	Forty-Niner Member	506.1-571.2
	Magenta Dolomite	571.2-594.2
	Tamarisk Member	594.2-688.6
	Culebra Dolomite Member	688.6-712.8
	Unnamed Lower Member	712.8-820.9
	Salado Formation	820.9-830.5+

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-1**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	327' FSL, 551' FWL of Sec. 29, SW 1/4 Sec. 29, T 22 S, R 31 E
ELEVATION:	3345'
TOTAL DEPTH:	1591'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/23/76 **Date Completed:** 09/02/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 203' of casing left in hole between 591-794' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	358-677'
TOP OF SALADO:	677'
MARKER BED 124:	1477-1486'
PLUGGING SCHEDULE:	From: 1591' To: 0' Int: 1591' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-1	Holocene Deposits	0-10
	Pleistocene Rocks	
	Gatuna Formation	10-40
	Permian Rocks	
	Dewey Lake Red Beds	40-358
	Rustler Formation	358-677
	Magenta Dolomite Member	423-448
	Culebra Dolomite Member	538-565
	Salado Formation	677-1591
	Upper Member	677-1191
	McNutt Potash Zone	1191-1583
	Vaca Triste Sandstone Member	1191-1201
	11th Ore Zone	1246-1250
	MB 117	1259-1262
	MB 118	1282-1285
	MB 119	1307-1309
	10th Ore Zone	1319-1324
	MB 120	1334-1335
	9th Ore Zone	1338-1343
	MB 121	1347-1349
	MB 122	1356-1357
	8th Ore Zone	1361-1370
	Union Anhydrite	1381-1393
	7th Ore Zone	1400-1404
	6th Ore Zone	1414-1416
	5th Ore Zone	1419-1432
	MB 123	1462-1469
	MB 124	1477-1486
	4th Ore Zone	1490-1503
	3d Ore Zone	1511-1526
	2d Ore Zone	1533-1538
	1st Ore Zone	1554-1562
	MB 126	1582-1583
	Lower Member	1583-1587

POTASH BOREHOLE DATA BASE

BOREHOLE: P-2
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 125' FNL, 172' FEL of Sec. 28, NE1/4
Sec. 28, T 22 S, R 31 E

ELEVATION: 3478'
TOTAL DEPTH: 1895'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 08/25/76 **Date Completed:** 09/02/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Unknown
RUSTLER FORMATION: 690-1008'
TOP OF SALADO: 1008'
MARKER BED 124: 1787-1795'

PLUGGING SCHEDULE: From: 1895'
To: 0'
Int: 1895'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-2	Holocene Deposits	0-18
	Pleistocene Rocks	
	Gatuna Formation	18-38
	Triassic Rocks	
	Santa Rosa Sandstone	38-164
	Permian Rocks	
	Dewey Lake Red Beds	164-690
	Rustler Formation	690-1008
	Magenta Dolomite Member	748-773
	Culebra Dolomite Member	857-883
	Salado Formation	1008-1895
	Upper Member	1008-1506
	McNutt Potash Zone	1506-1883
	Vaca Triste Sandstone Member	1506-1512
	11th Ore Zone	1562-1565
	MB 117	1574-1576
	MB 118	1599-1601
	MB 119	1622-1626
	10th Ore Zone	1632-1639
	MB 120	1646-1647
	9th Ore Zone	1652-1656
	MB 121	1662-1663
	MB 122	1670-1671
	8th Ore Zone	1678-1687
	Union Anhydrite	1695-1705
	7th Ore Zone	1712-1719
	6th Ore Zone	1731-1733
	5th Ore Zone	1738-1745
	MB 123	1774-1781
	MB 124	1787-1795
	4th Ore Zone	1799-1809
	3d Ore Zone	1818-1832
	2d Ore Zone	1836-1840
	1st Ore Zone	1859-1870
	MB 126	1882-1883
	Lower Member	1883-1894

POTASH BOREHOLE DATA BASE

BOREHOLE: P-3
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 103' FSL, 3122' FEL of Sec. 20, SW1/4
Sec. 20, T 22 S, R 31 E

ELEVATION: 3382'
TOTAL DEPTH: 1676'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 08/26/76 **Date Completed:** 09/07/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: 336' of casing left in hole between 490-826' below land surface.

WATER HORIZONS: Unknown
RUSTLER FORMATION: 468-786'
TOP OF SALADO: 786'
MARKER BED 124: 1571-1579'

PLUGGING SCHEDULE: From: 1676'
To: 0'
Int: 1676'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-3	Holocene Deposits	0-10
	Pleistocene rocks	
	Gatuna Formation	10-41
	Permian Rocks	
	Dewey Lake Red Beds	41-468
	Rustler Formation	468-786
	Magenta Dolomite Member	529-553
	Culebra Dolomite Member	642-665
	Salado Formation	786-1668
	Upper Member	786-1287
	McNutt Potash Zone	1287-1668
	Vaca Triste Sandstone Member	1287-1295
	11th Ore Zone	1346-1349
	MB 117	1357-1358
	MB 118	1375-1378
	MB 119	1405-1407
	10th Ore Zone	1415-1420
	MB 120	1428-1429
	9th Ore Zone	1434-1438
	MB 121	1443-1445
	MB 122	1452-1453
	8th Ore Zone	1458-1467
	Union Anhydrite	1473-1481
	7th Ore Zone	1494-1499
	6th Ore Zone	1509-1511
	5th Ore Zone	1515-1525
	MB 123	1555-1563
	MB 124	1571-1579
	4th Ore Zone	1585-1595
	3d Ore Zone	1599-1617
	2d Ore Zone	1623-1627
	1st Ore Zone	1645-1656
	MB 126	1667-1668

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-4**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	146' FSL, 1487' FEL of Sec. 28, SE1/4 Sec. 28, T 22 S, R 31 E
ELEVATION:	3441'
TOTAL DEPTH:	1857'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 08/28/76 **Date Completed:** 09/04/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water at 850'.
RUSTLER FORMATION:	609-930'
TOP OF SALADO:	930'
MARKER BED 124:	1742-1752'
PLUGGING SCHEDULE:	From: 1857' To: 0' Int: 1857' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-4	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-99
	Permian Rocks	
	Dewey Lake Red Beds	99-609
	Rustler Formation	609-930
	Magenta Dolomite Member	662-686
	Culebra Dolomite Member	775-802
	Salado Formation	930-1857
	Upper Member	930-1446
	McNutt Potash Zone	1446-1853
	Vaca Triste Sandstone Member	1446-1452
	11th Ore Zone	1506-1509
	MB 117	1519-1521
	MB 118	1544-1547
	MB 119	1570-1572
	10th Ore Zone	1581-1589
	MB 120	1596-1597
	9th Ore Zone	1603-1607
	MB 121	1610-1612
	MB 122	1620-1621
	8th Ore Zone	1628-1637
	Union Anhydrite	1646-1659
	7th Ore Zone	1667-1671
	6th Ore Zone	1683-1686
	5th Ore Zone	1690-1700
	MB 123	1728-1735
	MB 124	1742-1752
	4th Ore Zone	1756-1768
	3d Ore Zone	1777-1792
	2d Ore Zone	1798-1803
	1st Ore Zone	1824-1835
	MB 126	1852-1853

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-5**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	202' FSL, 165' FEL of Sec. 17, SE1/4 Sec. 17, T 22 S, R 31 E
ELEVATION:	3472'
TOTAL DEPTH:	1830'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/10/76 **Date Completed:** 09/21/76
	Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: 568' of casing left in hole between 435-1003' below land surface.
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	623-947'
TOP OF SALADO:	947'
MARKER BED 124:	1695-1705'
PLUGGING SCHEDULE:	From: 1830' To: 0' Int: 1830' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-5	Holocene deposits	0-13
	Triassic Rocks	
	Santa Rosa Sandstone	13-146
	Permian Rocks	
	Dewey Lake Red Beds	146-623
	Rustler Formation	623-947
	Magenta Dolomite Member	686-711
	Culebra Dolomite Member	804-827
	Salado Formation	947-1830
	Upper Member	947-1429
	McNutt Potash Zone	1429-1785
	Vaca Triste Sandstone Member	1429-1436
	11th Ore Zone	1482-1486
	MB 117	1492-1494
	MB 118	1514-1517
	MB 119	1541-1543
	10th Ore Zone	1550-1556
	MB 120	1560-1561
	9th Ore Zone	1567-1571
	MB 121	1573-1575
	MB 122	1580-1582
	8th Ore Zone	1589-1595
	Union Anhydrite	1604-1611
	7th Ore Zone	1623-1628
	6th Ore Zone	1635-1638
	5th Ore Zone	1643-1659
	MB 123	1680-1687
	MB 124	1695-1705
	4th Ore Zone	1709-1717
	3d Ore Zone	1725-1737
	1st Ore Zone	1742-1746
	MB 126	1784-1785
	Lower Member	1785-1830
	MB 127	1810-1811
	MB 128	1821-1822

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-6**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	2767' FSL, 199' FWL of Sec. 30, NW1/4 Sec. 30, T 22 S, R 31 E
ELEVATION:	3354'
TOTAL DEPTH:	1573'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/03/76 **Date Completed:** 09/16/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	357-659'
TOP OF SALADO:	659'
MARKER BED 124:	1453-1462'
PLUGGING SCHEDULE:	From: 1573' To: 0' Int: 1573' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

POTASH BOREHOLE DATA BASE

BOREHOLE: P-7
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 513' FNL, 396' FWL of Sec. 5, NW1/4
Sec. 5, T 23 S, R 31 E

ELEVATION: 3332'
TOTAL DEPTH: 1574'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/04/76 **Date Completed:** 09/21/76

Remarks: Encountered air pocket at 980' below land surface, and lost casing seat. Encountered several air pockets between 980-1264'. Lost mud at 1234'.

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: 210' of casing left in hole between 530-740' below land surface.

WATER HORIZONS: Unknown
RUSTLER FORMATION: 312-630'
TOP OF SALADO: 630'
MARKER BED 124: 1448-1459'

PLUGGING SCHEDULE: From: 1830'
To: 0'
Int: 1830'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-7	Holocene Deposits	0-11
	Pleistocene Rocks	
	Gatuna Formation	11-45
	Permian Rocks	
	Dewey Lake Red Beds	45-312
	Rustler Formation	312-630
	Magenta Dolomite Member	373-398
	Culebra Dolomite Member	496-522
	Salado Formation	630-1574
	Upper Member	630-1155
	McNutt Potash Zone	1155-1566
	Vaca Triste Sandstone Member	1155-1162
	11th Ore Zone	1215-1220
	MB 117	1228-1230
	MB 118	1252-1256
	MB 119	1277-1279
	10th Ore Zone	1291-1296
	MB 120	1307-1308
	9th Ore Zone	1312-1316
	MB 121	1326-1328
	MB 122	1330-1331
	8th Ore Zone	1335-1346
	Union Anhydrite	1358-1372
	7th Ore Zone	1377-1382
	6th Ore Zone	1391-1393
	5th Ore Zone	1398-1407
	MB 123	1433-1441
	MB 124	1448-1459
	4th Ore Zone	1467-1484
	3d Ore Zone	1492-1507
	2d Ore Zone	1513-1518
	1st Ore Zone	1537-1547
	MB 126	1565-1566

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-8**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	642' FNL, 96' FWL of Sec. 4, NW1/4 Sec. 4, T 23 S, R 31 E
ELEVATION:	3336'
TOTAL DEPTH:	1660'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/08/76 **Date Completed:** 09/15/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	No water reported by driller.
RUSTLER FORMATION:	391-715'
TOP OF SALADO:	715'
MARKER BED 124:	1537-1545'
PLUGGING SCHEDULE:	From: 1660' To: 0' Int: 1660' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-8	Holocene Deposits	0-9
	Pleistocene Rocks	
	Gatuna Formation	9-39
	Permian Rocks	
	Dewey Lake Red Beds	39-391
	Rustler Formation	391-715
	Magenta Dolomite Member	450-474
	Culebra Dolomite Member	563-585
	Salado Formation	715-1660
	Upper Member	715-1237
	McNutt Potash Zone	1237-1652
	Vaca Triste Sandstone Member	1237-1245
	11th Ore Zone	1297-1301
	MB 117	1308-1310
	MB 118	1333-1337
	MB 119	1360-1362
	10th Ore Zone	1373-1380
	MB 120	1389-1390
	9th Ore Zone	1395-1399
	MB 121	1405-1407
	MB 122	1413-1414
	8th Ore Zone	1421-1430
	Union Anhydrite	1440-1455
	7th Ore Zone	1461-1465
	6th Ore Zone	1472-1475
	5th Ore Zone	1481-1492
	MB 123	1517-1524
	MB 124	1537-1545
	4th Ore Zone	1554-1567
	3d Ore Zone	1577-1596
	2d Ore Zone	1601-1604
	1st Ore Zone	1624-1633
	MB 126	1661-1662

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-9**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	1493' FSL, 143' FEL of Sec. 33, SE1/4 Sec. 33, T 22 S, R 31 E
ELEVATION:	3409'
TOTAL DEPTH:	1796'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/16/76 **Date Completed:** 09/25/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Driller reported water at 220' below land surface, making about 25 gpm.
RUSTLER FORMATION:	562-881'
TOP OF SALADO:	881'
MARKER BED 124:	1686-1695'
PLUGGING SCHEDULE:	From: 1796' To: 0' Int: 1796' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-9	Holocene Deposit	0-11
	Triassic Rocks	
	Santa Rosa Sandstone	11-66
	Permian Rocks	
	Dewey Lake Red Beds	66-562
	Rustler Formation	562-881
	Magenta Dolomite Member	617-644
	Culebra Dolomite Member	734-757
	Salado Formation	881-1796
	Upper Member	881-1401
	McNutt Potash Zone	1401-1796
	Vaca Triste Sandstone Member	1401-1410
	11th Ore Zone	1458-1462
	MB 117	1471-1473
	MB 118	1496-1499
	MB 119	1519-1521
	10th Ore Zone	1530-1538
	MB 120	1546-1547
	9th Ore Zone	1552-1555
	MB 121	1561-1563
	MB 122	1569-1570
	8th Ore Zone	1577-1585
	Union Anhydrite	1597-1608
	7th Ore Zone	1613-1618
	6th Ore Zone	1626-1629
	5th Ore Zone	1634-1643
	MB 123	1668-1676
	MB 124	1686-1695
	4th Ore Zone	1699-1714
	3d Ore Zone	1723-1738
	2d Ore Zone	1744-1748
	1st Ore Zone	1769-1778
	MB 126	1795-1796

POTASH BOREHOLE DATA BASE

BOREHOLE: P-10
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 2315' FNL, 339' FWL of Sec. 26, NW1/4
Sec. 26, T 22 S, R 31 E

ELEVATION: 3508'
TOTAL DEPTH: 2009'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/24/76 **Date Completed:** 10/15/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Unknown
RUSTLER FORMATION: 686-1086'
TOP OF SALADO: 1086'
MARKER BED 124: 1880-1888'

PLUGGING SCHEDULE: From: 2009'
To: 0'
Int: 2009'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-10	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-151
	Permian Rocks	
	Dewey Lake Red Beds	151-686
	Rustler Formation	686-1086
	Magenta Dolomite Member	757-781
	Culebra Dolomite Member	931-957
	Salado Formation	1086-2009
	Upper Member	1086-1594
	McNutt Potash Zone	1594-1983
	Vaca Triste Sandstone Member	1594-1603
	11th Ore Zone	1652-1655
	MB 117	1662-1664
	MB 118	1686-1688
	MB 119	1710-1712
	10th Ore Zone	1717-1725
	MB 120	1733-1734
	9th Ore Zone	1740-1744
	MB 121	1751-1753
	MB 122	1759-1760
	8th Ore Zone	1765-1775
	Union Anhydrite	1784-1798
	7th Ore Zone	1807-1811
	6th Ore Zone	1822-1825
	5th Ore Zone	1831-1841
	MB 123	1868-1875
	MB 124	1880-1888
	4th Ore Zone	1892-1905
	3d Ore Zone	1913-1929
	2d Ore Zone	1934-1938
	1st Ore Zone	1961-1969
	MB 126	1982-1983
	Lower Member	1983-2009
	MB 127	2005-2008

