Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment

WBS 1.3.5.3.1
Pkg. No. 510062

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Annual Compliance Monitoring
Parameter Assessment

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Executive Summary

This document reports the third annual (2001) derivation and assessment of the Waste Isolation Pilot Plant Compliance Monitoring Parameters (COMPs). The COMPs program is a requirement of the Environmental Protection Agency (EPA) disposal regulations (EPA 1993 and 1996). The concept of deriving and assessing COMPs is explained in Sandia National Laboratories (SNL) Nuclear Waste Management Program (NWMP) Analysis Plan, AP-069 titled: *An Analysis Plan for Annually Deriving Compliance Monitoring Parameters and their Assessment Against Performance Expectations to Meet the Requirements of 40 CFR 194.42* (SNL 2000a).

The Waste Isolation Pilot Plant (WIPP) has many monitoring programs, each designed to meet various regulatory and operational safety requirements. The comprehensive monitoring effort is not under the auspice of one program, but is comprised of many discrete elements. One element is designed to fulfill the Environmental Protection Agency requirements found at 40 CFR Parts 191 and 194. The expected performance of the repository has been determined through a Performance Assessment (PA) implemented by SNL, the Scientific Advisor (SA), for the Department of Energy (DOE). Monitoring parameters that are related to the long-term performance of the repository have been identified in a Sensitivity Study[1] (since these parameters fulfill a regulatory function, they are termed Compliance Monitoring Parameters so that they will not be confused with similar Performance Assessment parameters).

PA is used to predict repository radioactive waste containment performance for the WIPP. COMPs can indicate conditions that are not within PA expectations which result in alerting the project of potential conditions not accounted for or expected. COMPs values and ranges have been developed such that exceedance of these values would indicate a condition that is potentially outside PA expectations. These values are appropriately termed "trigger values." Deriving COMPs trigger values is the first step in assessing the monitoring data. Trigger values have been derived and documented in the *Trigger Value Derivation Report* (SNL 2000b). In some instances a COMP will not have a trigger value because they have been shown to be insensitive to PA results though EPA's sensitivity analysis (EPA 1998).

As the quantity of information in the monitoring database grows over time, it will become more useful for assessing the monitoring program's performance and usefulness. With each annual assessment and knowledge gained through ongoing activities, the basis for assessing COMPs and assigning trigger values will undergo improvements. A monitoring program analysis will be conducted periodically to evaluate the effectiveness of the entire compliance monitoring program. The first program analysis shall take place prior to the first WIPP recertification.

Ten COMPs are required by EPA, two relating to human activities, five relating to geotechnical performance, two relating to regional hydrogeology and one relating to the radioactive components of the waste. Existing WIPP monitoring programs are used to gather data and information to develop the COMPs. The EPA also requires the DOE to report any negative condition that would indicate the repository will not function as predicted or a condition that is substantially different from the information contained in the most recent compliance application. Annual assessments of COMPs will allow the DOE to monitor the predicted performance of the repository and report any

[1] Attachment MONPAR to Appendix MON in the CCA (DOE 1996) documents the analysis of monitoring parameters. The analysis was performed to fulfill 40 CFR 194.42 requirements.

condition adverse to the containment performance. This compliance monitoring program is described in greater detail in DOE's *40 CFR Parts 191 and 194 Compliance Monitoring Implementation Plan* (MIP; DOE 1999).

As outlined in the MIP, the Management and Operating Contractor (M&OC), currently Westinghouse TRU Solutions (WTS), is responsible for implementing the monitoring programs that collect and report the monitoring data. The SA is responsible for assessing these data and compiling the results as they pertain to compliance. The SA is also responsible for making recommendations to improve or change the monitoring programs based on the results. This document reports these results and the recommendations based on the calendar year 2001 COMPs assessment. This assessment concludes that the current COMP values do not indicate a condition adverse to the predicted performance of the repository. However, because Culebra water levels are above expected values at some wells, the project has initiated work to revise the current groundwater model. Additionally, the trigger value for the drilling rate COMP is expected to be exceeded within the next one to two years. This condition is expected due to the method by which the drilling rate is calculated (as prescribed by EPA). In all cases, the monitoring data do not indicate a condition for which the repository will perform in a manner other than that predicted in the PA.

1 Introduction

The WIPP is governed by the EPA's general radioactive waste disposal regulations at 40 CFR Part 191 (EPA 1993) and the implementing WIPP-specific criteria at 40 CFR Part 194 (EPA 1996). Monitoring WIPP performance is an "assurance requirement " (see 40 CFR 1941.14) of these regulations and is intended to provide additional assurance that the WIPP will protect the public and environment. In the WIPP Compliance Certification Application (CCA; DOE 1996), the DOE made commitments to conduct a number of monitoring activities to comply with the criteria at 40 CFR § 194.42 and to ensure that deviations from the expected long-term performance of the repository are identified at the earliest possible time. These DOE commitments are represented by ten Compliance Monitoring Parameters (COMPs), which are listed in Section 2.

The COMPs are an integral part of the overall WIPP monitoring strategy. The DOE's Monitoring Implementation Plan (MIP; DOE 1999) describes the overall monitoring program and responsibilities for COMPs derivation and assessment. Collecting and reporting data from the WIPP monitoring programs are the responsibilities of the M&OC. SNL, as the SA, uses these monitoring data and observations to derive "trigger values" for the ten COMPs, derive data values which indicate potential issues, and evaluate the COMPs against performance expectations for the disposal system. The performance expectations are based on scenarios, conceptual models and computational results using the WIPP Performance Assessment methodology and its associated codes and parameter values that form part of the DOE's Compliance Baseline. The results of the SA's evaluation are reported to the DOE Carlsbad Field Office (CBFO) via the Office of Regulatory Compliance (ORC). This report documents the results of the calendar year 2001 COMPs assessment.

1.2 Monitoring and Evaluation Strategy

The MIP illustrates the process for evaluation of COMP-related monitoring data and observations (Fig 4.2; DOE 1999). Figure 1.1 (of this document) graphically describes the three basic Compliance Monitoring Program elements which include the trigger value generation and reporting function, the Annual COMP Reporting Cycle and the Five-Year Recertification element. The Compliance Monitoring Program is an integrated effort between the M&OC, the SA and the CBFO. The M&OC operates the monitoring systems at the WIPP site and generates the basic data, while the SA is responsible for generating the COMPs from the basic data and assessing the results. The CBFO oversees and directs the monitoring program to ensure compliance with the EPA monitoring and reporting requirements. The SA is also responsible for the development and maintenance of the trigger values. Exceedance of these values represents a condition that requires further actions, but does not necessarily indicate an out-of-compliance condition. Rather, this approach guarantees that any condition adverse to expected repository performance is recognized as early as possible, before an out-of-compliance condition actually occurs. These conditions may include data inconsistent with the conceptual models implemented in PA, or invalidation of assumptions and arguments used in the screening of Features, Events and Processes (FEPs) screened into PA.

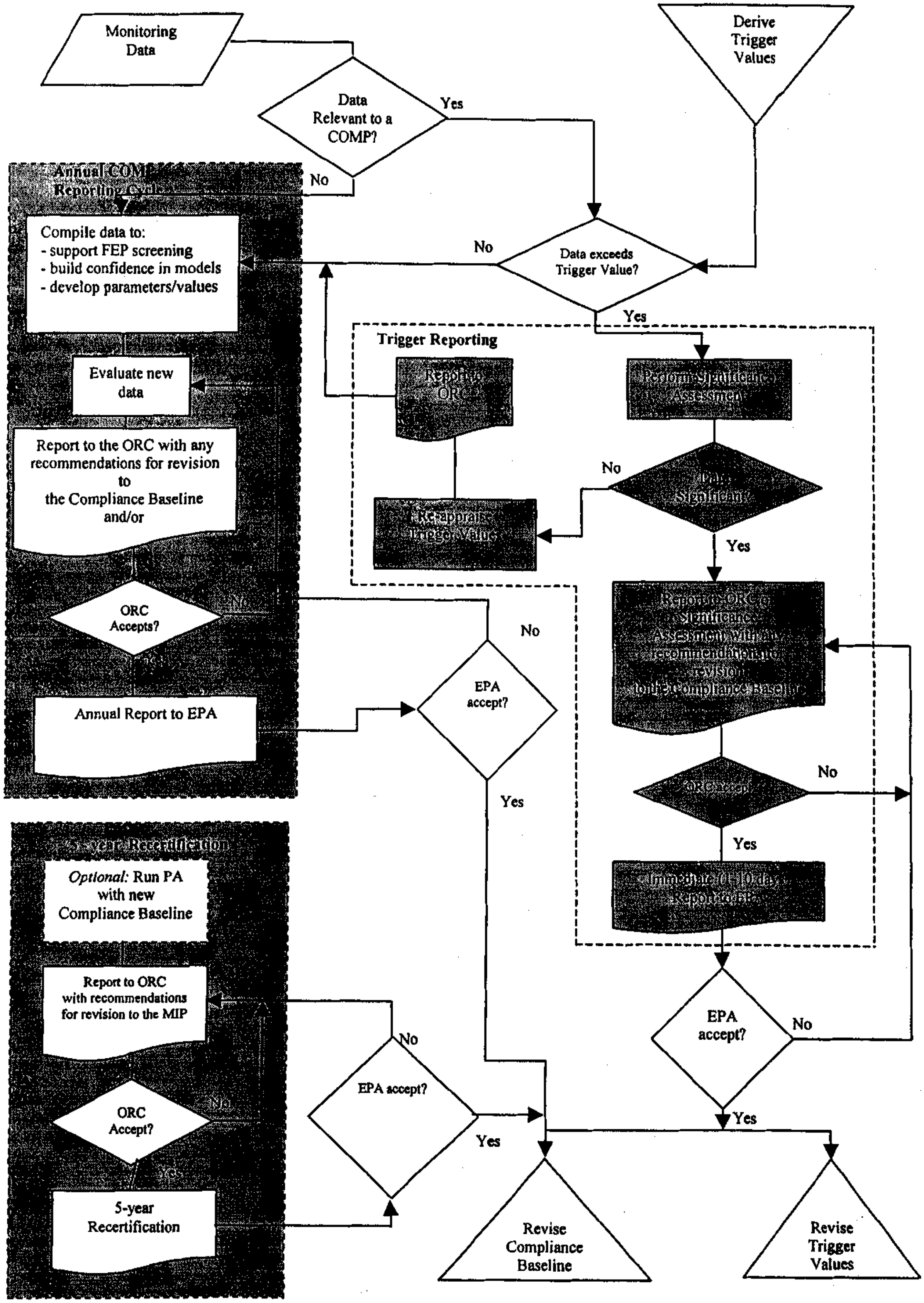

Figure 1.1: Activities Evaluating and Reporting Compliance Monitoring Parameters

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This long-term performance requires that impacts be projected years into the future, based upon data collected in the present. Therefore, this monitoring is not intended to detect operational releases. The WIPP M&OC has operational monitoring programs designed to detect operational releases.

1.3 Annual Reporting Cycle

Reporting results of the annual COMPs assessment is necessary to meet the EPA monitoring requirements. Under 40 CFR §194.4, the DOE is required to report significant, along with non-significant, changes to the EPA. Monitored parameters that change must be reported even if the assessment concludes there is no impact on the repository. Whether or not the monitoring data agree with expectations, as defined by the evaluation, all the data will ultimately be compiled and reported to the DOE to assist in DOE's annual reporting cycle to the EPA. The SA's role in this reporting cycle is to use the monitoring data to derive the COMPs, and to use the new and updated information to make any recommendations for modification to the Compliance Baseline, to monitoring programs, and to trigger values.

2 Assessment of COMPs

The compliance monitoring program tracks the following ten COMPs:

1. Drilling Rate
2. Probability of Encountering a Castile Brine Reservoir
3. Waste Activity
4. Subsidence
5. Changes in Culebra Groundwater Flow
6. Change in Culebra Groundwater Composition
7. Creep Closure
8. Extent of Deformation
9. Initiation of Brittle Deformation
10. Displacement of Deformation Features

In the following section, each COMP is evaluated and compared to the applicable trigger value. This assessment is performed under Analysis Plan AP-069 (SNL 2000a). This section summarizes the results of the 2001 calendar year assessment. An annual review of these COMPs is necessary to meet the intent of 40 CFR §191.14 assurance requirements, which states:

> "(b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring."

Specifically, AP-069 contains five steps to derive trigger values and assess COMPs. Steps 1 and 2 generate a table that maps COMP related data to PA parameters, FEPs screening arguments, conceptual models, model assumptions and the M&OC organization that generates the data used to derive each COMP. Table 2.1 contains this information which was derived using information in the CCA (DOE 1996).

Table 2.1 Monitoring Parameters

40 CFR 194 Monitoring Parameter	Responsible Program M&OC/*SA* (SA in italics)	Trigger Value(s)	Related Performance Assessment Parameter	Major FEPs Screening Decisions Related to Monitoring (EPA #)
Creep Closure and Stresses	Geotechnical Monitoring Program *Rock Mechanics Program*	Greater than 1 order of magnitude increase in the rate.	Not directly related to a PA Parameter. *Provides a short-term (operational) observation of the deformational properties of halite and anhydrite. Can provide confidence in the CCA creep closure model.*	*Salt creep(W20), room closure(W22), excavation-induced stress changes(W19), changes in stress field(W21), pressurization(W26, consolidation of waste(W32). Data from this monitoring program will be evaluated during recertification.*
Extent of Deformation	Geotechnical Monitoring Program *Rock Mechanics Program*	Greater than 1 m/year increase.	Not directly related to a PA Parameter. *Provides a short-term observation of the extent of deformation. Can provide confidence in the long-term behavior of Disturbed Rock Zone (DRZ) as modeled in CCA and DRZ parameters (e.g., permeability and porosity). Intrinsic shaft DRZ permeability.*	*DRZ(W18), roof falls(W22), Consolidation of seal elements(W36), compaction of waste(W32).*
Initiation of Brittle Deformation	Geotechnical Monitoring Program *Seals and Rock Mechanics Programs*	None	Not directly related to a PA parameter. *Provides related repository observation data on initiation or displacement of major brittle deformation features in the roof or surrounding rock.*	*Disruption due to gas effects(W25).*
Displacement of Deformation Features	Geotechnical Monitoring Program *Rock Mechanics Program*	Obscured borehole (qualitative)	Not directly related to a PA Parameter. *Provides related repository operational data on initiation or displacement of major brittle deformation features in the roof or surrounding rock.*	*Seismic activity(N22), creep closure(W20), consolidation of waste(W32).*

40 CFR 194 Monitoring Parameter	**Responsible Program M&OC/*SA*** (SA in italics)	**Trigger Value(s)**	**Related Performance Assessment Parameter**	**Major FEPs Screening Decisions Related to Monitoring (EPA #)**
Culebra Ground Water Compositions	Ground Water Monitoring Program *Far Field Monitoring Program*	TBD – Pending finalization of RCRA baseline and determination of considerations of analytical error	Average Culebra brine composition and matrix distribution coefficient for U (IV,VI), Pu(III,IV), Th(IV), Am(III). *Matrix distribution coefficient is not a sensitive parameter for the CCA PA. Can provide information on well integrity around the site.*	*Groundwater geochemistry(W32), actinide sorption(W61).*
Change in Culebra Ground Water Flow (Water Level)	Ground Water Monitoring Program *Far Field Monitoring Program*	Comparison to ranges of freshwater heads used in CCA T-Fields (Table 4.1 of Trigger Report)	Culebra transmissivity, fracture & matrix porosity, fracture spacing, dispersivity, & climate Index. *The CCA modeling allowed the water level to rise to the land surface. Can provide information on well integrity around the site.*	*Groundwater flow and (N23,24) recharge/discharge (N53,54); Infiltration and Precipitation(N59).*
Drilling Rate	Delaware Basin Monitoring Program *Direct Release Program*	53.5 boreholes per square kilometer per 10,000 yrs.	Drilling rate per unit area. *In the CCA the drilling rate was determined to be 46.8 boreholes per square kilometer per 10,000 yrs.*	*Drilling(H1,2,4,8,9).*
Probability of Encountering a Castile Brine Reservoir	Delaware Basin Monitoring Program *Direct Release Program*	None	Probability of encountering a Castile brine reservoir, reservoir pressure, and volume. *In the CCA, 8% was used; in the Performance Assessment Validation Test, a range of 1 - 60% was used.*	*Drilling fluid flow(H21), Drilling fluid loss(H22), Blowout(H23) and brine reservoirs (N2).*
Subsidence Measurements	Subsidence Monitoring Program	10 mm/year	Not directly related to a PA Parameter. *Can provide spatial information on surface subsidence (if any) over the influence area of the*	*Changes to ground water flow due to mining effects(H37), Subsidence baseline.*