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-11**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	175' FNL and 177' FWL of Sec. 23, NW1/4 Sec. 23, T 22 S, R 31 E
ELEVATION:	3506'
TOTAL DEPTH:	1940'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/24/76 **Date Completed:** 10/16/76 Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.
CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	745-1058'
TOP OF SALADO:	1058'
MARKER BED 124:	1824-1833'
PLUGGING SCHEDULE:	From: 1940' To: 0' Int: 1940' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-11	Holocene Deposits	0-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-224
	Permian Rocks	
	Dewey Lake Red Beds	224-745
	Rustler Formation	745-1058
	Magenta Dolomite Member	798-823
	Culebra Dolomite Member	912-938
	Salado Formation	1058-1942
	Upper Member	1058-1550
	McNutt Potash Zone	1550-1917
	Vaca Triste Sandstone Member	1550-1557
	11th Ore Zone	1604-1608
	MB 117	1616-1618
	MB 118	1640-1642
	MB 119	1664-1666
	10th Ore Zone	1674-1682
	MB 120	1687-1688
	9th Ore Zone	1693-1698
	MB 121	1702-1704
	MB 122	1711-1712
	8th Ore Zone	1717-1724
	Union Anhydrite	1735-1740
	7th Ore Zone	1754-1759
	6th Ore Zone	1767-1770
	5th Ore Zone	1775-1785
	MB 123	1811-1818
	MB 124	1824-1833
	4th Ore Zone	1837-1846
	3d Ore Zone	1853-1866
	2d Ore Zone	1871-1874
	1st Ore Zone	1890-1901
	MB 126	1916-1917
	Lower Member	1917-1942
	MB 127	1940-1941

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-12**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	167' FNL, 195' FEL of Sec. 24, NE1/4 Sec. 24, T 22 S, R 30 E
ELEVATION:	3376'
TOTAL DEPTH:	1598'
TYPE OF WELL:	Potash Core Test
DRILLER:	Pennsylvania Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/17/76 **Date Completed:** 10/20/76

Remarks: Lost circulation at 742' and 813' below land.

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	461-749'
TOP OF SALADO:	749'
MARKER BED 124:	1494-1509'
PLUGGING SCHEDULE:	From: 1598' To: 0' Int: 1598' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-12	Holocene Deposits	0-8
	Permian Rocks	
	Dewey Lake Red Beds	8-461
	Rustler Formation	461-749
	Magenta Dolomite Member	519-543
	Culebra Dolomite Member	633-656
	Salado Formation	749-1598
	Upper Member	749-1226
	McNutt Potash Zone	1226-1597
	Vaca Triste Sandstone Member	1226-1233
	11th Ore Zone	1280-1284
	MB 117	1290-1292
	MB 118	1314-1317
	MB 119	1338-1340
	10th Ore Zone	1346-1353
	MB 120	1361-1362
	9th Ore Zone	1367-1370
	MB 121	1376-1378
	MB 122	1384-1385
	8th Ore Zone	1390-1398
	Union Anhydrite	1407-1417
	7th Ore Zone	1432-1436
	6th Ore Zone	1442-1445
	5th Ore Zone	1450-1459
	MB 123	1486-1492
	MB 124	1494-1509
	4th Ore Zone	1514-1523
	3d Ore Zone	1533-1546
	2d Ore Zone	1550-1555
	1st Ore Zone	1572-1582
	MB 126	1596-1597

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-13**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	125' FNL, 116' FWL of Sec. 18, NW1/4 Sec. 18, T 22 S, R 31 E
ELEVATION:	3345'
TOTAL DEPTH:	1576'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/17/76 **Date Completed:** 09/23/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Hit water at 630'.
RUSTLER FORMATION:	427-721'
TOP OF SALADO:	721'
MARKER BED 124:	1462-1471'
PLUGGING SCHEDULE:	From: 1576' To: 0' Int: 1576' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-13	Holocene Deposits	0-12
	Pleistocene Rocks	
	Gatuna Formation	12-38
	Permian Rocks	
	Dewey Lake Red Beds	38-427
	Rustler Formation	427-721
	Magenta Dolomite Member	490-514
	Culebra Dolomite Member	604-627
	Salado Formation	721-1573
	Upper Member	721-1201
	McNutt Potash Zone	1201-1547
	Vaca Triste Sandstone Member	1201-1208
	11th Ore Zone	1252-1255
	MB 117	1264-1265
	MB 118	1287-1289
	MB 119	1309-1311
	10th Ore Zone	1317-1323
	MB 120	1330-1331
	9th Ore Zone	1336-1340
	MB 121	1344-1346
	MB 122	1355-1356
	8th Ore Zone	1359-1368
	Union Anhydrite	1377-1382
	7th Ore Zone	1395-1400
	6th Ore Zone	1407-1410
	5th Ore Zone	1413-1423
	MB 123	1447-1453
	MB 124	1462-1471
	4th Ore Zone	1474-1483
	3d Ore Zone	1491-1501
	2d Ore Zone	1506-1510
	1st Ore Zone	1525-1533
	MB 126	1547-1548
	Lower Member	1548-1573
	MB 127	1572-1573

POTASH BOREHOLE DATA BASE

BOREHOLE: P-14
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 307' FSL, 615.8' FWL of Sec. 24, SW1/4
Sec. 24, T 22 S, R 30 E

ELEVATION: 3358'
TOTAL DEPTH: 1545'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 09/24/76 **Date Completed:** 10/03/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Hit water at 589'.
RUSTLER FORMATION: 387-687'
TOP OF SALADO: 687'
MARKER BED 124: 1410-1419'

PLUGGING SCHEDULE:

From: 1545'
To: 775'
Int: 770'
Material: Cement

From: 775'
To: 0'
Int: 775'
Material: Well

Note: Hole plugged from 1545'-775' with cement and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-14	Holocene Deposits	0-10
	Pleistocene Rocks	
	Gatuna Formation	10-42
	Permian Rocks	
	Dewey Lake Red Beds	42-387
	Rustler Formation	387-687
	Magenta Dolomite Member	453-475
	Culebra Dolomite Member	573-595
	Salado Formation	687-1540
	Upper Member	687-1133
	McNutt Potash Zone	1133-1510
	Vaca Triste Sandstone Member	1133-1141
	11th Ore Zone	1186-1190
	MB 117	1199-1200
	MB 118	1225-1228
	MB 119	1251-1253
	10th Ore Zone	1257-1263
	MB 120	1273-1274
	9th Ore Zone	1277-1282
	MB 121	1287-1289
	MB 122	1297-1298
	8th Ore Zone	1302-1310
	Union Anhydrite	1319-1328
	7th Ore Zone	1342-1345
	6th Ore Zone	1352-1355
	5th Ore Zone	1361-1370
	MB 123	1394-1400
	MB 124	1410-1419
	4th Ore Zone	1423-1435
	3d Ore Zone	1443-1455
	2d Ore Zone	1461-1465
	1st Ore Zone	1482-1492
	MB 126	1509-1510
	Lower Member	1510-1540
	MB 127	1534-1536

POTASH BOREHOLE DATA BASE

BOREHOLE: **P-15**
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 410.8' FSL, 192.32' FWL of Sec. 21, SW1/4
Sec. 31, T 22 S, R 31 E

ELEVATION: 3309.7'
TOTAL DEPTH: 1465'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/04/76 **Date Completed:** 10/14/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2": Casing Unknown
Recovered: 210' of casing left in hole between 530-740' below land surface.

WATER HORIZONS:
RUSTLER FORMATION:
TOP OF SALADO:
MARKER BED 124:

PLUGGING SCHEDULE:

From: 1465'
To: 620'
Int: 845'
Material: Cement

From: 620'
To: 0'
Int: 620'
Material: Well

Note: Hole plugged from 1465'-620' with cement, and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-15	Holocene Deposits	0-11
	Pleistocene Rocks	
	Gatuna Formation	11-32
	Permian Rocks	
	Dewey Lake Red Beds	32-231
	Rustler Formation	231-542
	Magenta Dolomite Member	294-321
	Culebra Dolomite Member	413-435
	Salado Formation	542-1465
	Upper Member	542-1057
	McNutt Potash Zone	1057-1453
	Vaca Triste Sandstone Member	1057-1065
	11th Ore Zone	1116-1119
	MB 117	1128-1130
	MB 118	1149-1152
	MB 119	1176-1178
	10th Ore Zone	1187-1195
	MB 120	1203-1204
	9th Ore Zone	1208-1212
	MB 121	1216-1218
	MB 122	1225-1226
	8th Ore Zone	1234-1244
	Union Anhydrite	1251-1263
	7th Ore Zone	1271-1275
	6th Ore Zone	1284-1288
	5th Ore Zone	1292-1301
	MB 123	1326-1333
	MB 124	1343-1353
	4th Ore Zone	1361-1376
	3d Ore Zone	1384-1397
	2d Ore Zone	1404-1408
	1st Ore Zone	1426-1436
	MB 126	1452-1453

POTASH BOREHOLE DATA BASE

BOREHOLE:	**P-16**
OPERATOR:	U.S. Department of Energy
PERMIT NO.:	Unknown
LOCATION:	951' FSL, 1629' FEL of Sec. 5, SW1/4 Sec. 5, T 23S, R 31E
ELEVATION:	3323'
TOTAL DEPTH:	1585'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company (for Sandia Laboratories)
DRILLING RECORD:	**Date Started:** 09/27/76 **Date Completed:** 10/05/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD:	4-1/2" Casing: Unknown Recovered: All
WATER HORIZONS:	Unknown
RUSTLER FORMATION:	316-646'
TOP OF SALADO:	646'
MARKER BED 124:	1460-1470"
PLUGGING SCHEDULE:	From: 1585' To: 0' Int: 1585' Material: Cement
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-16	Holocene Deposits	0-14
	Pleistocene Rocks	
	Gatuna Formation	14-32
	Permian Rocks	
	Dewey Lake Red Beds	32-316
	Rustler Formation	316-646
	Magenta Dolomite Member	376-401
	Culebra Dolomite Member	500-523
	Salado Formation	646-1587
	Upper Member	646-1174
	McNutt Potash Zone	1174-1585
	Vaca Triste Sandstone Member	1174-1182
	11th Ore Zone	1235-1237
	MB 117	1245-1247
	MB 118	1269-1273
	MB 119	1293-1295
	10th Ore Zone	1307-1313
	MB 120	1323-1324
	9th Ore Zone	1328-1331
	MB 121	1336-1338
	MB 122	1345-1346
	8th Ore Zone	1352-1365
	Union Anhydrite	1373-1390
	7th Ore Zone	1396-1400
	6th Ore Zone	1411-1412
	5th Ore Zone	1417-1425
	MB 123	1450-1456
	MB 124	1460-1470
	4th Ore Zone	1480-1501
	3d Ore Zone	1510-1526
	2d Ore Zone	1533-1536
	1st Ore Zone	1556-1568
	MB 126	1583-1585

POTASH BOREHOLE DATA BASE

BOREHOLE: P-17
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 1372.2' FSL, 401.9' FWL of Sec. 4, SW1/4
Sec. 4, T 23 S, R 31 E

ELEVATION: 3340'
TOTAL DEPTH: 1660'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/18/76 **Date Completed:** 10/26/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: Unknown

WATER HORIZONS: Hit water at 265' and at 600'.
RUSTLER FORMATION: 382-715'
TOP OF SALADO: 715'
MARKER BED 124: 1527-1535'

PLUGGING SCHEDULE:

From: 1660'
To: 731'
Int: 929'
Material: Cement

From: 731'
To: 0'
Int: 731'
Material: Well

Note: Hole plugged from 1660'-731 with cement and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-17	Holocene Deposits	0-14
	Pleistocene Rocks	
	Gatuna Formation	14-46
	Permian Rocks	
	Dewey Lake Red Beds	46-382
	Rustler Formation	382-715
	Magenta Dolomite Member	438-463
	Culebra Dolomite Member	558-583
	Salado Formation	715-1662
	Upper Member	715-1234
	McNutt Potash Zone	1234-1648
	Vaca Triste Sandstone Member	1234-1242
	11th Ore Zone	1294-1299
	MB 117	1306-1308
	MB 118	1330-1334
	MB 119	1358-1359
	10th Ore Zone	1368-1376
	MB 120	1387-1388
	9th Ore Zone	1391-1396
	MB 121	1402-1404
	MB 122	1410-1411
	8th Ore Zone	1418-1428
	Union Anhydrite	1438-1453
	7th Ore Zone	1456-1461
	6th Ore Zone	1471-1474
	5th Ore Zone	1478-1487
	MB 123	1513-1521
	MB 124	1527-1535
	4th Ore Zone	1544-1563
	3d Ore Zone	1573-1587
	2d Ore Zone	1594-1599
	1st Ore Zone	1619-1630
	MB 126	1647-1648

POTASH BOREHOLE DATA BASE

BOREHOLE: P-18
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 138.5' FSL, 732.7' FEL of Sec. 26, SE1/4
Sec. 26, T 22 S, R 31 E

ELEVATION: 3479'
TOTAL DEPTH: 1998'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/19/76 **Date Completed:** 11/05/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: Unknown

WATER HORIZONS: Unknown
RUSTLER FORMATION: 626-1088'
TOP OF SALADO: 1088'
MARKER BED 124: 1880-1889'

PLUGGING SCHEDULE:

From: 1998'
To: 1125'
Int: 873'
Material: Cement

From: 1125'
To: 0'
Int: 1125'
Material: Well

Note: Hole plugged from 1998-1125' with cement, and converted to hydrologic observation well in Rustler Formation.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-18	Holocene Deposits	0-9
	Triassic Rocks	
	Santa Rosa Sandstone	9-87
	Permian Rocks	
	Dewey Lake Red Beds	87-626
	Rustler Formation	626-1088
	Magenta Dolomite Member	704-730
	Culebra Dolomite Member	909-938
	Salado Formation	1088-2000
	Upper Member	1088-1604
	McNutt Potash Zone	1604-1987
	Vaca Triste Sandstone Member	1604-1614
	11th Ore Zone	1658-1662
	MB 117	1670-1672
	MB 118	1692-1694
	MB 119	1716-1718
	10th Ore Zone	1726-1734
	MB 120	1741-1742
	9th Ore Zone	1749-1752
	MB 121	1756-1758
	MB 122	1765-1766
	8th Ore Zone	1772-1783
	Union Anhydrite	1793-1808
	7th Ore Zone	1812-1817
	6th Ore Zone	1828-1830
	5th Ore Zone	1835-1844
	MB 123	1868-1875
	MB 124	1880-1889
	4th Ore Zone	1897-1910
	3d Ore Zone	1919-1933
	2d Ore Zone	1938-1942
	1st Ore Zone	1961-1972
	MB 126	1986-1987

POTASH BOREHOLE DATA BASE

BOREHOLE: **P-19**
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 1652' FSL, 2330' FWL of Sec. 23, SW1/4
Sec. 23, T 22 S, R 31 E

ELEVATION: 3546.3'
TOTAL DEPTH: 2000'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/19/76 **Date Completed:** 11/04/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS:
RUSTLER FORMATION:
TOP OF SALADO:
MARKER BED 124:

PLUGGING SCHEDULE: From: 2000'
To: 0'
Int: 2000'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-19	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-232
	Permian Rocks	
	Dewey Lake Red Beds	232-758
	Rustler Formation	758-1117
	Magenta Dolomite Member	814-839
	Culebra Dolomite Member	967-997
	Salado Formation	1117-2002
	Upper Member	1117-1621
	McNutt Potash Zone	1621-2011
	Vaca Triste Sandstone Member	1621-1628
	11th Ore Zone	1677-1681
	MB 117	1688-1690
	MB 118	1711-1713
	MB 119	1735-1737
	10th Ore Zone	1745-1753
	MB 120	1760-1761
	9th Ore Zone	1767-1771
	MB 121	1776-1778
	MB 122	1785-1786
	8th Ore Zone	1792-1801
	Union Anhydrite	1812-1822
	7th Ore Zone	1835-1840
	6th Ore Zone	1850-1854
	5th Ore Zone	1858-1872
	MB 123	1892-1901
	MB 124	1909-1917
	4th Ore Zone	1923-1933
	3d Ore Zone	1944-1955
	2d Ore Zone	1962-1967
	1st Ore Zone	1983-1994

POTASH BOREHOLE DATA BASE

BOREHOLE: P-20
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 794' FSL, 103' FEL of Sec. 14, SE1/4
Sec. 14, T 22 S, R 31 E

ELEVATION: 3552.9'
TOTAL DEPTH: 1995'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/06/76 **Date Completed:** 10/14/76

Remarks: Very weak air flow noted during logging operation on October 14, 1976. Air pocket escaped detection throughout coring operation.

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS:
RUSTLER FORMATION:
TOP OF SALADO:
MARKER BED 124:

PLUGGING SCHEDULE: From: 1995'
To: 0'
Int: 1995'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-20	Holocene Deposits	0-6
	Triassic Rocks	
	Santa Rosa Sandstone	6-261
	Permian Rocks	
	Dewey Lake Red Beds	261-780
	Rustler Formation	780-1103
	Magenta Dolomite Member	839-866
	Culebra Dolomite Member	953-979
	Salado Formation	1103-1996
	Upper Member	1103-1604
	McNutt Potash Zone	1604-1977
	Vaca Triste Sandstone Member	1604-1612
	11th Ore Zone	1658-1662
	MB 117	1671-1673
	MB 118	1696-1697
	MB 119	1720-1721
	10th Ore Zone	1728-1735
	MB 120	1742-1743
	9th Ore Zone	1747-1750
	MB 121	1756-1758
	MB 122	1764-1765
	8th Ore Zone	1771-1779
	Union Anhydrite	1789-1795
	7th Ore Zone	1807-1811
	6th Ore Zone	1821-1823
	5th Ore Zone	1828-1839
	MB 123	1866-1873
	MB 124	1880-1891
	4th Ore Zone	1893-1904
	3d Ore Zone	1911-1924
	2d Ore Zone	1928-1932
	1st Ore Zone	1947-1961
	MB 126	1975-1977
	Lower Member	1977-1996

POTASH BOREHOLE DATA BASE

BOREHOLE: P-21
OPERATOR: U.S. Department of Energy
PERMIT NO.: Unknown

LOCATION: 852' FNL, 150' FEL of Sec. 15, NE1/4
Sec. 15, T 22 S, R 31 E

ELEVATION: 3510'
TOTAL DEPTH: 1915'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company (for Sandia Laboratories)

DRILLING RECORD: **Date Started:** 10/15/76 **Date Completed:** 10/26/76

Conventional Rotary Drilling procedures were used to bore to the top of the potash-bearing section, and consecutive cores, 2-1/4" in diameter, were taken through the full thickness of the potash-bearing section.

CASING RECORD: 4-1/2" Casing: Unknown
Recovered: All

WATER HORIZONS: Driller reported water between 525-595'.
RUSTLER FORMATION: 734-1043'
TOP OF SALADO: 1043'
MARKER BED 124: 1796-1805'

PLUGGING SCHEDULE: From: 1915'
To: 0'
Int: 1915'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
P-21	Holocene Deposits	0-8
	Triassic Rocks	
	Santa Rosa Sandstone	8-225
	Permian Rocks	
	Dewey Lake Red Beds	225-734
	Rustler Formation	734-1043
	Magenta Dolomite Member	788-812
	Culebra Dolomite Member	899-924
	Salado Formation	1043-1918
	Upper Member	1043-1526
	McNutt Potash Zone	1526-1887
	Vaca Triste Sandstone Member	1526-1533
	11th Ore Zone	1579-1583
	MB 117	1591-1593
	MB 118	1615-1616
	MB 119	1637-1638
	10th Ore Zone	1647-1653
	MB 120	1659-1660
	9th Ore Zone	1665-1669
	MB 121	1676-1678
	MB 122	1685-1686
	8th Ore Zone	1690-1699
	Union Anhydrite	1707-1714
	7th Ore Zone	1727-1732
	6th Ore Zone	1740-1744
	5th Ore Zone	1748-1757
	MB 123	1781-1789
	MB 124	1796-1805
	4th Ore Zone	1811-1817
	3d Ore Zone	1824-1837
	2d Ore Zone	1841-1845
	1st Ore Zone	1859-1873
	MB 126	1886-1887
	Lower Member	1887-1918
	MB 127	1912-1913

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-374
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359163

LOCATION: 424' North 45 degrees West from S1/4 Corner of Section 30, SW1//4 Section 30, Township 22 South, Range 31 East. NMPM

ELEVATION: 3340'
TOTAL DEPTH: 1538'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 04/15/65 **Date Completed:** 04/27/65
Rotary Drill
6-1/4" Rockbit: 0-714'
3-7/8" Rockbit: 714-1149'
3-7/8" Corebit: 1149-1538'

CASING RECORD: 4" Casing: 0-714'
Recovered: 0-437'

PLUGGING SCHEDULE:

From: 1538'
To: 714'
Int: 824'
Material: Cement

From: 714'
To: 470'
Int: 244'
Material: Cement

From: 470'
To: 20'
Int: 450'
Material: Mud

From: 20'
To: 0'
Int: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 360'
Top of Salt: 690'
Top of USGS 124 Bed: 1399'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-375
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359161

LOCATION: 144' South 24 degrees East from Northwest Corner of Section 33, NW1/4 Section 33, Township 22 South, Range 31 East. NMPM

ELEVATION: 3390'
TOTAL DEPTH: 1746'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 04/28/65 **Date Completed:** 05/13/65
Rotary Drill
6-1/4" Rockbit: 0-520'
3-7/8" Rockbit: 520-1300'
3-7/8" Corebit: 1300-1746'

CASING RECORD: 4" Casing: 0-817'
Recovered: 0-129'

PLUGGING SCHEDULE:

From: 1746'
To: 817'
Int: 929'
Material: Cement

From: 817'
To: 510'
Int: 307'
Material: Cement

From: 510'
To: 20'
Int: 490'
Material: Mud

From: 20'
To: 0'
Int: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 470'
Top of Salt: 790'
Top of USGS 124 Bed: 1602'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-376
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384583

LOCATION: 400' South 75 degrees East from Northwest Corner of Section 20, NW1/4 Section 20, Township 22 South, Range 31 East. NMPM

ELEVATION: 3410'
TOTAL DEPTH: 1702'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 06/15/65 **Date Completed:** 06/23/65
Rotary Drill
6-1/4" Rockbit: 0-840'
3-7/8" Rockbit: 840-1328'
3-7/8" Corebit: 1328-1702'

CASING RECORD: 4" Casing: 0-840'
Recovered: 0-840'

PLUGGING SCHEDULE:

From: 1702'
To: 800'
Int: 902'
Material: Cement

From: 800'
To: 720'
Int: 80'
Material: Mud

From: 720'
To: 660'
Int: 60'
Material: Cement

From: 660'
To: 540'
Int: 120'
Material: Mud

From: 540'
To: 480'
Int: 60'
Material: Cement

From: 480'
To: 30'
Int: 450'
Material: Mud

From: 30'
To: 0'
Int: 30'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 500'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

Top of Salt: 840'
Top of USGS 124 Bed: 1581'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-377
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 105' South 48 degrees East from Northwest Corner of Section 22, NW1/4 Section 22, Township 22 South, Range 31 East. NMPM

ELEVATION: 3490'
TOTAL DEPTH: 1876'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Co.

DRILLING RECORD: **Date Started:** 06/26/65 **Date Completed:** 07/16/65
Rotary Drill
6-1/4" Rockbit: 0-996'
3-7/8" Rockbit: 996-1530'

CASING RECORD: 4" Casing: 0-996'
Recovered: 0-996'

PLUGGING SCHEDULE:

From: 1876'
To: 996'
Int: 880'
Material: Cement

From: 996'
To: 925'
Int: 71'
Material: Mud

From: 925'
To: 885'
Int: 40'
Material: Cement

From: 885'
To: 730'
Int: 155'
Material: Mud

From: 730'
To: 700'
Int: 30'
Material: Cement

From: 700'
To: 10'
Int: 690'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 700'
Top of Salt: 1014'
Top of USGS 124 Bed: 1770'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-383
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0359160

LOCATION: 287' South 52 degrees East from W1/4 Corner of Section 1, SW1/4 Section 1, Township 23 South, Range 30 East. NMPM

ELEVATION: 3272'
TOTAL DEPTH: 1307'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 07/19/65 **Date Completed:** 08/26/65
Rotary Drill
6-1/4" Rockbit: 0-481'
3-7/8" Rockbit: 481-1000'
3-7/8" Corebit: 1000-1307'

CASING RECORD: 4" Casing: 0-481'
Recovered: 0-105'

PLUGGING SCHEDULE:

From: 1307'
To: 481'
Int: 826'
Material: Cement

From: 481'
To: 320'
Int: 161'
Material: Cement

From: 320'
To: 210'
Int: 110'
Material: Mud

From: 210'
To: 150'
Int: 60'
Material: Cement

From: 150'
To: 15'
Int: 135'
Material: Mud

From: 15'
To: 0'
Int: 15'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 160'
Top of Salt: 475'
Top of USGS 124 Bed: 1211'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-456
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 300' from South Line and 2650' from East Line of Section 22, SW1/4 Section 22, Township 22 South, Range 31 East. NMPM

ELEVATION: 3520'
TOTAL DEPTH: 1975'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 06/22/76 **Date Completed:** 07/07/76
Rotary Drill
6-1/4" Rockbit: 0-940'
3-7/8" Rockbit: 940-1580'
3-7/8" Corebit: 1580-1975'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: From: 1975'
To: 0'
Int: 1975'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 790'
Top of Salt: 1080'
Top of USGS 124 Bed: 1853'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE:	**I-457**
OPERATOR:	International Minerals & Chemical Corp.
PERMIT NO.:	Potassium Prospecting Permit NM-0384584
LOCATION:	200' from South Line and 1200' from West Line of Section 27, SW1/4 Section 27 Township 22 South, Range 31 East. NMPM
ELEVATION:	3460'
TOTAL DEPTH:	1885'
TYPE OF WELL:	Potash Core Test
DRILLER:	Boyles Bros. Drilling Company
DRILLING RECORD:	**Date Started:** 07/08/76 **Date Completed:** 07/22/76 Rotary Drill 6-1/4" Rockbit: 0-940' 3-7/8" Rockbit: 940-1480' 3-7/8" Corebit: 1480-1885'
CASING RECORD:	4" Casing: 0-980' Recovered: 0-980'
PLUGGING SCHEDULE:	From: 1885' To: 0' Int: 1885' Material: Cement
STRATIGRAPHIC SUMMARY:	Rustler Formation: 660' Top of Salt: 980' Top of USGS 124 Bed: 1777'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-458
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 2500' from North Line and 400' from East Line of Section 4, NE1/4 Section 4, Township 23 South, Range 31 East. NMPM

ELEVATION: 3410'
TOTAL DEPTH: 1750'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 07/23/76 **Date Completed:** 08/09/76
Rotary Drill
6-1/4" Rockbit: 0-960'
3-7/8" Rockbit: 960-1385'
3-7/8" Corebit: 1385-1750'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: From: 1750'
To: 0'
Int: 1750'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 580'
Top of Salt: 970'
Top of USGS 124 Bed: 1623'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: I-459
OPERATOR: International Minerals & Chemical Corp.
PERMIT NO.: Potassium Prospecting Permit NM-0384584

LOCATION: 2500' from North Line and 2000' from East Line of Section 3, NE1/4 Section 3, Township 23 South, Range 31 East. NMPM

ELEVATION: 3385'
TOTAL DEPTH: 1855'
TYPE OF WELL: Potash Core Test
DRILLER: Boyles Bros. Drilling Company

DRILLING RECORD: **Date Started:** 08/11/76 **Date Completed:** 08/24/76
Rotary Drill
6-1/4" Rockbit: 0-900'
3-7/8" Rockbit: 900-1330'
3-7/8" Corebit: 1330-1855'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: From: 1855'
To: 0'
Int: 1885'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 580'
Top of Salt: 940'
Top of USGS 124 Bed: 1739'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: NFU-1
OPERATOR: Farmers Educational and Cooperative Union of America
PERMIT NO.: Potassium Prospecting Permit NM-065503

LOCATION: 100' from North Line and 100' from West Line of Section 9, NW1/4 Section 9, Township 22 South, Range 31 East. NMPM

ELEVATION: 3422'
TOTAL DEPTH: 1747'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 12/19/50 **Date Completed:** 01/21/51
Rotary Drill
6-1/4" Rockbit: 0-944'

CASING RECORD: 4" Casing: 940'
Recovered: 675'

PLUGGING SCHEDULE: 4 sacks cement at 1640'
7 sacks cement at 955'
7 sacks cement at 840'
8 sacks cement at 740'

Could not pull 4" casing, but broke circulation around it before pumping in 7 sacks at 955'. Shot casing at 900', 700', and 675'. Recovered 675' of 940'. Filled hole with mud and placed 4" pipe marker.