40 CFR 194 Monitoring Parameter	Responsible Program M&OC/*SA* (SA in italics)	Trigger Value(s)	Related Performance Assessment Parameter	Major FEPs Screening Decisions Related to Monitoring (EPA #)
	Rock Mechanics Program		*underground openings during operations.*	
Waste Activity	WIPP Waste Information System (WWIS) *PA Methodology*	5.1 Million Curies (RH Only)	Radionuclide inventory. *In the CCA, the SA used the Baseline Inventory Report information scaled to the Land Withdrawal Act (LWA) limits of 6.2 million cubic feet for CH TRU waste and 5.1 million curies for RH TRU waste (limits are listed in table WCA-1 in the CCA)*	*Waste characteristics (W2,3), radiological characteristics, consolidation of waste, actinide source term(W32).*

2.1 Human Activities COMPs

The CCA identifies ten COMPs that the DOE is required to monitor and assess during the WIPP operational period. Two of these parameters monitor "Human Activities" in the WIPP vicinity which include:

- Probability of Encountering a Castile Brine Reservoir
- Drilling Rate

2.1.1 Probability of Encountering a Castile Brine Reservoir

The CCA data were compiled from record searches of available drilling data from the region surrounding the WIPP. The results of this search recorded 27 drilling encounters with pressurized brine (water) in the Castile Formation. Of these encounters, 25 were hydrocarbon wells scattered over a wide area in the vicinity of the WIPP site; two wells, ERDA 6 and WIPP 12, were drilled in support of the WIPP site characterization effort. The Delaware Basin Drilling Surveillance Program reviews the well files of all new wells drilled in the New Mexico portion of the Delaware Basin each year looking for instances of Castile brine encounters. The program also sends out an annual survey to operators of new wells asking if they encountered pressurized brine during the drilling process. Since the CCA, data have been compiled through September 2001. No pressurized Castile brine encounters have been reported in the drilling records for wells drilled in the New Mexico portion of the Delaware Basin (WID 1999b; WID 2001).

Two Castile brine encounters have been reported by area drillers to WIPP site personnel that were not reported in the state drilling records or in the annual surveys. One encounter was located near ERDA 6 northeast of the WIPP site. Reports from this encounter indicated that several hundred barrels of brine per hour were observed at the surface. All brine was contained within the drilling

pits, thus requiring no report to the State. The other brine encounter was to the southwest of the WIPP site. In this encounter, sulfur water was reported at approximately 2900 feet below ground surface; flow from this depth dissipated in a matter of minutes.

The impacts of brine encounters are modeled in the PA. The original assessment included 27 encounters in the WIPP vicinity and determined a 0.08 probability of encountering brine reservoirs. In the PAVT, the EPA mandated a range of 0.01 to 0.6. Even when the high values within this range were considered, the probability of encountering a brine reservoir did not influence the predicted performance of the repository. Thus, the EPA determined that this parameter (PBRINE, # 3493) does not have a significant impact on PA results (EPA 1998).

Probability of Encountering a Brine Reservoir - 2001:

Trigger Value Derivation	
COMP Title:	Probability of Encountering a Castile Brine Reservoir
COMP Units:	Unitless

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
DBMP(1)	NA	Driller's survey – observations	0.08 constant – CCA 0.01 to .60 - PAVT

COMP Derivation Procedure

Analysis of encounters of pressurized brine recorded and reported by industry in the 9-township area centered on WIPP.

Year 2001 COMP Assessment Value

No new data reported to the State for the year; two occurrences reported to site personnel.

Related Performance and Compliance Elements

Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Probability of Encountering Brine	Parameter PRBRINE ID # 3493	CCA MASS Attachment 18-6 geostatistical study based on area occurrences. EPA TSD justified the upper value in their range by rounding up the upper value interpreted from the TDEM survey, which suggested a 10 to 55% areal extent.	0.08 0.01 to 0.60	Not a sensitive parameter.

Monitoring Data Trigger Values

Monitoring Parameter ID	Trigger Value	Basis
Probability of Encountering a Castile Brine Reservoir	None	After the DOE proposed the brine reservoir probability as potentially significant in the CCA Appendix MONPAR, the EPA conducted analyses that indicate a lack of significant effects on performance from changes in this parameter. Since no value of this parameter can significantly affect the performance of the disposal system predicted by the CCA PA and since the parameter is evaluated at least once annually, no trigger value is needed.

(1) Delaware Basin Monitoring Program

2.1.2 Drilling Rate

The drilling rate COMP tracks intrusion activities relating to resource extraction. Drilled boreholes relating to resources include potash and sulfur core holes, hydrocarbon exploration wells, saltwater disposal wells and water wells. The drilling rate that was reported in the CCA was determined using an equation provided in 40 CFR Part 194. The formula is as follows: number of deep holes times 10,000 years divided by 100 years (the latest 100 years, 1896 – 1996 for the CCA value). Deep holes are defined as any resource hole that terminated at a depth equal to or greater than the repository depth. The rate reported in the CCA using this equation was 46.8 boreholes per square kilometer over 10,000 years. Including the time period after the CCA (June 1995 to September 2000) increases the rate to 52.2 boreholes per square kilometer per 10,000 years (WID 2001).

Table 2.2 Drilling Rates for Each Year Since the CCA

Year	Number of Boreholes Deeper than 2,150 feet	DRILLING RATE (BORE HOLES PER SQUARE KILOMETER PER 10,000 YEARS)
1996 (CCA Value)	10,804	46.8
1997	11,444	49.5
1998	11,616	50.3
1999	11,684	50.6
2000	11,828	51.2
2001	12,056	52.2

As shown in Table 2.2, the drilling rate has risen from 46.8 holes per square kilometer to 52.2 holes per square kilometer since 1996. The rate will continue to climb because of the method used to calculate the rate. Since the first well drilled in the area occurred in 1911, it will be 2011 before one well is dropped from the count and 2014 before the next well is dropped from the count. In the mean time, numerous wells will have been added, driving up the drilling rate. For this reason, other methods and approaches are being investigated to derive a more meaningful trigger value. Some of the approaches that may be considered include using a rate change as the trigger indicator or using a different rate calculation that uses all data and more than a 100-year window for the COMP. A formal assessment of this COMP is planned to be completed prior to publishing the 2003 COMPs report.

The trigger value for this COMP is 53.5 and is not based on calculated performance because an order of magnitude change in the drilling rate does not result in an out-of-compliance condition (EEG 1998). However, the FEPs-related assumptions used in the CCA may be affected by increases in the drilling rate. For this reason, a trigger value of 53.5 was chosen so that when this rate was reached, the FEPs-related arguments would be revisited to assure that there is no impact to the original arguments. It should be stated that an exceedance of this trigger value is not an indication of an out-of-compliance condition, but is a point at which further analysis is needed to refine the baseline of the compliance monitoring program.

Drilling Rate - 2001:

Trigger Value Derivation			
COMP Title:	Drilling Rate		
COMP Units:	Deep boreholes (i.e., > 2,150 feet deep)/square kilometer/10,000 years		
Related Monitoring Data			
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
DBMP	Deep hydrocarbon boreholes drilled	Integer per year	10,640 per 100 years
DBMP	Deep sulfur coreholes drilled	Integer per year	89 per 100 years
DBMP	Deep potash coreholes drilled	Integer per year	19 per 100 years
DBMP	Deep stratigraphic coreholes drilled	Integer per year	56 per 100 years (excluding WIPP test holes)
DBMP	Other deep boreholes drilled	Integer per year	0

COMP Derivation Procedure
(Total number of deep boreholes drilled/number of years of observations) x (10,000/23,102.1) [i.e., over 10,000 years divided by the area of the Delaware Basin in square kilometers]
Year 2001 COMP Assessment Value
(12,056 boreholes on record for the Delaware Basin) Drilling Rate = 52.2 boreholes per square kilometer per 10,000 yrs.

Related Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Drilling rate	Parameter LAMBDAD #3494	COMP/10,000 years	4.68E-03 per square kilometer per year	23-fold increase over 10,000 years exceeds release limits at 0.1 probability (EEG, 1998). Proportional increase in cuttings/cavings releases.

Monitoring Data Trigger Values		
Monitoring Parameter ID	Trigger Value	Basis
Deep boreholes drilled (derived from the sum of the five monitoring parameters given above)	53.5 boreholes per square kilometer per 10,000 yrs.	CCA direct releases are sensitive to drilling rate changes, however only a dramatic and improbable change in drilling rate could affect containment of radionuclides. The sensitivity of FEP screening decisions to changes in drilling assumptions has not been evaluated to date. There is little information upon which to justify the choice of a trigger value based on FEP screening decisions. A change of drilling rate greater than 10% (i.e., greater than 53.5 boreholes per square kilometer per 10,000 years) is considered prudent as a trigger value to revisit the low-consequence assumptions associated with the effects of abandoned boreholes on fluid flow and climatic changes used to construct the performance assessment calculations.