STRATIGRAPHIC SUMMARY: Rustler Formation: 635'
Top of Salt: 935'
Base of USGS 124 Bed: 1641'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-70
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit LC-065506

LOCATION: 177' from South Line and 177' from West Line of Section 7, NE1/4 Section 7, Township 22 South, Range 31 East. NMPM

ELEVATION: 3388'
TOTAL DEPTH: 1603'
TYPE OF WELL: Potash Core Test
DRILLER: Joy Mfg. Company, Drilling Division

DRILLING RECORD: **Date Started:** 09/26/56 **Date Completed:** 10/09/56
Rotary Drill
6-1/4" Rockbit: 0-902'
Corebit: 902-1603'

CASING RECORD: 4-1/2" Casing: 902'
Recovered: 902'

PLUGGING SCHEDULE:

From: 1603'
To: 1370'
Int: 233'
Material: Brine & Salt

From: 1370'
To: 902'
Int: 468'
Material: Cement

From: 902'
To: 10'
Int: 892'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 541'
Top of Salt: 898'
USGS 124 Bed: 1515'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-82
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-057290

LOCATION: 154' from South Line and 37' from West Line of Section 8, Township 22 South, Range 31 East. NMPM

ELEVATION: 3382'
TOTAL DEPTH: 1684'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 09/21/61 **Date Completed:** 10/03/61
6-1/4" Rockbit: 0-922'
Corebit: 922-1684'

CASING RECORD: 5-1/2" Casing: 922'
Recovered: 922'

PLUGGING SCHEDULE:

From: 1684'
To: 922'
Int: 762'
Material: Cement

From: 922'
To: 710'
Int: 212'
Material: Brine & Salt

From: 710'
To: 510'
Int: 200'
Material: Cement

From: 510'
To: 10'
Int: 500'
Material: Mud

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 538'
Top of Salt: 910'
USGS 124 Bed: 1593'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-91
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-075014

LOCATION: 200' from South Line and 200' from West Line of Section 10, SW1/4, Township 22 South, Range 31 East. NMPM

ELEVATION: 3460'
TOTAL DEPTH: 1788'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/07/62 **Date Completed:** 04/17/62
Rotary Drill
Rockbit: 0-1070'
Corebit: 1070-1788'

CASING RECORD: 4-1/4" Casing: 1070'
Recovered: 1070'

PLUGGING SCHEDULE:

From: 1788'
To: 1060'
Int: 728'
Material: Cement

From: 1060'
To: 840'
Int: 220'
Material: Cuttings & Brine

From: 840'
To: 800'
Int: 40'
Material: Cement

From: 800'
To: 10'
Int: 790'
Material: Cuttings & Brine

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: 630'
Top of Salt: 1070'
Base of USGS 124 Bed: Unknown

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: FC-92
OPERATOR: Farm Chemical Resources Development Corporation
PERMIT NO.: Potassium Prospecting Permit NM-094314

LOCATION: 200' from South Line and 200' from East Line of Section 8, SE1/4, Township 22 South, Range 31 East. NMPM

ELEVATION: 3420'
TOTAL DEPTH: 1818'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 04/21/62 **Date Completed:** 05/03/62
Rockbit: 0-1058'
Corebit: 1058-1818'

CASING RECORD: 4-1/2" Casing: 1058'
Recovered: 1058'

PLUGGING SCHEDULE:

From: 1818'
To: 945'
Int: 873'
Material: Cement

From: 945'
To: 850'
Int: 95'
Material: Cuttings & Brine

From: 850'
To: 810'
Int: 40'
Material: Cement

From: 810'
To: 10'
Int: 800'
Material: Cuttings & Brine

From: 10'
To: 0'
Int: 10'
Material: Cement

STRATIGRAPHIC SUMMARY: Rustler Formation: Unknown
Top of Salt: 950'
Base of USGS 124 Bed: Unknown

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: **D-104**
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit PPP-058761

LOCATION: 2585' from North Line and 1394' from East Line of Section 24, NE1/4 Section 24, Township 22 South, Range 30 East. NMPM

ELEVATION: 3388'
TOTAL DEPTH: 1597'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 09/25/52 **Date Completed:** 10/07/52
Rotary Drill
6-1/4" Rockbit: 0-759'
Corebit: 759-1597'
Lost Circulation: 730-747'

CASING RECORD: 4" Casing: Unknown
Recovered: All

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 62 sacks mixed with brine and 3% CaCl^2 at bottom of hole.
2) 30 sacks mixed with fresh water bottomed at 660'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 520'
Top of Salt: 759'
Top of USGS 124 Bed: 1504'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-120
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit PPP-058761

LOCATION: 1562' South and 1565' East of NW Corner Section 13, NW1/4 Section 13, Township 22 South, Range 30 East. NMPM

ELEVATION: 3338'
TOTAL DEPTH: 1500'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 02/14/53 **Date Completed:** 02/27/53
Rotary Drill
6-1/4" Rockbit: 0-704'
3-13/16" Corebit: 704-1500'

CASING RECORD: 4" Casing: 704'
Recovered: 704'

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 62 sacks of cement mixed with brine and 3% CaCl^2 and brine at bottom of hole.
2) 30 sacks of cement mixed with fresh water bottomed at 590'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 330'
Top of Salt: 684'
Top of USGS 124 Bed: 1407'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-123
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit LC-066112

LOCATION: 2614' North and 277' West of Southeast Corner of Section 34, NE1/4 Section 34, Township 22 South, Range 31 East. NMPM

ELEVATION: 3432'
TOTAL DEPTH: 1880'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 07/19/53 **Date Completed:** 08/07/53
Rotary Drill
6-1/4" Rockbit: 0-934'
Corebit: 934-1880'

CASING RECORD: 4" Casing: 934'
Recovered: 692'

PLUGGING SCHEDULE: Shot casing at 910' and 850'. Pulled 692' leaving 242' in hole. The following cement plugs were run:
1) 73 sacks of cement mixed with 3% CaCl^2 and brine at bottom of hole.
2) 45 sacks of cement mixed with fresh water bottomed at 880'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 670'
Top of Salt: 988'
Top of USGS 124 Bed: 1779'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-160
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit M-2618

LOCATION: 2464' from South Line and 1117' from West Line of Section 36, SW1/4 Section 36, Township 22 South, Range 30 East. NMPM

ELEVATION: 3305'
TOTAL DEPTH: 1354'
TYPE OF WELL: Potash Core Test
DRILLER: Weaver Drilling Company

DRILLING RECORD: **Date Started:** 07/21/54 **Date Completed:** 07/31/54
Rotary Drill
6-1/4" Rockbit: 0-596'
Corebit: 596-1354'
Encountering an air blow at 860' causing seat to leak.

CASING RECORD: 4" Casing: 596'
Recovered: 596'

PLUGGING SCHEDULE: All casing was pulled and the following plugs run:
1) 58 sacks of cement mixed with brine and 3% CaCl^2 and brine at bottom of hole.
2) 37 sacks of cement mixed with fresh water bottomed at 445'.

The remainder of the hole was filled with cuttings, a four-foot marker post set, and the hole abandoned.

STRATIGRAPHIC SUMMARY: Rustler Formation: 240'
Top of Salt: 543'
Top of USGS 124 Bed: 1301'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: **D-207**
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit NM-08285

LOCATION: 1480' North and 1330' East of Southwest Corner of Section 19, SW1/4 Section 19 Township 22 South, Range 31 East. NMPM

ELEVATION: 3406'
TOTAL DEPTH: 1613'
TYPE OF WELL: Potash Core Test
DRILLER: Joy Drilling Company

DRILLING RECORD: **Date Started:** 06/16/58 **Date Completed:** 07/03/58
Rotary Drill
6-1/4" Rockbit: 0-811'
3-13/16" Corebit: 811-1613'

CASING RECORD: 4" Casing: 811'
Recovered: 811'

PLUGGING SCHEDULE: All casing was pulled and the following cement plugs were run:
1) 66 sacks of cement mixed with 3% CaCl^2 and brine at bottom of hole.
2) 25 sacks of cement mixed with fresh water bottomed at 560'.

The remainder of the hole was filled with cuttings and soil, a four-foot marker post set, and the location left in good order.

STRATIGRAPHIC SUMMARY: Rustler Formation: 330'
Top of Salt: 811'
Top of USGS 124 Bed: 1519'

COMMERCIALLY DRILLED POTASH BOREHOLE DATA BASE

BOREHOLE: D-235
OPERATOR: Duval Sulphur & Potash Company
PERMIT NO.: Potassium Prospecting Permit LC-062188

LOCATION: 2878' from South Line and 789' from West Line of Section 25, NW1/4 Section 25, Township 22 South, Range 30 East. NMPM

ELEVATION: 3336'
TOTAL DEPTH: 1506'
TYPE OF WELL: Potash Core Test
DRILLER: Pennsylvania Drilling Company

DRILLING RECORD: **Date Started:** 10/11/77 **Date Completed:** 11/03/77
Rotary Drill
6-1/4" Rockbit: 0-689'
3-7/8" Corebit: 689-1506'
Encountering an air blow at 860'

CASING RECORD: 4" Casing: 689'
Recovered: 400'

PLUGGING SCHEDULE: 400' of 4" casing was pulled. Pennsylvania Drilling Company then cemented the hole with 110 sacks of neat cement making a continuous plug from T.D. to surface. A four-foot marker post was then set and drill location was left in good order.

STRATIGRAPHIC SUMMARY: Rustler Formation: Unknown
Top of Salt: 670'
Top of USGS 124 Bed: 1390'

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-1
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499833.57, E666341.70

ELEVATION: 3412.48'
TOTAL DEPTH: 58.2'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/29/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/27/78 **Date Completed:** 12/29/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-1	Silty Sand, Sand	0-9.5
	Caliche	9.5-14.5
	Gatuna	14.5-38
	(Santa Rosa) Sandstone	38-58.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-1A
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499833.20, E666356.32

ELEVATION: 3412.48'
TOTAL DEPTH: 12.9'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/29/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/29/78 **Date Completed:** 12/29/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D, 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-1A	Sand	0-11.2
	Caliche	11.2-12.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-2**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499835.35, E666841.60
ELEVATION:	3411.62'
TOTAL DEPTH:	33.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/22/78 **Date Completed:** 11/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D, 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-2	Sand	0-6.5
	Caliche	6.5-15.5
	Gatuna	15.5-23
	Siltstone	23-30.6
	Intercalated Sandstone and Soil	30.6-33.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-3
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499837.13, E667341.49

ELEVATION: 3415.33'
TOTAL DEPTH: 29'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/18/78 **Date Completed:** 12/18/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed wtih 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-3	Sand	0-7.8
	Caliche	7.8-14
	Gatuna	14-24.2
	Siltstone	24.2-25
	Sandstone	25-28
	Siltstone	28-29

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-4
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499838.91, E667841.39

ELEVATION: 3417.08'
TOTAL DEPTH: 38.8'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/18/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/17/78 **Date Completed:** 12/18/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and wither air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-4	Silty Sand	0-8.5
	Caliche	8.5-19
	Gatuna	19-37
	Claystone	37-38.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-4A
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499837.97, E667829.91

ELEVATION: 3417.08'
TOTAL DEPTH: 13.6'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/19/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/19/78 **Date Completed:** 12/19/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds of downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-4A	Silty Sand	0-11.5
	Caliche	11.5-13.6

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-5**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499840.69, E668341.29
ELEVATION:	3417.43'
TOTAL DEPTH:	32.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-5	Silty Sand	0-8.2
	Caliche	8.2-17
	Gatuna	17-22.4
	Sandsone	22.4-26.9
	Intercalated Siltstone	26.9-32.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-6**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499842.47, E668841.15
ELEVATION:	3422.01'
TOTAL DEPTH:	26.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/17/78 **Date Completed:** 12/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-6	Silty Sand	0-3.5
	Caliche	3.5-10.1
	Gatuna	10.1-26.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-7**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499333.68, E666343.48
ELEVATION:	3404.19'
TOTAL DEPTH:	34.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/21/78 **Date Completed:** 11/21/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-7	Sand	0-5.5
	Caliche	5.5-20
	Gatuna	20-25
	Sandstone	25-27.5
	Santa Rosa	27.5-34.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-8
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499335.46, E666843.36

ELEVATION: 3408.55'
TOTAL DEPTH: 100'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/03/79 **Date Completed:** 01/03/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-8	Sand	0-7
	Caliche	7-12
	Gatuna	12-35.7
	Santa Rosa	35.7-40
	Dewey Lake	40-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-9
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499337.27, E667343.26

ELEVATION: 3410.47'
TOTAL DEPTH: 38.3
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/19/78 **Date Completed:** 12/19/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test corings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-9	Sand	0-8.1
	Caliche	8.1-18
	Gatuna	18-32.1
	Siltstone	32.1-36
	Sandstone	36-38.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-10
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499339.05, E6678434.11

ELEVATION: 3413'
TOTAL DEPTH: 32'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/19/78 **Date Completed:** 12/19/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-10	Sand	0-10.2
	Caliche	10.2-17
	Gatuna	17-26.5
	Siltstone	26.3-27
	Sandstone	27-32

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-11
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499340.83, E668343.05

ELEVATION: 3414.30'
TOTAL DEPTH: 30'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/15/78 **Date Completed:** 12/15/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-11	Sand	1.2-4.1
	Caliche	4.1-13.5
	Gatuna	13.5-30

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-12**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499342.61, E668842.93
ELEVATION:	3421.77'
TOTAL DEPTH:	41.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/01/78 **Date Completed:** 12/01/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-12	Sand	0-6
	Caliche	6-13
	Gatuna	13-20
	Sandstone	20-26
	Claystone	26-27
	Sandstone	27-31.5
	Claystone	31.5-33.5
	Sandstone	33.5-38.5
	Intercalated Sandstone	38.5-41.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-13
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498833.82, E666345.25

ELEVATION: 3403.91'
TOTAL DEPTH: 28.3'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/12/78 **Date Completed:** 12/16/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-13	Sand	0-7
	Caliche	7-12.5
	Gatuna	12.5-26
	Claystone	26-28.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-14**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498835.60, E666845.14
ELEVATION:	3406.57'
TOTAL DEPTH:	24.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/13/78 **Date Completed:** 12/13/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-14	Sand	0-4.8
	Caliche	4.8-9.9
	Gatuna	9.9-14
	Claystone	14-24.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-15**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498837.40, E667345.06
ELEVATION:	3408.64'
TOTAL DEPTH:	56.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/16/78 **Date Completed:** 11/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-15	Sand	0-9
	Caliche	9-13
	Silty Sand	13-26
	Gatuna	26-51.5
	Santa Rosa	51.5-55
	Shale	54.5-56.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-16
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498839.19, E667844.94

ELEVATION: 3411.21'
TOTAL DEPTH: 31'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/15/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/14/78 **Date Completed:** 12/15/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-16	Sand	0-7
	Caliche	7-15
	Gatuna	15-31

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-17
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498840.97, E668343.86

ELEVATION: 3413.26'
TOTAL DEPTH: 25.8'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/13/78 **Date Completed:** 12/13/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-17	Silty Sand	0-5.1
	Caliche	5.1-10.5
	Gatuna	10.5-25.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-18**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498842.75, E668844.75

ELEVATION: 3419.32'
TOTAL DEPTH: 33.3'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/15/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/14/78 **Date Completed:** 12/15/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-18	Sand	0-7.1
	Caliche	7.1-15
	Gatuna	15-33.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-19**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498333.94, E666347.03

ELEVATION: 3399.84'
TOTAL DEPTH: 38.8'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 11/30/78 **Date Completed:** 11/30/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-19	Sand	0-8.5
	Caliche	8.5-18.5
	Gatuna	18.5-21.1
	Sandstone	21.1-38.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-20
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498335.72, E666846.91

ELEVATION: 3403.53'
TOTAL DEPTH: 14'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/12/78 **Date Completed:** 12/16/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-20	Sand	0-10
	Caliche	10-14

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-20A
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498341.34, E666847.10

ELEVATION: 3403.53'
TOTAL DEPTH: 34.2'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 12/16/78
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/12/78 **Date Completed:** 12/16/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-20A	Sand	0-13.9
	Caliche	13.9-19
	Gatuna	19-34.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-21**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498337.50, E667346.75
ELEVATION:	3404.55'
TOTAL DEPTH:	40.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 11/17/78 **Date Completed:** 11/17/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-21	Sand	0-9.5
	Caliche	9.5-20
	Gatuna	20-32.5
	Sandstone	32.5-40.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-22
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498339.28, E667846.73

ELEVATION: 3406.85'
TOTAL DEPTH: 27.8'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/11/78 **Date Completed:** 12/11/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-22	Sand	0-7.5
	Caliche	7.5-13
	Gatuna	13-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-23**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498341.06, E668346.63
ELEVATION:	3412.07'
TOTAL DEPTH:	40.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/06/78 **Date Completed:** 12/06/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-23	Sand	0-6
	Caliche	6-14.3
	Gatuna	14.3-40.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-24**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498342.84, E668846.53
ELEVATION:	3417.87'
TOTAL DEPTH:	29.3'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/07/78 **Date Completed:** 12/07/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-24	Sand	0-5.5
	Caliche	5.5-12
	Gatuna	12-29.3

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-25
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499414.91, E666693.11

ELEVATION: 3408.19'
TOTAL DEPTH: 901.8'
TYPE OF WELL: Deep Exploratory Drilling
DRILLER: Gil's Drilling Co.