2.2 Geotechnical COMPs

The CCA lists ten monitoring parameters that the DOE is required to monitor and assess during the WIPP operational period. Five of these parameters are considered "geotechnical" in nature and include:

- Creep Closure
- Extent of Deformation
- Initiation of Brittle Deformation
- Displacement of Deformation Features
- Subsidence

Data needed to derive and evaluate the geotechnical COMPs are available from the most recent annual Geotechnical Analysis Report (GAR; DOE 2001a), annual Subsidence Monument Leveling Survey (DOE 2000a) and results extracted from the geotechnical experimental programs (SNL 2001a; SNL 2000e) undertaken cooperatively by the SA and the M&OC to characterize the disturbed rock zone (DRZ). Three of the geotechnical parameters lend themselves to quantification: creep closure, displacement of deformation features and subsidence. While, in contrast, extent of deformation and initiation of brittle deformation are qualitative and/or observational parameters.

The WIPP GARs have been available since 1983 and are currently prepared by the M&OC on an annual basis. The purpose of the GAR is to present and interpret geotechnical data from the underground excavations. These data are obtained as part of a regular monitoring program and are used to characterize current conditions, to compare actual performance to the design assumptions and to evaluate and forecast the performance of the underground excavations during operations. Additionally, the GAR fulfills various regulatory requirements and, through the monitoring program, provides for early detection of conditions that could affect operational safety, evaluation of disposal room closure to ensure adequate access, and guidance for design changes. Data are presented for specific areas of the facilities including: (1) Shafts and keys, (2) Shaft Stations, (3) Northern Experimental Area, (4) Access Drifts, and (5) Waste Disposal Areas. Data are acquired using a variety of instruments including convergence points and meters, multipoint borehole extensometers, rockbolt load cells, pressure cells, strain gauges, piezometers and joint meters. All of geotechnical COMPs involve analyses of deformations/displacements so the most pertinent data derived from the GAR are convergence and extensometer data. The most recent GAR (DOE 2001a) summarizes data collected from July 1999 through June 2000. Data is also used from the previous GAR (DOE 2000b) which summarizes data collected from July 1998 to June 1999.

The Subsidence Monitoring Leveling Survey is also prepared by the M&OC on an annual basis and presents the results of leveling surveys performed for ten vertical control loops comprising approximately 18 linear miles traversed over the ground surface of the WIPP site. Elevations are determined for 51 monuments and 14 National Geodetic Survey vertical control points using digital leveling techniques to achieve Second-Order Class II loop closures or better. The data are used to estimate total subsidence and subsidence rates in fulfillment of regulatory requirements. The most recent survey (DOE 2000a) summarizes data collected during September and October 2000.

Geotechnical experimental programs conducted jointly by the SA and M&OC are currently underway to characterize the DRZ that develops around underground openings in salt. Components of the program include an observational phase, core studies, nuclear magnetic resonance testing, geochemical analyses, moisture content analyses, cross-hole and same-hole acoustic wave testing, resistivity testing, and in situ gamma ray densitometry and tomography. Data from the program will be used primarily for Performance Assessment (PA) and improvements to seal design, but will also provide useful information for characterizing extent of deformation, initiation of brittle deformation and possibly displacement of deformation features. Results from the program are reported as they become available. Two such reports (Bryan et al. 2001; SNL 2001c) are available for this COMPs assessment and address in situ cross-hole ultrasonic wave speed measurements and laboratory core analyses.

Comparisons between available data and the trigger values allow evaluation of the most recent geotechnical observations in the context of a reportable change. The cited reports and programs provide a good evaluation of all observations where deviations from historical normal occurrences are recorded. This process, as engaged for COMPs assessments, not only focuses attention on monitored parameters, it allows for reassessment of the proposed trigger values. Notable deviations are addressed in the GAR and other references, and are reexamined here in the context of COMPs and trigger values.

Geotechnical COMPs can be derived from or related to the repository's operational safety monitoring program, which is performed to ensure worker and mine safety. By nature, changes in geotechnical conditions evolve slowly, however, they are monitored continuously and reported annually. Since pertinent data from the underground reflect slowly evolving conditions, relationships that correlate to geotechnical COMPs also evolve slowly. Geotechnical conditions warranting action for operational safety will become evident before such conditions would impact long-term waste isolation. Monitoring underground response allows continuing assessment of conceptual geotechnical models supporting certification. In effect, these annual comparisons of actual geotechnical response with expected response serve to validate or improve models.

Annual reviews allow discovery of conditions or trends that lay outside expectations. In principal, the annual geotechnical analysis seeks trends or conditions that are "off normal." At this early stage of the repository history, the WIPP monitoring program is establishing parametric values, rates, conditions or observations that would signal further evaluation. It needs to be re-emphasized that conditions beyond normal or outside expectations do not automatically impact compliance determinations. Conditions differing from expectations alert the geotechnical program to scrutinize incoming data more closely and to make assessments of possible performance impact.

Displacement, deformation, closure, and fracture evolve slowly. Therefore, annual assessment of the geotechnical COMPs will adequately address conditions that would be of concern for predicting repository performance or that are related to long-term regulatory compliance. This assessment contains the third geotechnical monitoring report since disposal operations began. Implementation and evaluation of possible trigger events, features, phenomena, trends, and conditions that would warrant further actions will be refined as experience is gained.

The previous annual assessments of geotechnical COMPs provided the opportunity to review parameters and phenomena in the context of the EPA rule. The geomechanical monitoring program reported in the GAR is implemented primarily for continuous assessment of the

underground facilities. Data for interpreting the behavior of underground openings are compared with established design criteria. The SA evaluates these data with respect to performance assessment as required by the EPA rule.

2.2.1 Creep Closure

The GAR compiles all geotechnical operational safety data gathered from the underground. The most readily quantifiable geomechanical response in the WIPP underground is creep closure. The GAR routinely measures and reports creep deformation, either from rib-to-rib, roof-to-floor, or extensometer borehole measurements. Rates of closure are relatively constant within each zone of interest and usually range from about 1-5 cm/yr. A closure rate in terms of cm/yr can be expressed as a global or nominal creep rate by dividing the displacement by the room dimension and converting time into seconds. Nominally these rates are of the order of 1×10^{-10} /sec and are quite steady over significant periods. From experience, increases and decreases of rates such as these might vary by 20 percent without undue concern. Therefore the "trigger value" for creep deformation was set as one order of magnitude increase in creep rate. Such a rate increase would alert the geotechnical staff to scrutinize the area exhibiting accelerating creep rates. Tertiary creep is an expected (eventually) phenomenon and its manifestation would help validate predictive capabilities of the computational models.

Extensive GAR data suggest that possible trigger values could be derived from creep rate changes. The WIPP underground is very stable, relative to most operating production mines, and deformation is steady for long periods. However, under certain conditions, creep rates accelerate which indicates a structural change of the deformation processes. Arching of microfractures to an overlying clay seam might create the onset of the roof beam de-coupling, and increase the measured closure rate. Phenomena of fracture coalescence and DRZ growth comprise important elements of compliance confirmation. Therefore, a measured creep rate change over a yearly period constitutes the COMP trigger value for creep closure. Rate changes would necessarily be evaluated on a case-by-case basis since closure is related to many factors such as age of the opening, location in the room or drift, convergence history, recent excavations, and geometry of the excavations.

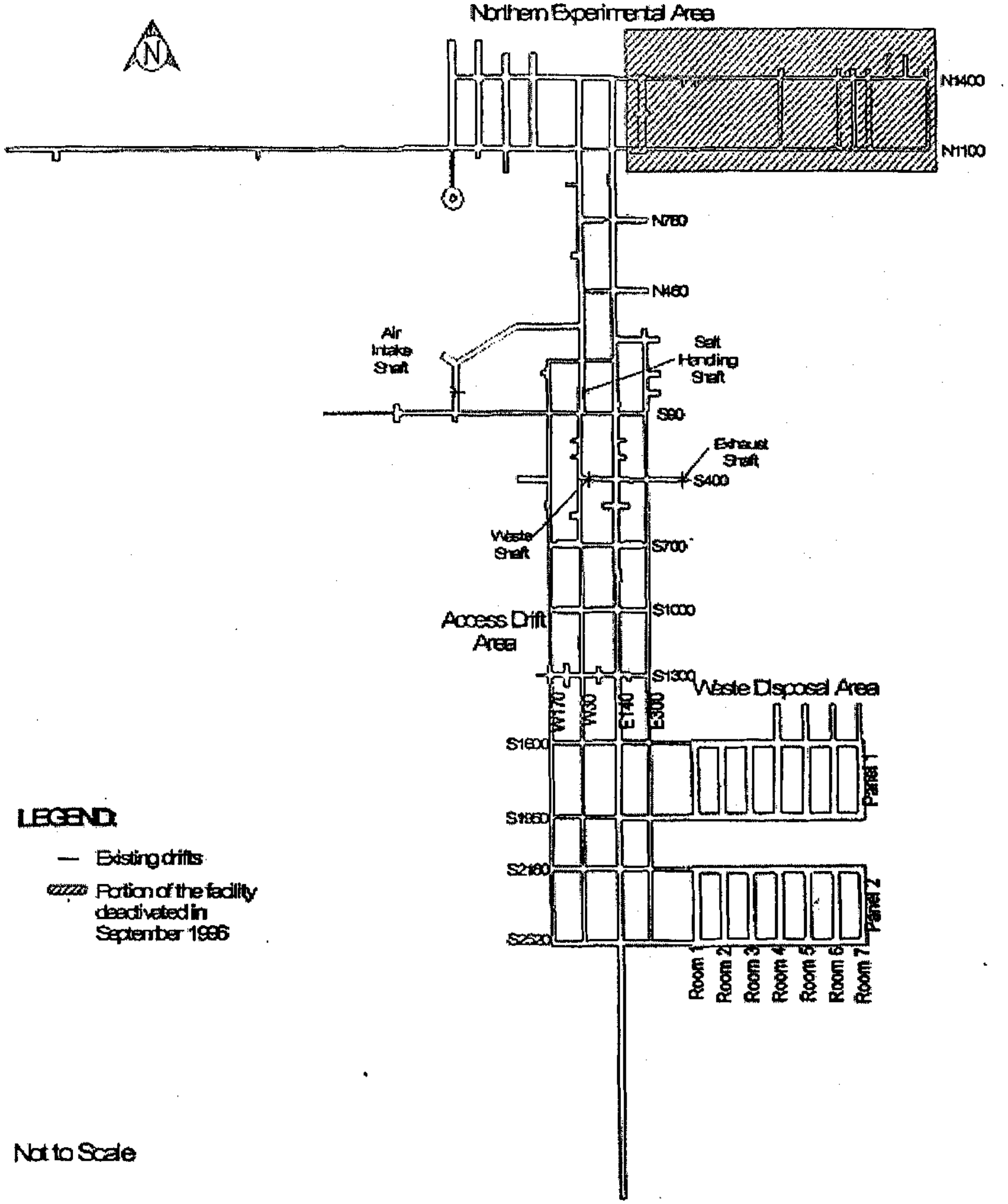

Figure 2.1 Current Configuration of the WIPP Underground (after DOE 2001a).

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The creep deformation COMP is addressed by examining the deformations measured in specific regions of the underground including: (1) Shafts and Shaft Stations, (2) the Northern Experimental Area, and (3) Access Drifts and Waste Disposal Areas. Figure 2.1 shows the current configuration of the WIPP underground with specific elements and regions annotated for reference. Details of the examination for each of these three regions are discussed below under separate headings.

2.2.1.1 Shafts and Shaft Stations

The WIPP underground is serviced by four vertical shafts including the following: (1) Salt Handling Shaft, (2) Waste Shaft, (3) Exhaust Shaft, and (4) Air Intake Shaft. At the repository level (approximately 650 meters below ground surface), enlarged rooms have been excavated around the shafts to allow for movement of equipment, personnel, mined salt and waste into or out of the facility. The enlarged rooms are called shaft stations and assigned designations consistent with the shaft they service, e.g., Salt Handling Shaft Station.

Shafts. With the exception of the Salt Handling Shaft, the shafts are configured similarly. From the ground surface to the top of the Salado Formation, the shafts are lined with unreinforced concrete. Reinforced concrete keys are cast at the Salado/Rustler interface with the shafts extending through the keys to the Salado. Below the keys, the shafts are essentially "open holes" through the Salado Formation and terminate either at the repository horizon or at sumps that extend approximately 40 meters below the repository horizon. In the Salt Handling Shaft, a steel liner is grouted in place from the ground surface to the top of the Salado. Similar to the three other shafts, the Salt Handling Shaft is configured with a reinforced concrete key and is "open-hole" to its terminus. For safety purposes, the portions of the open shafts that extend through the Salado are typically supported using wire mesh anchored with rock bolts to contain rock fragments that may become detached from the shaft walls. Within the Salado Formation, the diameters of the four shafts range from approximately 4 m to 7 m.

Data available for assessing creep deformations in the salt surrounding the shafts are derived exclusively from routine inspections and extensometers extending radially from the shaft walls. These data are reported in the GAR. The Salt Handling Shaft, Waste Shaft, and Air Intake Shaft are inspected weekly by underground operations personnel. Although the primary purpose of these inspections is to assess the conditions of the hoisting and mechanical equipment, observations are also made to determine the condition of the shaft walls, particularly with respect to water seepage, loose rock, and sloughing. In contrast to the other three shafts, the Exhaust Shaft is inspected quarterly using remote-controlled video equipment. *Based on these visual observations, all four shafts are in satisfactory condition and have required no significant ground-control support during the reporting period.*

Shortly after its construction, each shaft was instrumented with extensometers to measure the inward movement of the salt at three levels within the Salado Formation. In addition to COMPs assessment, measurements of shaft closure are used periodically as a calibration of calculational models and have been used in shaft seal system design. The approximate depths corresponding to the three instrumented levels are 330 m, 480 m and 630 m. Three extensometers are emplaced at each level to form an array. The extensometers comprising each array extend radially outward from the shaft walls and are equally spaced around the perimeter of the shaft wall. Over the years,

some of these extensometers have malfunctioned. As a result, reliable data are not available at some locations.

Table 2.3 provides a summary of the current (1999-2000) displacement rates of the shaft walls based on extensometer data reported in the GAR. The rates make use of collar displacement measured relative to the deepest anchor for individual extensometers. Rates range from 0.018 cm/yr to 0.241 cm/yr and increase with depth, as expected, because of the higher stress levels associated with the overburden at greater depth. Dividing the displacement rates by the typical shaft radius (say 3 m) and expressing the results in units of 1/sec yields creep rates that range from $1.9x10^{-12}$/sec to $2.5x10^{-11}$/sec. These creep rates are very low and are typical of rates for stable openings mined from salt. Table 2.3 also gives displacement rates for the previous reporting period (1998 to 1999) and the percentage change in these rates compared to the current rates. In general, the rate changes are small and some are slightly negative. Negative rate changes indicate the displacement of salt into the shafts is slowing with time. One rather large increase in displacement rate is shown for the 627-m level of the Salt Handling Shaft. This rate increase follows a similar trend measured during the last reporting period; however, the current rate is still lower than the rates measured in the Waste Handling and Exhaust shafts at similar depths. Deformations at this location will be monitored closely during the next reporting period. *Based on visual observations and quantitative displacement measurements, creep deformations associated with the WIPP shafts are acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

Shaft Station. Shaft station openings are typically rectangular in cross-section with heights ranging from approximately 4 to 6 m and widths ranging from 6 to 10 m. Over the life-time of the individual shaft stations, modifications have been made that have altered the dimensions of the openings. For example, portions of the Salt Handling Shaft Station have been enlarged by removing the roof beam that extended up to anhydrite "b". In the Waste Handling Shaft Station, the walls have been trimmed to enlarge the openings for operational purposes.

The effects of creep on the shaft stations are assessed through visual observations and displacement measurements made using extensometers and convergence points. Because of the modifications made over the years, some of the original instrumentation has been removed or relocated. In addition, some instruments have malfunctioned or been damaged and no longer provide reliable data. Displacement rates available from the GAR for the current reporting period (1999-2000) and the previous reporting period (1998-1999) are summarized in Table 2.3. Most of the measurements are for vertical closure; however, at least one measurement of horizontal closure is available for both the Salt Handling and Waste Shaft Stations. Based on convergence data, current vertical displacement rates range from about 0.9 to 5.3 cm/yr, while current horizontal displacement rates range from about 2.4 to 2.9 cm/yr. Dividing convergence rates by the average room dimension (say 6 m) and expressing the results in units of 1/sec yields vertical and horizontal creep rates of approximately $2x10^{-10}$/sec. These rates are somewhat higher than those measured in the shafts but are still low and represent typical creep rates for stable openings in salt. An examination of the percentage changes in displacement rates shown in Table 2.3 suggests the current displacement rates are essentially identical to those measured during the previous reporting period. Based on the extensometer and convergence data, as well as the limited maintenance required in the shaft stations during the last year, *creep deformations associated with the WIPP shaft stations are considered acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

2.2.1.2 Northern Experimental Area

The Northern Experimental Area was constructed in the early 1980's to characterize the site and obtain in situ geotechnical data from underground excavations. During the experiments, the area was heavily instrumented to examine the structural response of the openings. Following completion of the experiments, access to the area was blocked in 1996 and only a few of the instruments (primarily extensometers and convergence meters) remain active. These instruments have been monitored remotely in the past few years because of restricted access to the area. During the current reporting period for the GAR, portions of the Northern Experimental Area were reopened to assess ground conditions. Following spot bolting, systematic pattern bolting in Site Preliminary Design Validation (SPDV) Test Room 4 and activation of ventilation, operational use of the area for salt storage was established. Some manual convergence measurements were re-established following re-entry and new convergence meters were also installed in some areas; however, some of the existing instrumentation was removed to allow for vehicular traffic.