DRILLING RECORD: **Date Started:** 12/01/78 **Date Completed:** 01/18/79

CASING RECORD: Drilling Equipment:
GD-2000 drill.

PLUGGING SCHEDULE:

From: 909'
To: 750.4'
Interval: 158.6'
Material: Salt Grout

From: 750.4'
To: 466'
Interval: 284.4'
Material: Freshwater Grout

From: 466'
To: 20'
Interval: 446'
Material: Sand

From: 20'
To: Surface
Interval: 20'
Material: Cement

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-25	Sand	0-10
	Caliche	10-14
	Gatuna	14-34.7
	Santa Rosa	34.7-44.8
	Dewey Lake	44.8-533
	Rustler Formation	533-842.9
	Magenta Member	592.7-617
	Culebra Member	704.1-728
	Salado Formation	842.9-901.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-26**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499600.58, E666892.43
ELEVATION:	3410.19'
TOTAL DEPTH:	27.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/03/79 **Date Completed:** 01/03/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-26	Sand	0-5
	Caliche	5-11
	Gatuna	11-23
	Siltstone	23-27.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-27**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498982.08, E665854.70
ELEVATION:	3400.20'
TOTAL DEPTH:	25.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/11/79 **Date Completed:** 01/11/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-27	Sand	0-4
	Caliche	4-11
	Gatuna	11-22
	Sandstone	22-22.5
	Claystone	22.5-23
	Sandstone	23-24
	Intercalated Sandstone	24-25.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-28**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499295.02, E666718.53
ELEVATION:	3408.17'
TOTAL DEPTH:	27'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/04/79 **Date Completed:** 01/04/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-28	Sand	0-6
	Caliche	6-12
	Gatuna	12-21
	Sandstone	21-27

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-29**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499397.21, E667253.07
ELEVATION:	3410.87'
TOTAL DEPTH:	28.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/30/78 **Date Completed:** 12/30/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-29	Sand	0-13
	Gatuna	13-28.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-30**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499185.81, E666933.86
ELEVATION:	3408.75'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/28/78 **Date Completed:** 12/28/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-30	Sand	0-7.5
	Caliche	7.5-11.5
	Gatuna	11.5-17.6
	Sandstone	17.6-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-31**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499206.60, E667143.76
ELEVATION:	3410.27
TOTAL DEPTH:	30.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 12/29/78 **Date Completed:** 12/29/78
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-31	Sand	0-7.8
	Caliche	7.8-13.4
	Gatuna	13.4-30.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-32**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499187.96, E667523.76
ELEVATION:	3410.89'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/07/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-32	Sand	0-12.5
	Caliche	12.5-19.5
	Gatuna	19.5-26.5
	Siltstone & Claystone	26.5-43
	Santa Rosa	43-53
	Dewey Lake	53-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-33
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498874.29, E666470.03

ELEVATION: 3404.05'
TOTAL DEPTH: 30.7'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 12/29/78 **Date Completed:** 12/29/78

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide curring faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-33	Sand	0-6.7
	Caliche	6.7-15.8
	Gatuna	15.8-19
	Sandstone	19-24
	Intercalated Siltstone & Mudstone	24-29.8
	Sandstone	29.8-30.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-34
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498205.49, E666762.36

ELEVATION: 3401.97'
TOTAL DEPTH: 100'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/09/79 **Date Completed:** 01/09/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-34	Sand	0-9.1
	Caliche	9.1-14.8
	Gatuna	14.8-40
	Siltstone & Claystone	40-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-35
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498326.97, E667196.82

ELEVATION: 3402.55'
TOTAL DEPTH: 32'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/05/79 **Date Completed:** 01/05/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-35	Sand	0-7
	Caliche	7-12
	Gatuna	12-23
	Sandstone	23-32

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-36**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499293.25, E669018.07
ELEVATION:	3422.03'
TOTAL DEPTH:	27.8'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/07/79 **Date Completed:** 01/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-36	Sand	0-5.9
	Caliche	5.9-13.2
	Gatuna	13.2-25
	Siltstone	25-27.8

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-37**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499297.91, E670352.77
ELEVATION:	3438.91'
TOTAL DEPTH:	27.5'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/09/79 **Date Completed:** 01/09/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-37	Sand	0-5.5
	Caliche	5.5-12.5
	Gatuna	12.5-20
	Siltstone	20-20.3
	Sandstone	20.3-27.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-37A**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499260.53, E669370.39
ELEVATION:	3426.68'
TOTAL DEPTH:	22.4'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-37A	Sand	0-5.5
	Caliche	5.5-13.5
	Gatuna	13.5-22.4

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-38
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499155.65, E669683.42

ELEVATION: 3429.88'
TOTAL DEPTH: 50'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 1/23/79
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/11/79 **Date Completed:** 01/23/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-38	Sand	0-5.5
	Caliche	5.5-14
	Gatuna	14-20.5
	Sandstone	20.5-40.2
	Santa Rosa	40.2-43.7
	Dewey Lake	43.7-50

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-39
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499018.31, E669019.04

ELEVATION: 3422.08'
TOTAL DEPTH: 27.6'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/06/79 **Date Completed:** 01/07/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-39	Sand	0-7
	Caliche	7-13
	Gatuna	13-27.6

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-40**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499023.04, E670353.77
ELEVATION:	3438.48'
TOTAL DEPTH:	27.9'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/10/79 **Date Completed:** 01/10/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-40	Sand	0-7.6
	Caliche	7.6-13
	Gatuna	13-19
	Sandstone	19-27.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-41**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.51, E666858.36
ELEVATION:	3407.86'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/05/79 **Date Completed:** 01/05/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-41	Sand	0-6
	Caliche	6-15
	Gatuna	15-42
	Santa Rosa	42-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-42**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499335.57, E666873.35
ELEVATION:	3408.99'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-42	Sand	0-6
	Caliche	6-14
	Gatuna	14-42
	Santa Rosa	42-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-43**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499202.96, E667523.70
ELEVATION:	3410.75'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/06/79 **Date Completed:** 01/06/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-43	Sand	0-12
	Caliche	12-20
	Gatuna	20-43
	Santa Rosa	43-53
	Dewey Lake	53-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-44**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N499172.96, E667523.82
ELEVATION:	3411.48'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-44	Sand	0-16
	Caliche	16-21
	Gatuna	21-38
	Santa Rosa	38-52
	Dewey Lake	52-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-45
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N498205.44, E666747.36

ELEVATION: 3401.51'
TOTAL DEPTH: 100'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/10/79 **Date Completed:** 01/17/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-45	Sand	0-7.5
	Caliche	7.5-15.3
	Gatuna	15.3-31.3
	Dewey Lake	31.3-44.2
	Sandstone	44.2-44.7
	Siltstone	44.7-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-46**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498205.54, E666777.36
ELEVATION:	3401.98'
TOTAL DEPTH:	100'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/08/79 **Date Completed:** 01/08/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-46	Sand	0-8
	Caliche	8-13
	Gatuna	13-41
	Santa Rosa	41-48
	Dewey Lake	48-100

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-47
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499206.77, E667193.82

ELEVATION: 3409.49'
TOTAL DEPTH: 17.5'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/25/79 **Date Completed:** 01/25/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-47	Sand	0-8.9
	Caliche	8.9-15
	Gatuna	15-17.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-48**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498839.26, E667854.93
ELEVATION:	3412.12'
TOTAL DEPTH:	15.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/24/79 **Date Completed:** 01/24/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-48	Sand	0-9
	Caliche	9-15.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-49**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498937.22, E667294.71
ELEVATION:	3409.07'
TOTAL DEPTH:	19.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/24/79 **Date Completed:** 01/24/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-49	Sand	0-8.5
	Caliche	8.5-10.5
	Silty Sand	10.5-15
	Gatuna	15-19.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-50**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498487.09, E667236.23
ELEVATION:	3405.65'
TOTAL DEPTH:	23.7'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/26/79 **Date Completed:** 01/26/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-50	Sand	0-9.5
	Caliche	9.5-15
	Gatuna	15-23.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-51**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N498337.48, E667341.75
ELEVATION:	3404.74'
TOTAL DEPTH:	15.2'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/25/79 **Date Completed:** 01/25/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-51	Sand	0-7.5
	Caliche	7.5-14.5
	Gatuna	14.5-15.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-52**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	N496981.21, E665461.91
ELEVATION:	3385.48'
TOTAL DEPTH:	30.0'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 01/26/79 **Date Completed:** 01/26/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Grouted with cement.
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-52	Sand	0-3.1
	Caliche	3.1-8.5
	Gatuna	8.5-19
	Dewey Lake	19-30

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-53
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N496651.28, E665463.05

ELEVATION: 3386.65'
TOTAL DEPTH: 30.2'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 01/30/79 **Date Completed:** 01/30/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Grouted with cement.

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-53	Sand	0-8.5
	Caliche	8.5-15.7
	Gatuna	15.7-23.7
	Dewey Lake	23.7-30.2

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-54
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: N499386.52, E666651.92

ELEVATION: 3408.60'
TOTAL DEPTH: 210'
TYPE OF WELL: Shallow Exploratory Drilling Converted to Observation Well 02/14/79
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/13/79 **Date Completed:** 02/14/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE:

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-54	Sand	0-6
	Caliche	6-12
	Gatuna	12-25
	Santa Rosa	25-30
	Dewey Lake	30-210

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-301
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 39.7'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/08/79 **Date Completed:** 02/08/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-301	Sand	0-1
	Caliche	1-24
	Dewey Lake	24-39.7

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-302
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 39'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/07/79 **Date Completed:** 02/07/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-302	Sand	0-10.4
	Caliche	10.4-23
	Dewey Lake	23-39.0

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-303**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	39.1'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/07/79 **Date Completed:** 02/07/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-303	Sand	0-15.5
	Caliche	15.5-18
	Dewey Lake	18-39.1

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-304
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 41.5'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/06/79 **Date Completed:** 02/06/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-304	Sand	0-20.6
	Caliche	20.6-33
	Sand	33-41.5

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-305
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: North Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 41'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/06/79 **Date Completed:** 02/06/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-305	Sand	0-14.5
	Caliche	14.5-19.5
	Sand	19.5-25.5
	Caliche	25.5-33
	Sand	33-41

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE:	**B-306**
OPERATOR:	Sergent, Hauskins, & Beckwith
PERMIT NO.:	Unknown
LOCATION:	North Access Road
ELEVATION:	Not Recorded
TOTAL DEPTH:	38'
TYPE OF WELL:	Shallow Exploratory Drilling
DRILLER:	Sergent, Hauskins & Beckwith
DRILLING RECORD:	**Date Started:** 02/02/79 **Date Completed:** 02/02/79
CASING RECORD:	Drilling Equipment: Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.
PLUGGING SCHEDULE:	Backfilled with native drilled material
STRATIGRAPHIC SUMMARY:	Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-306	Sand	0-7.3
	Caliche	7.3-18
	Santa Rosa	18-38

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: B-307
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: Railroad

ELEVATION: Not Recorded
TOTAL DEPTH: 40'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/01/79 **Date Completed:** 02/01/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-307	Caliche	0-5.6
	Sand	5.6-11.1
	Gatuna	11.1-17.1
	Dewey Lake	17.1-40

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-308**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: Railroad

ELEVATION: Not Recorded
TOTAL DEPTH: 39.9'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/01/79 **Date Completed:** 02/01/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-308	Caliche	0-10.5
	Gatuna	10.5-19.5
	Dewey Lake	19.5-39.9

SUBSURFACE EXPLORATION BOREHOLE DATA BASE

BOREHOLE: **B-309**
OPERATOR: Sergent, Hauskins, & Beckwith
PERMIT NO.: Unknown

LOCATION: South Access Road

ELEVATION: Not Recorded
TOTAL DEPTH: 39.4'
TYPE OF WELL: Shallow Exploratory Drilling
DRILLER: Sergent, Hauskins & Beckwith

DRILLING RECORD: **Date Started:** 02/02/79 **Date Completed:** 02/02/79

CASING RECORD: Drilling Equipment:
Truck-mounted CME-55 drill rigs powered with 6 cylinder Ford industrial engines were used in advancing test borings. The 6 cylinder engines are capable of delivering about 6,500 foot/pounds torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock was performed with 6 1/2 inch O.D., 3 1/4 inch I.D. hollow stem auger. Carbide insert teeth were used on the auger bits. Core drilling in bedrock was performed using NX size core bits with either diamond or carbide cutting faces and either air or water for drilling fluid.

PLUGGING SCHEDULE: Backfilled with native drilled material

STRATIGRAPHIC SUMMARY: Attached

STRATIGRAPHIC SUMMARY

BOREHOLE	ROCK UNIT	DEPTH INTERVAL IN FEET
B-309	Sand	0-5.6
	Caliche	5.6-14
	Gatuna	14-19.8
	Santa Rosa	19.8-22
	Dewey Lake	22-39.4

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USGS OFR 81-488, Geologic Data for Borehole ERDA-9, Eddy County, New Mexico

APPENDIX D7
PROBABLE MAXIMUM PRECIPITATION

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CALC. NO. CS24 - C-015
DESIGN CLASS III - B
SHEET NO. 1 OF 12

CALCULATION SHEET

NUCLEAR FUEL OPERATIONS

BECHTEL JOB 12484
DEPARTMENT OF ENERGY
WASTE ISOLATION PILOT PLANT

CCP-5

STATEMENT OF PROBLEM: PROBABLE MAXIMUM PRECIPITATION (PMP) - UPLAND DESIGN BERMS TO DIVERT PMP RUNOFF AWAY FROM PLANT SITE

- PERIPHERAL PMP BERMS
- SALT AREA PMP BERM

SAR CHECKED YES SAR CHANGE REQ'D. YES SAR CHANGE REQUEST MADE YES

SOURCE OF DATA:
1. TOPOGRAPHIC MAPS: USGS 15' QUADRANGLE SHEETS
   AERIAL SURVEY, BOHANNAN-HUSTON, 1978
2. HYDROMET. REPORT 51, U.S. NOAA NATIONAL WEATHER SERV., 1978
3.

SOURCE OF FORMULAS & REFERENCES:
1. DESIGN BASIS D-24-C-04 "PLANT SITE STORM DRAINAGE"
2. NATIONAL ENGG. HANDBOOK, SECT. 4, U.S. SOIL CONSERV. SERVICE
3. FINE'S HANDBOOK OF HYDRAULICS
4. FLUID MECH. & HYDRAULICS BY R. GILES
5. HYDRAULIC ENGG. CIRCULAR NO. 5 BY FED. HWY ADM.

TITLE OF COMPUTER PROGRAM(S) USED - NONE

COMPUTER PROGRAM(S) VERIFICATION - NONE

TYPE OF CALCULATION: PRELIM. ____ FINAL ✓ SUPERSEDES CALC. NO. ____

SUPERSEDED ____

REFERENCES	P & ID/DWG. NO./REV. NO.	ENTITLED
1.	24-C-053 / Rev. 2	Site Development - Overall Plan
2.	24-C-060 / Rev. 8	Rough Grading - Plan Sh. 1 of 2
3.	24-C-061 / Rev. 8	" " " 2 of 2
4.	24-C-075 / Rev. 2	Rough Grading - Plan & Sect. Sh. 1 of 2
5.	24-C-076 / Rev. 2	" " " " Sh 2 of 2

REV.	DESCRIPTION	BY	DATE	CHK'D	DATE	APPR'D	DATE
△							
△							
△	ISSUED FOR TITLE II	SLN	6/27/82	[illegible]	8/11/82	[illegible]	11/19/82

RECORD OF ISSUES

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	LS-24-C-015
SHEET NO.	23 OF 112
REV. NO.	0
CHECKED BY	[illegible] DATE 8/11/82

DESIGN ASSUMPTIONS

RUNOFF $Q_{PMP} = C \cdot I_{PMP} \cdot A$ RATIONAL METHOD

RUNOFF COEFFICIENT $C = 0.85$ FOR NAT. GROUND & UPLAND

$= 0.90$ FOR CALICHE AREA

RAINFALL INTENSITY I_{PMP} IN./HR

(SEE SH. 110)

DRAINAGE AREA A IN ACRES

TIME OF CONCENTRATION $T_c = \dfrac{L}{3600\,V}$ IN HRS

LENGTH OF DRAINAGE AREA L IN FT.