A summary of the displacement rates measured for openings in the Northern Experimental Area is provided in Table 2.4 for both the current reporting period and the previous reporting period. With the exception of one location (Room L4, Roof), the current displacement rates are about the same or slightly lower than rates measured during the previous reporting period. The higher rate in Room L4 is possibly a result of lateral displacement and some opening of a clay seam above the roof. This location will be monitored closely during the next reporting period to evaluate the possibility of roof beam instability. With the exception of this one location, *creep deformations associated with openings in the Northern Experimental Area are considered acceptable and meet the TV requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

Table 2.3 Summary of Closure Rates for WIPP Shafts and Shaft Stations

Location	Inst. Type[a]	Displacement Rate (cm/yr)		Change In Rate (%)
		1998–1999	1999–2000	
Salt Handling Shaft				
627 m level, S45W	Ext	0.102	0.147	45.0
Waste Handling Shaft				
326 m level, N45W	Ext	0.030	0.018	-41.7
326 m level, S15W	Ext	0.028	0.018	-36.4
477 m level, N45W	Ext	0.081	0.086	6.3
477 m level, N75E	Ext	0.071	0.069	-3.6
477 m level, S15W	Ext	0.079	0.089	12.9
628 m level, N45W	Ext	0.213	0.203	-4.8
628 m level, N75E	Ext	0.193	0.203	5.3
628 m level, S15W	Ext	0.224	0.241	8.0
Exhaust Shaft				
479 m level, N75E	Ext	NA[b]	0.061	NA
479 m level, N45W	Ext	NA	0.066	NA
479 m level, S15W	Ext	NA	0.066	NA
630 m level, N75E	Ext	NA	0.234	NA
630 m level, S15W	Ext	NA	0.173	NA
Salt Handling Shaft Station				
E0 Drift – N39 (Vertical, CL[c])	CP	5.403	5.316	-1.6
E0 Drift – N39 (Horizontal, CL)	CP	2.791	2.921	4.6
E0 Drift – W12 (Vertical, W. Rib)	CP	2.202	2.197	-0.2
E0 Drift – S18 (Vertical, CL)	CP	4.308	4.178	-3.0
E0 Drift – S18 (Vertical, E. Rib)	CP	4.917	4.133	-16.0
E0 Drift – S18 (Vertical, W. Rib)	CP	2.858	2.865	0.3
E0 Drift – S30 (Vertical, CL)	CP	4.623	4.442	-3.9
E0 Drift – S65 (Vertical, CL)	CP	3.432	3.434	0.1
Waste Shaft Station				
S400 Drift – W30 (Vertical, CL)	Ext	0.876	0.927	5.8
S400 Drift – E140 (Vertical, CL)	Ext	1.689	1.880	11.3
S400 Drift – E30 (Horizontal, CL)	CP	2.502	2.416	-3.5
S400 Drift – E90 (Horizontal, CL)	CP	2.700	2.695	-0.2

(a) Instrument Type: Ext = extensometer; CP = convergence point
(b) NA = Not available
(c) CL = Centerline

Table 2.4 Summary of Closure Rates for Openings in the Northern Experimental Area

Location	Inst. Type[a]	Displacement Rate (cm/yr)		Change In Rate (%)
		1998–1999	1999–2000	
Room L3, Roof	Ext	2.715	NA[b]	NA
Room L4, Roof	Ext	1.128	1.651	46.4
SPDV[c] Room 4 – N1325, Roof	Ext	2.487	2.319	-6.8
SPDV Room 4 – N1250, East ¼ Pt.	Ext	1.189	1.085	-8.7
SPDV Room 4 – N1250, Roof	Ext	2.093	1.811	-13.5
SPDV Room 4 – N1250, West ¼ Pt.	Ext	3.620	3.147	-13.1
SPDV Room 4 – N1175, Roof	Ext	1.435	1.499	4.5
N1420 Drift – E1551	CP	2.489	2.083	-16.3
N1420 Drift – E1451	CP	2.286	2.057	-10.0
Room D – N1432, Centerline	CP	3.023	2.565	-15.2
Room D – N1266, Centerline	CP	2.667	2.184	-18.1
Room D – N1187, Centerline	CP	2.692	2.184	-18.9
N1100 Drift – E1620	CP	1.422	1.372	-3.5
N1100 Drift – E1530	CP	1.702	NA	NA
E300 Drift – N1275	CP	8.509	7.772	-8.7

(a) Instrument Type: Ext = extensometer; CP = convergence point
(b) NA = Not available
(c) SPDV = Site Preliminary Design Validation

2.2.1.3 Access Drifts and Waste Disposal Area

Access Drifts. The access drifts comprise the four major North-South drifts extending southward from near the Salt Handling Shaft to the entries into the waste disposal panels and several short cross-drifts intersecting these major drifts (see Figure 2.1). Two of the North-South drifts also extend northward to provide access to the Northern Experimental Area. The portions of the four drifts extending to the south provide haulage ways for salt excavated from and waste transported to the waste disposal areas. In addition, the access drifts are used for ventilation. Drift E140 was excavated all the way to the southern boundary of the repository in the early 1980s. Drifts W170, W30, and E300 were developed at approximately the same time as Drift E140, but were terminated at S2180. *During the current reporting period of the GAR, the extension of the three drifts southward to S2520 was completed and other portions of the drifts were trimmed, scaled and milled all in an effort to allow access for mining of Waste Disposal Panel 2.* The access drifts are typically rectangular in cross-section with heights ranging from 2.4 m to 6.4 m and widths ranging from 4.3 m to 9.2 m.

Assessment of creep deformations in the access drifts is made through the examination of extensometer and convergence point data reported annually in the GAR. Tables 2.5 and 2.6 summarize, respectively, the vertical and horizontal displacement data reported in the most recent GAR. Each table examines percentage changes between displacement rates measured during the current and previous annual reporting periods and breaks these percentage changes into ranges of equal size (i.e., 20 percentage points). Only data from instruments located along the drift

centerlines are reported here. In addition, extensometer data are based on only the displacements of the collar relative to the deepest anchor. The numbers shown in the tables represent the number of instrumented locations that fall within the range of the indicated percentage change. For example, data from thirty vertically-oriented extensometers installed in the access drifts were assessed with seven of these instruments showing percentage changes between –20 and 0%, eighteen showing changes between 0 to 20%, three showing changes between 20 to 40%, one showing a change between 40 and 60% and one showing a change between 60 and 80%. The maximum displacement rates corresponding to these data are given below.

Maximum Vertical Displacement Rates Along Access Drift Centerlines:

5.872 cm/yr – based on extensometer data
8.176 cm/yr – based on convergence point data

Maximum Horizontal Displacement Rate Along Access Drift Centerlines:

3.940 cm/yr – based on convergence point data

Using a typical average drift dimension of 5 m and the maximum displacement rates shown above yields an inferred maximum creep rate of approximately 5×10^{-10}/sec. This rate is relatively high so further analyses were performed for this assessment as described below.

Most (approximately 95% of all data) of the changes in vertical and horizontal displacement rates fall within two categories or subdivisions shown in Tables 2.5 and 2.6, i.e., -20 to 0% and 0 to 20%, indicating that current creep deformations in the access drifts are approximately the same as they were for the previous reporting period. The remaining few data show relatively large changes in rate and indicate accelerations of displacement in some locations. As a general rule, accelerations in displacement would be cause for concern; however, a careful examination of these relatively large accelerations in displacement reveals that the extensometers/convergence points associated with these accelerations are, for the most part, located south of S1950 and east of W30 near recent excavations, i.e., the North-South Access Drift extensions and Panel 2 (see Figure 2.1). Because the highest displacement rates are probably induced by recently completed mining activities and will likely decrease with time, no remedial action is currently required; however, the rates will be carefully monitored during the next reporting period. Even when the high creep rates attributed to recent mining activities are considered, *creep deformations associated with the Access Drifts are acceptable and meet the trigger value requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

Waste Disposal Area: The Waste Disposal Area is located at the extreme southern end of the WIPP facility and is serviced by the access drifts described above. Eventually, the Waste Disposal Area will include eight disposal panels each comprising seven rooms. Panel 1 was excavated in the late 1980s and is currently being filled with waste. Excavation of Panel 2 was completed during the reporting period. The waste emplacement rooms are rectangular in cross-section with a height of 4 m and a width of 10 m. Entry drifts that provide access into the disposal rooms are also rectangular with heights of 3.65 m and widths of 4.3 m.