VELOCITY V IN FT/SEC

(SEE SH. 9 FOR NEARLY BARE & UNTILLED OVERLAND FLOW)

DITCHES

MANNING'S FORMULA $Q = \dfrac{1.486}{n} A R_h^{2/3} S^{1/2}$

$n = 0.03$ (UNLINED)

R_H HYDRAULIC RADIUS IN FT. $R_H = \dfrac{A}{P}$

A CROSS-SECTIONAL AREA IN SQ. FT.

P WETTED PERIMETER IN FT.

S SLOPE OF DITCH IN FT/FT

MAX. ALLOWABLE VELOCITY FOR PMP DITCHES 25 FT/SEC

CULVERTS

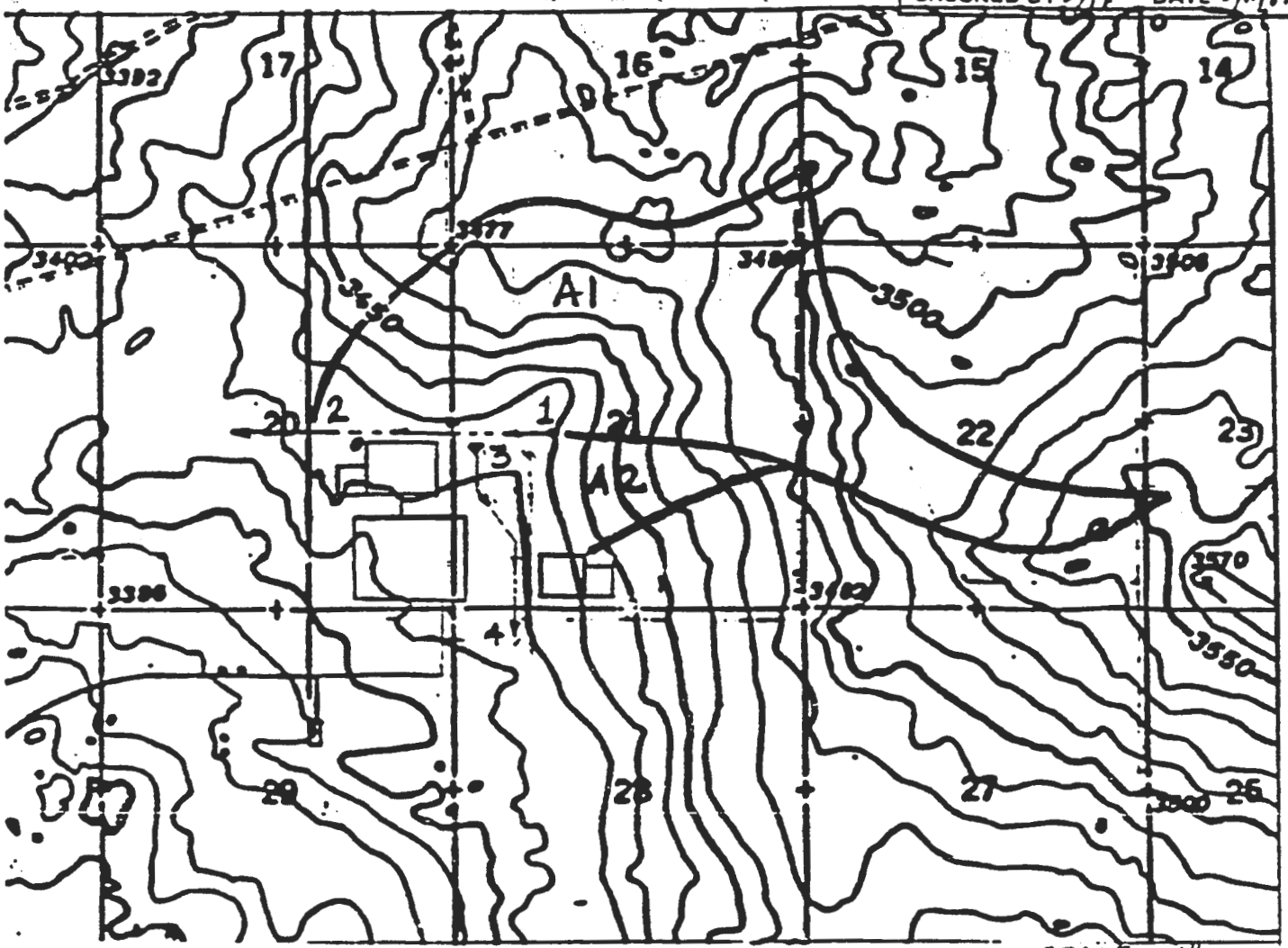
HYDRAULIC ENGG. CIRCULAR NO. 5.

BERMS PMP RUNOFF FROM UPLAND & SALT STORAGE SHALL BE DIVERTED BY INTERCEPT BERMS. NO PMP DITCH REQUIRED DUE TO ACCUMULATED SANDS WHICH ARE BLOWN BY WIND. BERMS SHALL BE STABILIZED WITH 6" OF CALICHE COVER

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO. 12484	
CALC. NO. 24-C-015	
SHEET NO. 3	OF 12
REV. NO. 0	
CHECKED BY	DATE 8/11/87



SCALE 1" = ½ MILE

AREAS	BERMS	SH. NO.
A1 = 600 AC.	1-2	4
A2 = 80 AC.	3-4	5

JOB NO.	12484
CALC. NO.	CS 24-C-015
SHEET NO.	4 OF 12
REV. NO.	0
CHECKED BY	AK DATE 8/11/82

BECHTEL

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

UPLAND NORTH OF PLANT SITE

BERM 1-2 ℄ BERM N 10,920

FLOW $Q = CIA$

$A = A_1 = 600$ ac.

$L = 14,300$ FT

$\Delta H = 3555 - 3430 = 125$ FT.

$S = 125/14,300 = 0.87\%$

$V = 0.96$ FPS

$T_c = 14300/3600 \times .96 = 4.14$ HRS

$I_{PMP} = 4.8$ IN/HR

$Q_{PMP} = 0.85 \times 4.8 \times 600 = 2448$ CFS ∴

START BERM @ E 9080 EL 3432.00

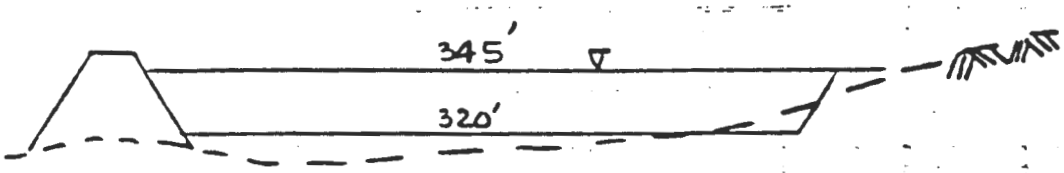
SLOPE OF BERM 0.00067

BERM @ E 6000 EL 3429.94. THEN DAYLIGHT

AVERAGE CROSS-SECTION AREA : $A = 1000$ FT^2

AVERAGE CHANNEL SLOPE $S = 0.00067$

ALLOW 1' FREEBOARD



AVERAGE DEPTH : 3'

HYDRAULIC RADIUS $R_H = \frac{A}{P} = \frac{1000}{320 + 2\sqrt{9^2 + 3^2}} = 2.95'$

$Q = \frac{1.486}{0.03} (2.95)^{2/3} \, 1000 \, (.00067)^{1/2}$

$Q = 2637$ CFS $> Q_{PMP} = 2448$ CFS OK

JOB NO.	12484
CALC. NO.	1324-C-015
SHEET NO.	5 OF 12
REV. NO.	0
CHECKED BY	AH DATE 8/11/82

BECHTEL

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

UPLAND EAST OF PLANT SITE

BERM 3-4

FLOW $Q = CIA$

$A = A2 = 80$ AC.

$L = 5600$ FT

$\Delta H = 3476 - 3410 = 66'$

$S = 1.17\%$

$V = 1.05$ FPS

$T_c = 5600 / 3600 \times 1.05 = 1.48$ HRS

$I_{PMP} = 8.4$ IN/HR

$Q_{PMP} = 0.85 \times 8.4 \times 80 = 572$ CFS ∴

START BERM @ EL. 3424.55.

SLOPE OF BERM 0.001 APPROX. DISTANCE 550'

@ 1ST BEND EL. 3424.00

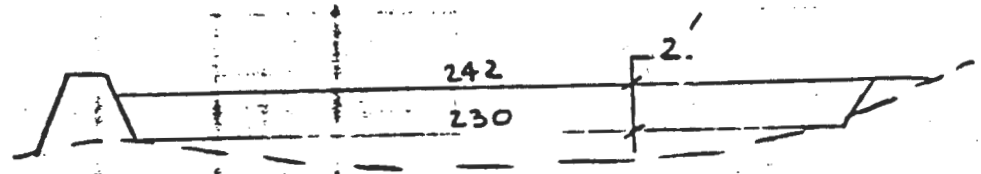
SLOPE 0.001 APPROX. DISTANCE 1000'

@ 2ND BEND EL. 3423.00

GB . SLOPE 0.0057 APPROX DISTANCE 700'

@ SALT HAUL RD EL. 3419.00

TYPICAL CROSS SECTION : 1' FREEBOARD



X-A = 472 SF

$R_h = 1.95$) $S_{avg.} = 0.0015$

$Q = \frac{1.486}{0.03} (1.95)^{2/3} (472) (.0015)^{1/2} = \underline{1410 \text{ CFS}} > 572 \text{ CFS}$

BECHTEL

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	CS24-C-015
SHEET NO.	6 OF 12
REV. NO.	0
CHECKED BY	[illegible] DATE 8/11/82

SALT STORAGE AREA PMP – BERM 5-6 SEE SH. 12

$Q = CIA$

$A = 1.4$ ac. (Nat. Gr.) + 9.65 ac. (Salt pile)

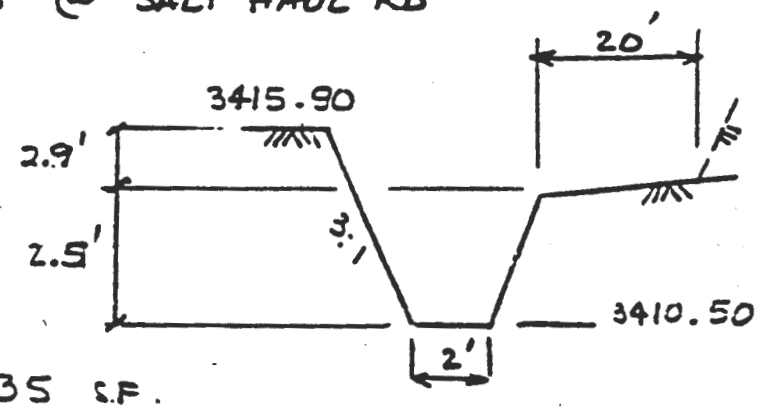
$S = 1\%$, $V = 1$ fps

$L = 640$

$t_c = \frac{640}{60 \times 1} = 10.7$ min. $I_{PMP} = 22.7$ in/hr

$Q = (.85 \times 1.4 + .90 \times 9.65)\ 22.7 = 224$ CFS

BERM 5-6 @ SALT HAUL RD



$A = 135$ S.F.

$P = 17.4 + 2' + 7.9 + 20 + 3 = 50.3'$

$R_h = 2.7'$

$Q_{CAP} = \frac{1.486}{0.03} (2.7)^{2/3}\ 135 \times (.004)^{1/2} = 817$ CFS

CONSIDER 1' FREEBOARD

$A = 80$ SF

$P = 14.2 + 2 + 7.9 + 20 + 2 = 46$

$R_h = 1.73$

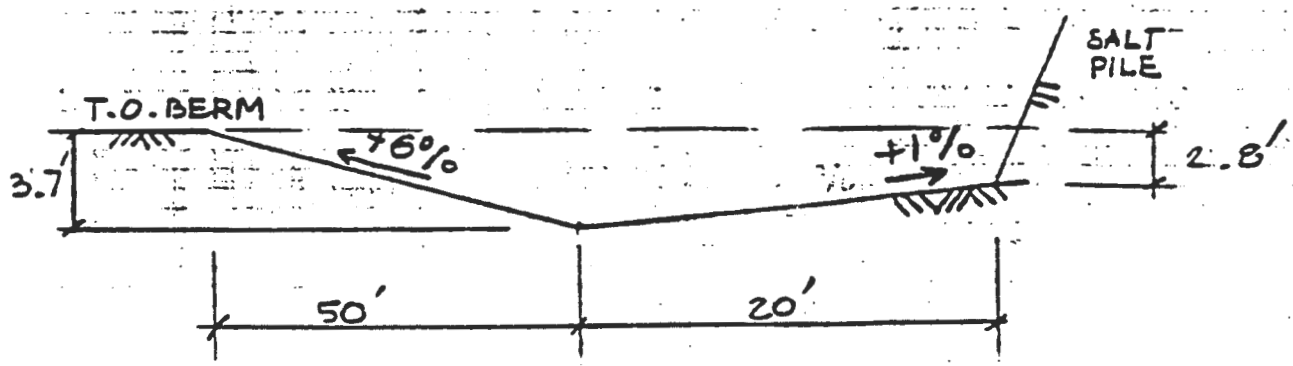
$Q_{CAP} = 361$ CFS OK

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	CS24-C-015
SHEET NO.	7 OF 12
REV. NO.	0
CHECKED BY	[illegible] DATE 8/11/82

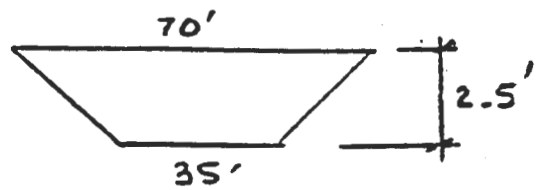
@ SALT HAUL RD, CHECK CAPACITY FOR PMP OVERFLOW



$$A = \frac{2.8+3}{2} \times 20 + \frac{3 \times 50}{2} = 133 \text{ S.F.}$$

$$Q_{WEIR} = 3.367\, b\, H^{3/2}$$ FOR TRAPEZOIDAL WEIR

EQUIVALENT TRAPEZOIDAL AREA



$b = 35$

$H = 2.5'$

$$Q_{WEIR\ CAPAC.} = 3.367\,(35)\,(2.5)^{3/2}$$

$$= 466 \text{ CFS} > 224 \text{ CFS} \quad \text{OK}$$

FOR ENTIRE SALT STORAGE PMP BERM 6-7 SEE SH. 12

$Q = CIA$

$A = 1.4\text{ ac (nat. gr)} + 19.3\text{ac (graded area)}$

$S = 1\%$

$$t_c = \frac{720}{60 \times 1} + \frac{1000}{60 \times 0.7} = 35.8 \text{ min}$$

$I_{PMP} = 12.4 \text{ in/hr}$

$$Q = (0.85 \times 1.4 + 0.9 \times 19.3)\,12.4 = 230 \text{ CFS}$$

SAME DESIGN AS BERM 5-6, NO FREEBOARD REQ'D.

NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	US24-C-015
SHEET NO.	8 OF 12
REV. NO.	0
CHECKED BY	HH DATE 8/11/82

EAST OF PLANT SITE ; PMP BERM 8-9 SEE SH. 12

- THERE ARE MINIMUM RUNOFF IN THIS AREA . A 2.5' HIGH BERM IS SUFFICIENT TO BLOCK ANY RUNOFF FROM EAST SIDE OF GRADING AREA .
- TOP OF SPOIL BANK SHALL BE SLOPED DOWN EASTWARD TO DIVERT RUNOFF ON THIS AREA
- LEAVE 10' STRIP BETWEEN EAST TOE OF 8-9 BERM AND TOE OF SPOIL BANK
- SOUTH PORTION OF BERM 8-9 TO BE REWORKED BY CCP-20, RAILROAD, AS FOLLOWS:

  a) SOUTH PORTION OF BERM 8-9 : TO - BE REMOVED TO MAKE WAY FOR THE R/R LINE WHICH RUNS INTO WASTE BLDG.

  b) PMP RUNOFF IN THIS AREA SHALL BE DIVERTED TO THE EAST END OF THE R/R TRACK

NUCLEAR FUEL
OPERATIONS
15-8

CALCULATION SHEET

JOB NO.	12484
CALC. NO.	CS 24-C-015
SHEET NO.	9 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/82

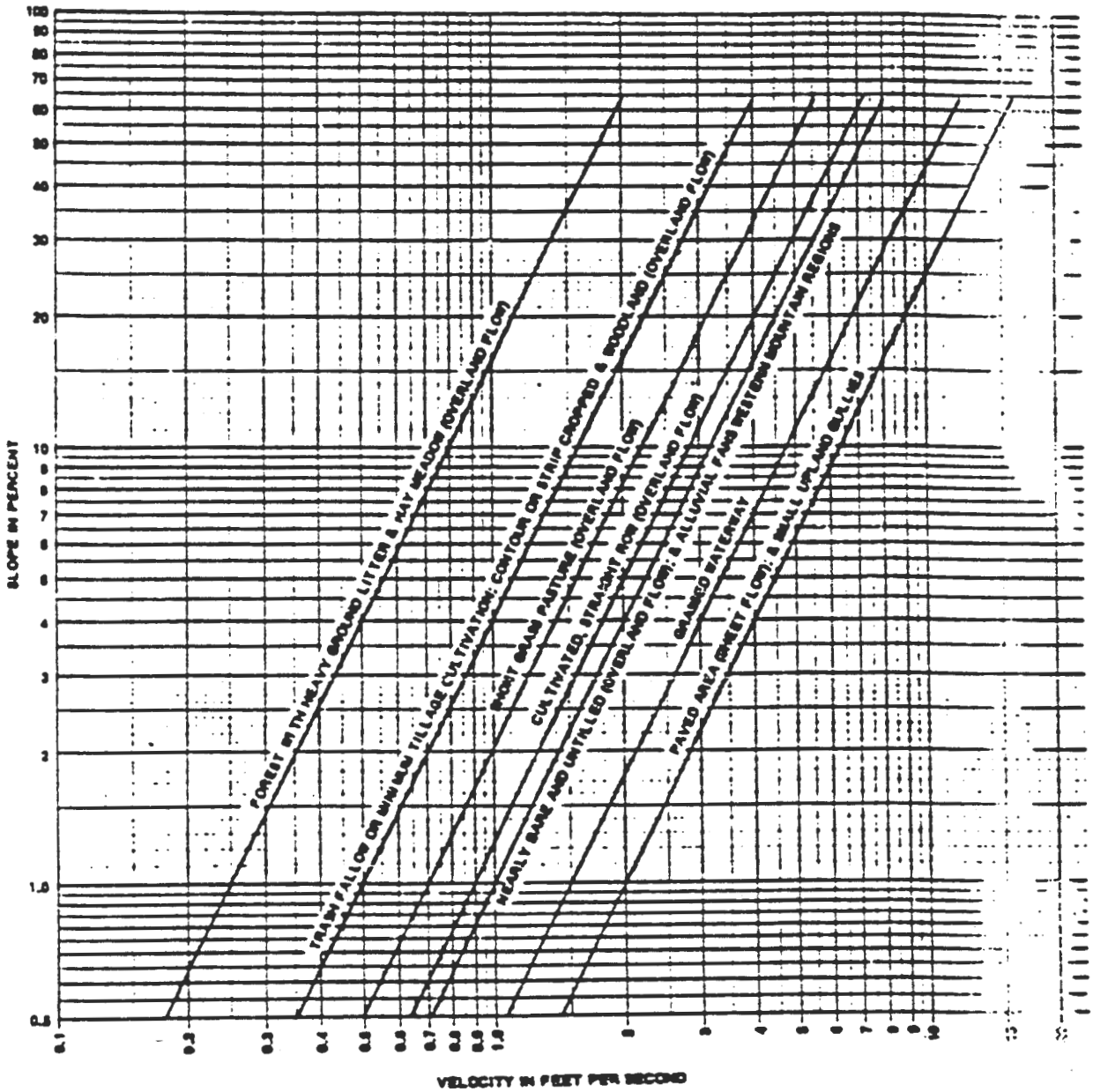


Figure 15.2.—Velocities for upland method of estimating T_c

BECHTEL

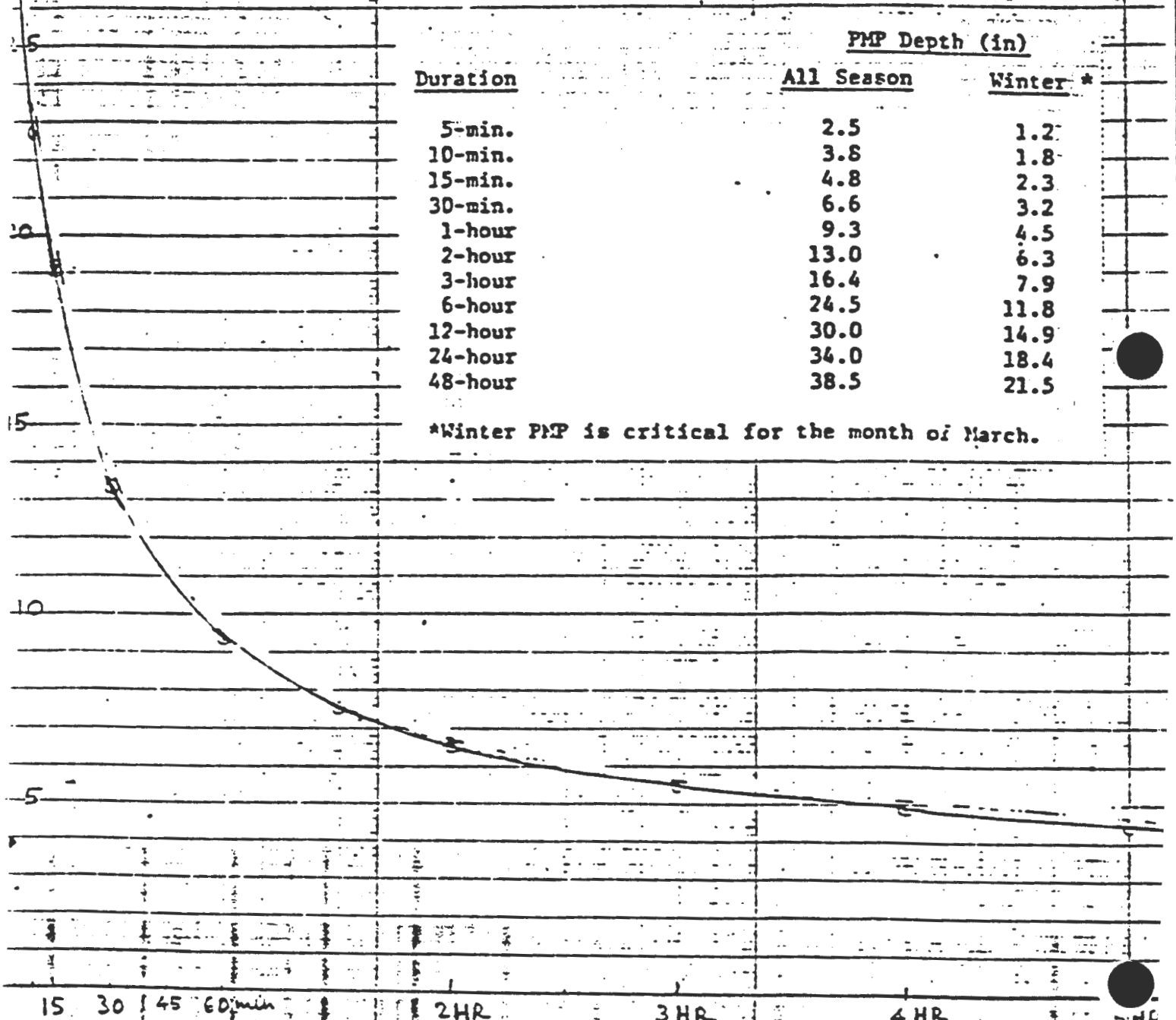
NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

JOB NO. 12484
CALC. NO. S24-C-015
SHEET NO. 10 OF 12
REV. NO. 0
CHECKED BY [illegible] DATE 8/14/80

Duration	PMP Depth (in) All Season	PMP Depth (in) Winter *
5-min.	2.5	1.2
10-min.	3.8	1.8
15-min.	4.8	2.3
30-min.	6.6	3.2
1-hour	9.3	4.5
2-hour	13.0	6.3
3-hour	16.4	7.9
6-hour	24.5	11.8
12-hour	30.0	14.9
24-hour	34.0	18.4
48-hour	38.5	21.5

*Winter PMP is critical for the month of March.



NUCLEAR FUEL OPERATIONS

CALCULATION SHEET

CALC. NO.	CS24-C-015
SHEET NO.	11 OF 12
REV. NO.	0
CHECKED BY	DATE 8/11/82

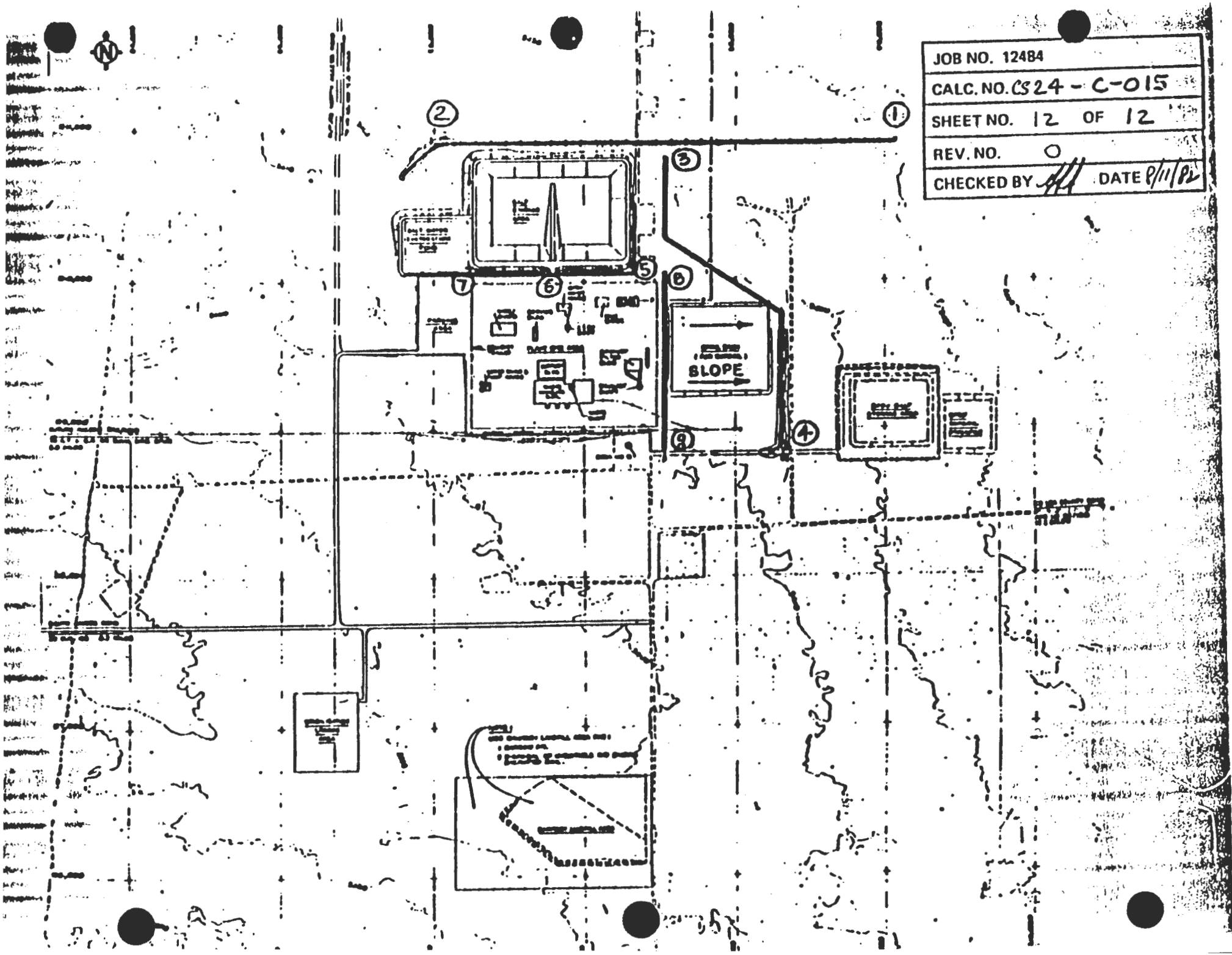
VALUES of DISCHARGE FACTOR K' in $Q = (K'/n)b^{8/3}S^{1/2}$ for TRAPEZOIDAL CHANNELS

(y = depth of flow, b = bottom width of channel)