Table 2.5 Summary of Changes in Vertical Displacement Rates Measured Along the Centerlines of the WIPP Access Drifts and Waste Disposal Area Openings

Location	Number of Instrument Locations Experiencing the Indicated Percentage Change				
	Percentage Change in Displacement Rate for Measurements Made During the 1998-1999 and 1999-2000 Reporting Periods				
	-20% to 0%	0% to 20%	20% to 40%	40% to 60%	60% to 80%
Access Drifts					
Extensometers[(a)]	7	18	3	1	1
Convergence Points	14	77	7	3	1
Waste Disposal Area					
Extensometers[(a)]	2	9	6	4	0
Convergence Points	7	28	8	9	1

(a) Based on displacement of collar relative to deepest anchor

Table 2.6 Summary of Changes in Horizontal Displacement Rates Measured Along the Centerlines of WIPP Access Drifts and Waste Disposal Area Openings

Location	Number of Instrument Locations Experiencing the Indicated Percentage Change				
	Percentage Change in Displacement Rate for Measurements Made During the 1998-1999 and 1999-2000 Reporting Periods				
	-20% to 0%	0% to 20%	20% to 40%	40% to 60%	60% to 80%
Access Drifts					
Extensometers[(a)]	0	0	0	0	0
Convergence Points	16	32	2	1	0
Waste Disposal Area					
Extensometers[(a)]	1	10	1	1	0
Convergence Points	4	18	12	1	0

(a) Based on displacement of collar relative to deepest anchor

Assessment of creep deformations in the waste disposal area is made through the examination of extensometer and convergence point data reported annually in the GAR. Tables 2.5 and 2.6 (presented previously) summarize, respectively, the vertical and horizontal displacement data reported in the most recent GAR. Each table examines percentage changes between displacement rates measured during the current and previous annual reporting periods and breaks these percentage changes into ranges of equal size (i.e., 20 percentage points). Only data from instruments located along the drift centerlines are reported here. In addition, extensometer data are based on only displacements of the collar relative to the deepest anchor. The maximum displacement rates corresponding to these data are given below.

Maximum Vertical Displacement Rates Along Waste Disposal Area Centerlines:

3.523 cm/yr – based on extensometer data
11.146 cm/yr – based on convergence point data

Maximum Horizontal Displacement Rates Along Waste Disposal Area Centerlines:

2.195 cm/yr – based on extensometer data
4.483 cm/yr – based on convergence point data

Using a typical average disposal-area-opening dimension of 7 m and the maximum displacement rates shown above yields an inferred maximum creep rate of approximately $2x10^{-10}$/sec to $5x10^{-10}$/sec. As with the access drift data, maximum creep rates for the waste disposal area are relatively high so further analyses were performed for this assessment as discussed below.

In contrast to the Access Drift data, only approximately 65% of all disposal area data indicate changes in vertical and horizontal displacement rates that fall within the -20 to 0% and 0 to 20% subdivisions. The remaining data show relatively large changes in rate (up to a 60 to 80% increase) indicating accelerations of displacement. A careful examination of these relatively large accelerations in displacement reveals that the extensometers/convergence points associated with these accelerations are, for the most part, located along the southern entry way to the rooms in Panel 1. Patchet et al. (2001) have conducted three-dimensional modeling to predict the effect of Panel 2 excavation on Panel 1 deformations and have concluded that convergence rates in Panel 1 could increase by as much as 60 to 96 percent which is consistent with the observations. Because the highest displacement rates are probably induced by recent mining activities and will likely decrease with time, no remedial action is currently required; however, the rates will be carefully monitored during the next reporting period. In addition, convergence points placed in the newly excavated Panel 2 will also be closely monitored to assess creep deformations. Even when the high creep rates attributed to recent mining activities are considered, *creep deformations associated with the Waste Disposal Area are acceptable and meet the trigger value requiring creep deformation rates to change by less than one-order of magnitude in a one-year period.*

Creep Closure - 2001:

Trigger Value Derivation				
COMP Title:	Creep Closure			
COMP Units:	Closure Rate (sec^{-1})			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Closure	Instrumentation throughout the underground.	Munson-Dawson (MD) Constitutive Model	
COMP Derivation Procedure				
Annually evaluate GAR for centerline closure rates, compare to previous year's rate. If closure rate increases by greater than one order of magnitude, initiate technical review.				
Compliance and Performance Models				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Repository Fluid Flow	Creep Closure	Porosity Surface, waste compaction, characteristics, waste properties, evolution of underground setting	SANTOS, surface porosity calculations	Provides validation of the CCA creep closure model.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Creep Closure	Greater than one order of magnitude increase in closure rate.	The closure rate increase signals potential de-coupling of rock.		

2.2.2 Extent of Deformation

The extent of brittle deformation can have important implications to PA. As modeled in PA, the DRZ releases brine to the disposal room while properties of the DRZ control hydrologic communication between disposal panels. Therefore, extent of deformation relates directly to a conceptual model used in performance determination. If characteristics could be tracked from inception, the spatial and temporal evolution of the DRZ would provide a validation benchmark for damage calculations. To this end, a hydrologic profile including permeability and pore pressure is being compiled within the SA Rock Mechanics Program.

Measurements in the GAR include borehole inspections, fracture mapping and borehole logging. These observations are linked closely to other monitoring requirements concerned with initiation of brittle deformation and displacement of deformation features. These monitoring requirements

define characteristics of the DRZ which could validate the baseline conceptual model, its flow characteristics, saturation and de-watering. The extent of deformation quantifies the DRZ, a significant element of performance assessment analyses.

The Geotechnical Engineering Department at WIPP has compiled back-fracturing data into a database. The supporting data for the GAR (Volume 2, DOE 2001a) plots plan and isometric views of fractures. Fracture development is most continuous parallel to the rooms and near the upper corners. These fractures are designated "low angle fractures" relative to the horizontal axis. The current excavation horizon results in a 2-meter thick beam of halite between the roof and Clay Seam G. Low angle fractures arch over rooms and asymptotically connect with Clay Seam G. The extent of back fracture occupies the roof beam to Clay Seam G, although some borehole offset is observed at Clay Seam H. Although the preponderance of monitoring information derives from the roof (back), buckling extends in the floor to the base of Marker Bed 139 which is located about 2 m below the disposal room floors. Fracture mapping thus far is consistent with expectations and tracks stress trajectories derived from computational work. At this time, a comprehensive model and supporting data for model parameters for damage evolution has not been developed and incorporated into PA.

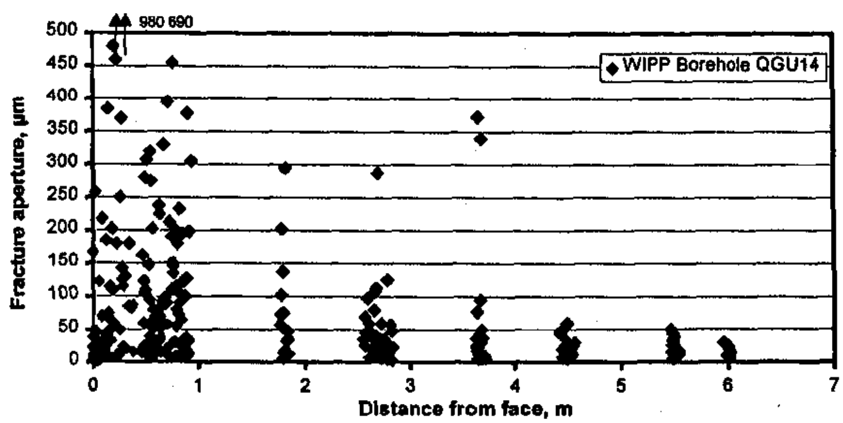
In addition to results presented in the GAR, two activities have been completed under the geotechnical experimental programs being undertaken cooperatively between the SA and the M&OC. These two activities have produced results appropriate for defining the extent of deformation around openings in salt and have been reported by Holcomb and Hardy in SNL's Technical Baseline Report (SNL 2001c) and Bryan et al. (2001). The activities included cross-hole acoustic velocity measurements and laboratory core analyses.