Side Slopes of Channel Section (horizontal to vertical)

y/b	Vertical	¼:1	½:1	¾:1	1:1	1½:1	2:1	2½:1	3:1	4:1
.01	.00068	.00068	.00069	.00069	.00069	.00069	.00069	.00069	.00070	.00070
.02	.00213	.00215	.00216	.00217	.00218	.00220	.00221	.00222	.00223	.00225
.03	.00414	.00419	.00423	.00426	.00428	.00433	.00436	.00439	.00443	.00449
.04	.00660	.00670	.00679	.00685	.00691	.00700	.00708	.00716	.00723	.00736
.05	.00946	.00964	.00979	.00991	.01002	.01019	.01033	.01047	.01060	.01086
.06	.0127	.0130	.0132	.0134	.0136	.0138	.0141	.0143	.0145	.0150
.07	.0162	.0166	.0170	.0173	.0175	.0180	.0183	.0187	.0190	.0197
.08	.0200	.0206	.0211	.0215	.0219	.0225	.0231	.0236	.0240	.0250
.09	.0241	.0249	.0256	.0262	.0267	.0275	.0282	.0289	.0296	.0310
.10	.0284	.0294	.0304	.0311	.0318	.0329	.0339	.0348	.0358	.0376
.11	.0329	.0343	.0354	.0364	.0373	.0387	.0400	.0413	.0424	.0448
.12	.0376	.0393	.0408	.0420	.0431	.0450	.0466	.0482	.0497	.0527
.13	.0425	.0446	.0464	.0480	.0493	.0516	.0537	.0556	.0575	.0613
.14	.0476	.0502	.0524	.0542	.0559	.0587	.0612	.0636	.0659	.0706
.15	.0528	.0559	.0585	.0608	.0627	.0662	.0692	.0721	.0749	.0805
.16	.0582	.0619	.0650	.0676	.0700	.0740	.0777	.0811	.0845	.0912
.17	.0638	.0680	.0716	.0748	.0775	.0823	.0866	.0907	.0947	.1026
.18	.0695	.0744	.0786	.0822	.0854	.0910	.0960	.1008	.1055	.1148
.19	.0753	.0809	.0857	.0899	.0936	.1001	.1059	.1115	.1169	.1277
.20	.0812	.0876	.0931	.0979	.1021	.1096	.1163	.1227	.1290	.1414
.22	.0934	.1015	.109	.115	.120	.130	.139	.147	.155	.171
.24	.1061	.1161	.125	.133	.140	.152	.163	.173	.184	.204
.26	.119	.131	.142	.152	.160	.175	.189	.202	.215	.241
.28	.132	.147	.160	.172	.182	.201	.217	.234	.249	.281
.30	.146	.163	.179	.193	.205	.228	.247	.267	.287	.324
.32	.160	.180	.199	.215	.230	.256	.281	.304	.327	.371
.34	.174	.198	.219	.238	.256	.287	.316	.343	.270	.423
.36	.189	.216	.241	.263	.283	.319	.353	.385	.416	.478
.38	.203	.234	.263	.288	.312	.353	.392	.429	.465	.537
.40	.218	.253	.286	.315	.341	.389	.434	.476	.518	.600
.42	.233	.273	.309	.342	.373	.427	.478	.526	.574	.668
.44	.248	.293	.334	.371	.405	.467	.525	.580	.633	.740
.46	.264	.313	.359	.401	.439	.509	.574	.636	.696	.816
.48	.279	.334	.385	.432	.474	.553	.625	.695	.763	.897
.50	.295	.355	.412	.463	.511	.598	.679	.757	.833	.983
.55	.335	.410	.482	.548	.609	.722	.826	.926	1.025	1.22
.60	.375	.468	.557	.640	.717	.858	.990	1.117	1.24	1.49
.70	.457	.592	.722	.844	.959	1.17	1.37	1.56	1.75	2.12
.80	.542	.725	.906	1.078	1.24	1.54	1.83	2.10	2.37	2.90
.90	.628	.869	1.11	1.34	1.56	1.98	2.36	2.74	3.11	3.83
1.00	.714	1.022	1.33	1.64	1.93	2.47	2.99	3.48	3.97	4.93
1.20	.891	1.36	1.85	2.33	2.79	3.67	4.51	5.32	6.11	7.67
1.40	1.07	1.74	2.45	3.16	3.85	5.17	6.42	7.64	8.84	11.2
1.60	1.25	2.16	3.14	4.14	5.12	6.99	8.78	10.52	12.2	15.6
1.80	1.43	2.62	3.93	5.28	6.60	9.15	11.5	14.0	16.3	20.9
2.00	1.61	3.12	4.82	6.58	8.32	11.7	14.9	18.1	21.2	27.3
2.25	1.84	3.81	6.09	8.46	10.8	15.4	19.8	24.1	28.4	36.7

*Values from King's "Handbook of Hydraulics", 4th edition, McGraw-Hill Co.



JOB NO. 12484	
CALC. NO. CS24 - C-015	
SHEET NO. 12 OF 12	
REV. NO. 0	
CHECKED BY [illegible]	DATE 8/11/92

APPENDIX D8
PHENOLINE® 305 FINISH PRODUCT DATA SHEET

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PHENOLINE® 305 FINISH

SELECTION DATA

GENERIC TYPE: Modified phenolic. Part A and Part B mixed prior to application.

GENERAL PROPERTIES: A heavy-duty topcoat, PHENOLINE 305 Finish sets to a hard, tough, smooth finish having very good abrasion resistance. The surface is glossy and easily cleaned. Has excellent resistance to a wide range of solvents, caustics, cleaning solutions and acid entrained vapors of high concentration. PHENOLINE 305 Finish has outstanding chemical, physical and application properties. PHENOLINE 305 Finish is easily repaired, has excellent resistance to hydraulic fluids and meets the applicable performance criteria of the American National Standards Institute ANSI N101.2-1972 and ANSI N5.12-1974. It has performed satisfactorily in radiation resistance and decontamination testing at Oak Ridge National Laboratory.

RECOMMENDED USES: PHENOLINE 305 Finish is an excellent coating for the protection of steel and concrete surfaces in nuclear power plants. Because of its glossy appearance and excellent physical properties, PHENOLINE 305 Finish is an excellent topcoat for use by manufacturers of industrial equipment and components. Also used in chemical processing plants, pulp and paper mills for the protection of structural steel and concrete against severe splash, spillage and fume conditions. The addition of 50 mesh silica provides a non-skid surface, making an excellent floor coating.

NOT RECOMMENDED FOR: Immersion service or continuous spillage of hot or concentrated acids.

CHEMICAL RESISTANCE GUIDE:

Exposure	Splash and Spillage	Fumes
Acids	Very Good	Excellent
Alkalies	Excellent	Excellent
Solvents	Excellent	Excellent
Salt	Excellent	Excellent
Water	Excellent	Excellent

TEMPERATURE RESISTANCE: (non-immersion)
Continuous: 200°F (93°C)
Non-continuous 250°F (121°C)

FLEXIBILITY: Fair **WEATHERING:** Very Good

ABRASION RESISTANCE: Very good

SUBSTRATES: Apply over suitably primed metal or cementitious surfaces. Surfacer may be required for concrete surfaces, depending on roughness and texture.

TOPCOAT REQUIRED: Normally none

COMPATIBILITY WITH OTHER COATINGS: May be applied over inorganic zincs, catalyzed epoxies, modified phenolics or others as recommended. Acceptable primers are CARBO ZINC® 11, CARBO ZINC 12, CARBOLINE® 195 Surfacer, CARBOLINE 295WB Surfacer, PHENOLINE 305 Primer, PHENOLINE 305 Concrete Primer, PHENOLINE 307 or others as recommended. A mist coat may be required when applied over inorganic zinc.

SPECIFICATION DATA

THEORETICAL SOLIDS CONTENT OF MIXED MATERIAL:

	By Volume
PHENOLINE 305 Finish	64% ± 2%

RECOMMENDED DRY FILM THICKNESS PER COAT:
4-6 mils (100-150 microns)

THEORETICAL COVERAGE PER MIXED KIT*:

1 gal. kit (yields 1.25 gal.)
1283 mil sq. ft. (25.6 m/l at 25 microns)
320 sq. ft. at 4 mils (6.4 sq. m/l at 100 microns)

5 gal. kit (yields 6.25 gal.)
6416 mil sq. ft. (25.6 sq. m/l at 25 microns)
1603 sq. ft. at 4 mils (6.4 sq. m/l at 100 microns)

*NOTE: Material losses during mixing and application will vary and must be taken into consideration when estimating job requirements.

SHELF LIFE: 24 months minimum

COLORS: Available in a variety of colors. Consult your local Carboline representative or Carboline Customer Service for availability.

GLOSS: Glossy

ORDERING INFORMATION

Prices may be obtained from Carboline sales representative or main office.

APPROXIMATE SHIPPING WEIGHT:

	1 Gal. Kit (1.25 gal.)	5 Gal. Kit (6.25 gal.)
PHENOLINE 305 Finish	17 lbs. (7.7 kg)	80 lbs. (36.3 kg)
PHENOLINE Thinner	9 lbs. (4.1 kg)	45 lbs. (20.5 kg)
CARBOLINE Thinner #2	9 lbs. (4.1 kg)	45 lbs. (20.5 kg)

FLASH POINT: (Pensky-Martens Closed Cup)

PHENOLINE 305 Finish Part A	68°F (20°C)
PHENOLINE 305 Finish Part B	60°F (16°C)
PHENOLINE Thinner	77°F (25°C)
CARBOLINE Thinner #2	30°F (-1°C)

March 84 Replaces May 83

To the best of our knowledge the technical data contained herein are true and accurate at the date of issuance and are subject to change without prior notice. User must contact Carboline to verify correctness before specifying or ordering. No guarantee of accuracy is given or implied. We guarantee our products to conform to Carboline quality control. We assume no responsibility for coverage, performance or injuries resulting from use. Liability, if any, is limited to replacement of products. Prices and cost data if shown, are subject to change without prior notice. NO OTHER WARRANTY OR GUARANTEE OF ANY KIND IS MADE BY THE SELLER, EXPRESS OR IMPLIED, STATUTORY, BY OPERATION OR LAW, OR OTHERWISE, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

APPLICATION INSTRUCTIONS

These instructions are not intended to show product recommendations for specific service. They are issued as an aid in determining correct surface preparation, mixing instructions, and application procedure. It is assumed that the proper product recommendations have been made. These instructions should be followed closely to obtain the maximum service from the materials.

607

SURFACE PREPARATION: Remove any oil or grease from surface to be coated with clean rags soaked in CARBOLINE Thinner #2 or toluol in accordance with SSPC-SP1-82.

Steel/Concrete: Apply over clean, dry, recommended primer or surfacer. Application over inorganic zincs may require a mist coat.

MIXING: Mix separately, then combine and mix thoroughly in the following proportions:

	1 Gal. Kit	5 Gal. Kit
PHENOLINE 305 Finish Part A	1 Gal.	5 Gal.
PHENOLINE 305 Finish Part B	1 Qt.	1.25 Gal.
	1.25 gal.	6.25 gal.

Thin up to 25% by volume with PHENOLINE Thinner.

NOTE: Use of thinners other than those supplied or approved by Carboline may adversely affect product performance and void product warranty, whether express or implied.

POT LIFE: One and one half hours at 75°F (24°C) and less at higher temperatures. Pot life ends when coating loses body and begins to sag.

APPLICATION TEMPERATURES:

	Material	Surfaces
Normal	65-85°F (18-29°C)	65-85°F (18-29°C)
Minimum	55°F (13°C)	50°F (10°C)
Maximum	90°F (32°C)	120°F (49°C)
	Ambient	**Humidity**
Normal	65-85°F (18-29°C)	30-60%
Minimum	50°F (10°C)	0%
Maximum	110°F (43°C)	90%

Do not apply when the surface temperature is less than 5°F (2°C) above the dew point.

Special thinning and application techniques may be required above or below normal conditions and when applying over inorganic zinc primers.

SPRAY: Use sufficient air volume for correct operation of equipment.

Use a 50% overlap with each pass of the gun. On irregular surfaces, coat the edges first, making an extra pass later.

NOTE: The following equipment has been found suitable; however, equivalent equipment may be substituted.

Conventional: Use a 3/8" minimum I.D. material hose. Hold gun approximately 12-14 inches from the surface and at a right angle to the surface.

Mfr. & Gun	Fluid Tip	Air Cap
Binks #18 or #62	66	63PB
DeVilbiss P-MBC or JGA	E	704
	approx. .070" I.D.	

Airless: Use a 3/8" minimum I.D. material hose. Hold gun approximately 18-20 inches from the surface and at a right angle to the surface.

Mfr. & Gun	Pump*
DeVilbiss JGB-507	QFA-519
Graco 205-591	President 30:1 or Bulldog 30:1
Binks Model 700	B8-36 37:1

*Teflon packings are recommended and are available from pump manufacturer.

Use a .015-.017" tip with 2200 psi.

BRUSH OR ROLLER: For touch-up only. Use natural bristle brush applying with full coat. Avoid rebrushing. Use lambswool roller with phenolic core. Avoid rerolling. Two coats may be required for proper hiding and film build.

APPLICATION FOR NON-SKID SURFACES:
For non-skid surfaces, mix Part A and Part B as usual and add, under agitation, 2½ pints (approximately 4.33 lbs.) of 50 mesh Ottawa Silica for each one-gallon kit of PHENOLINE 305 Finish. Thin up to 25% by volume with PHENOLINE Thinner. Keep material under mild agitation during application.

Conventional: Use a ½" minimum I.D. material hose and an agitated bottom outlet pot with ½" minimum I.D. outlet equipped with dual regulators. Hold gun approximately 12-14 inches from the surface and at a right angle to the surface.

Mfr. & Gun	Fluid Tip	Air Cap
Binks Model 18 or 62	68	68 PB
DeVilbiss P-MBC or JGA	AC	62
	approx. . 110" I.D.	

Airless: Not recommended (abrades tip).

DRYING TIMES:

Temperature	Between Coats	Final Cure
50°F (10°C)	72 hrs.	12 days
60°F (16°C)	36 hrs.	8 days
75°F (24°C)	18 hrs.	4 days
90°F (32°C)	12 hrs.	2 days

CLEAN UP: Use CARBOLINE Thinner #2 or xylol.

STORAGE CONDITIONS:
Temperature: 45-110°F (7-43°C) Humidity: 0-100%

For specific recommendations, consult Carboline Technical Service.

CAUTION: CONTAINS FLAMMABLE SOLVENTS. KEEP AWAY FROM SPARKS AND OPEN FLAMES. IN CONFINED AREAS WORKMEN MUST WEAR FRESH AIRLINE RESPIRATORS. HYPERSENSITIVE PERSONS SHOULD WEAR GLOVES OR USE PROTECTIVE CREAM. ALL ELECTRIC EQUIPMENT AND INSTALLATIONS SHOULD BE MADE AND GROUNDED IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE. IN AREAS WHERE EXPLOSION HAZARDS EXIST, WORKMEN SHOULD BE REQUIRED TO USE NONFERROUS TOOLS AND TO WEAR CONDUCTIVE AND NONSPARKING SHOES.

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NUCLEAR COATING SYSTEM

SYSTEM	PRODUCT	GENERIC TYPE	DRY FILM THICKNESS	VOLUME SOLIDS	COVERAGE
SURFACER	CARBOLINE 195	EPOXY	20 MILS	97%	78 ft²
TOPCOAT	PHENOLINE 305	PHENOLIC EPOXY	5 MILS	64%	257 ft²*

DESCRIPTION: A two or three coat epoxy surfacer system for floors or where excellent chemical resistance is required. Two coats of 195 Surfacer may be required depending on porosity of concrete. Exhibits excellent gloss and abrasion resistance. A proven system in nuclear plants for more than 18 years.

FEATURES

- High solids, low solvent content
- Excellent abrasion and chemical resistance
- Excellent gloss

BENEFITS

- Fewer fumes than conventional coatings, less effect on personnel and charcoal filters.
- Long wear life, resists chemical attack.
- Easily decontaminated, aesthetics.

*1.25 Gal. Kit

TEST DATA

TEST	METHOD	CONDITIONS	RESULTS
DESIGN BASIS ACCIDENT (DBA)	ANSI N101.2 - 1972 ASTM D3911-80	340°F/70 PSIG (ORNL)	ACCEPTABLE
RADIATION TOLERANCE	ANSI N5 12 - 1974 ASTM D4082-83	1 x 10⁹ RADS	ACCEPTABLE
DECONTAMINATION	ANSI N5 12 - 1974 ASTM D4256-83	PER TEST METHOD AND ORNL PROCEDURES (305)	99.1%
CHEMICAL RESISTANCE	ANSI N5 12 - 1974 ASTM D3912-80	5 DAY IMMERSION (305)	ACCEPTABLE EXCEPT FOR POTASSIUM PERMANGANATE
TABER ABRASION	ANSI N5 12 - 1974 FED STD 141 METHOD 6192	1000 CYCLES 1000g WEIGHT CS-17 WHEEL (305)	69.3 mg LOST

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