The cross-hole acoustic velocity measurements were conducted in a 9-hole pattern drilled in the rib of the Q Room access. Each hole was drilled normal to the rib face in a horizontal orientation and was 10.16 cm in diameter, and 6 m in depth. The holes were arranged in a grid pattern with three holes each located near the top (back), middle and bottom (floor) of the rib. The vertical or horizontal distance between adjacent pairs of holes was nominally one meter. Piezoelectric transducers were used as both the transmitter and receiver of ultrasonic elastic waves. These transducers were inserted into the holes and run in and out of the holes to measure cross-hole wave speeds at various distances in from the rib. Near the rib face, wave speeds were relatively low because of microfracturing. Away from the rib face wave speeds increased until undisturbed zones of salt were encountered. Beyond this point, the wave speeds remained constant at about 4.4 km/sec. The extent of the DRZ was inferred from the wave speed measurements as the depth in the hole at which the wave speeds reach a constant value. At the rib mid-height, the extent of the DRZ was two meters and possibly as much as four meters. Near the back and floor, the DRZ was shallower (one meter or less) and not detectable in some cases. The local lithology was thought to play a role in determining whether the DRZ develops in the zones near the back and floor, with some holes showing a DRZ and their neighbors a meter or two away showing little or nothing. A complete description of the investigation is provided in Section 6 of SNL Technical Baseline Report (SNL 2001c).

The laboratory core analyses were performed on cores recovered from one of the holes used for the cross-hole acoustic wave tests performed in the Room Q access. Analyses included measurement of fracture aperture and spacing, porosity, and microstructural dislocation density. Fracture aperture and spacing are directly relevant to the Extent of Deformation COMP. The cores used to

measure fracture aperture and spacing were sliced lengthwise into quarters, impregnated with fluorescent dye, ground flat, mounted on oversized glass plates, and then cut and polished as thick (2-3 mm) sections. Measurements were taken along the centerline of the thick sections (parallel to the core axis), which would intersect fractures oriented parallel to the opening axis and perpendicular to the core hole. Figure 2.2 plots fracture aperture versus distance from the rib face and shows that fractures were observed at depths up to 6 m; however, the largest fracture apertures (500 μm) were found near the rib face. At a depth of approximately four meters, the aperture size was reduced to about 50 to 100 μm and remained at this level to the full depth of the core (i.e., 6 m). Additional details of the study, including results for moisture content, porosity and dislocation density, can be found in Bryan et al. (2001).

Figure 2.2 Measured fracture apertures in salt cores extracted from disturbed rock zones adjacent to a ~10-year-old drift in the WIPP (after Bryan et al, 2001)



Data provided in the GAR suggest that brittle deformation extends at least 2 m (to Clay Seam G) and perhaps as much as 4.5 m (to Clay Seam H) above the roof of the WIPP openings. In addition, brittle deformation extends below the floor of the openings to at least the base of Marker Bed 139 (approximately 2 to 3 m). Recent studies performed under the geotechnical investigation programs have characterized the extent of brittle deformation in the ribs using ultrasonic velocity measurements and core analyses. The results of these studies indicate that micro- and macrofractures are present 2 m, and perhaps up to 4 or 6 m, from the rib face. These combined results are for older openings in which the DRZ and deformational features have matured (essentially a snapshot in time), but provide little information on how brittle deformation evolves with time. Therefore, it is evident that the preliminary trigger value of 1 meter of growth per year is neither tractable nor quantitatively meaningful with the current data set. The trigger value for extent of deformation may need to be re-evaluated or other means of monitoring may need to be developed if the current trigger value is to be retained. Owing to the fact that ground-control is not an issue, the need for immediate re-evaluation of the trigger value is not essential to underground operations.

Extent of Deformation - 2001:

Trigger Value Derivation				
COMP Title:	Extent of Deformation			
COMP Units:	Areal extent (length, direction)			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Displacement	Meters	Room geometry	
COMP Derivation Procedure				
Extent of deformation deduced from borehole extensometers, feeler gauges, and visual inspections are examined yearly for active cross sections. Anomalous growth is determined by comparison.				
Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
DRZ Conceptual Model	Micro- and macro-fracturing in the Salado Formation	Constitutive model from laboratory and field databases.	Permeability around panel closures was assigned a constant value of $10^{-15} m^2$	DRZ spatial and temporal properties have important PA implications for permeability to gas, brine, and two-phase flow.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Fractures at depth	Growth of 1 m/year[(a)]	Coalescence of fractures at depth in rock surrounding drifts will control panel closure functionality and design, as well as discretization of PA models.		

(a) Trigger value may need to be re-evaluated.

2.2.3 Initiation of Brittle Deformation

Initiation of brittle deformation around WIPP openings is not being directly measured and is therefore a qualitative observational parameter. By definition, qualitative COMPS can be subjective and are not prone to the development of well-defined trigger values. Brittle deformation eventually leads to features that are measured as part of geotechnical monitoring requirements, such as the extent and displacement of deformation features. Initiation of brittle deformation is expected to begin immediately upon creation of an opening. Initiation and growth of the DRZ are fundamental observational goals of the DRZ investigations currently being conducted under the geotechnical experimental programs, as discussed above. The ongoing cooperative geophysical program will help quantify damage evolution around WIPP openings. Initiation and growth of damaged rock zones are important considerations to operational period panel closures as well as compliance performance assessment calculations. Based on field observations, including the reshaping of Room 7, of Panel 1 for the first receipt of waste, brittle deformation is widely experienced by MB 139 as the floor heaves. Owing to the lithology and structural setting, brittle anhydrite response, as witnessed, is expected. Such observations help quantify modeling assumptions, but are routine and anticipated.

No changes to the technical positions are suggested for this COMP. Because initiation of brittle deformation is not readily quantifiable within the geotechnical monitoring system currently deployed at the WIPP, either additional monitoring techniques could be suggested (such as acoustic emission) or another parameter could be identified for monitoring.

Initiation of Brittle Deformation - 2001:

Trigger Value Derivation				
COMP Title:	Initiation of Brittle Deformation			
COMP Units:	Qualitative			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Geotechnical	Closure	Observational	Operational and Remedial	
COMP Derivation Procedure				
Qualitative and pertinent to operational considerations. Captured qualitatively in association with other COMPs				
Performance and Compliance Elements				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Not directly related to PA as currently measured	NA	NA	NA	NA
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Initiation of Brittle Deformation	None[(a)]	Qualitative COMPs can be subjective and are not prone to the development of meaningful trigger values.		

(a) Recommendation could be considered to add acoustic emissions for brittle monitoring or to replace this parameter with another more directly tied to performance assessment.

2.2.4 Displacement of Deformation Features

The displacement of deformation features primarily focuses on those features located in the immediate vicinity of the underground openings, e.g., mining-induced fractures and lithological units within several meters of the roof and floor. As discussed previously, fracture development is most continuous parallel to the openings and near the upper corners. These fractures tend to propagate or migrate by arching over and under the openings and, thus are designated "low angle fractures" relative to the horizontal axis. Typically, the fractures intersect or asymptotically approach lithologic units such as clay seams and anhydrite stringers. As a result, salt beams are formed. In the roof, the beams are de-coupled from the surrounding formation requiring use of ground support. In the floor, the beams sometimes buckle into the openings requiring floor milling and trimming. Lithologic units of primary interest are Clay G and H located approximately 2 m and 4.5 m, respectively, above the roof of a typical opening and Marker Bed 139 (anhydrite) located approximately 2 m below the floor.

Monitoring of these deformation features is accomplished by measuring the offset of boreholes drilled from the openings through the feature of interest. In general, these boreholes are aligned vertically (normal to the roof and floor surfaces) because of the location and orientation of the fractures and lithological units of interest. Currently, there are 142 observation boreholes located

throughout the WIPP underground. All of the holes are 7.6-cm (3-in) in diameter and many intersect more than one deformation feature. The ages of the observation holes vary from more than 17 years to less than one year (seven boreholes were drilled during the current reporting period of the GAR). Essentially all of the observation holes located in Panel 1 were drilled during 1999. Monitoring of deformation features via observation holes drilled in the floor of openings is no longer performed because of crushed-salt infilling in the holes.

The offset (or offsets) in each observation borehole is determined by visually estimating the degree of borehole occlusion. The direction of offset along displacement features is defined as the movement of the stratum nearer the observer relative to the stratum farther from the observer. Typically, the nearer stratum moves toward the center of the excavation. Based on previous observations in the underground, the magnitude of offset is usually greater in boreholes located near the ribs as compared to boreholes located along the centerline of openings.

Currently, 225 offsets are monitored in the 142 boreholes. To date, 23 offsets have completely occluded the observation boreholes and another 8 have partially occluded the holes by more than 75 percent. Of these totals, essentially all occluded and significantly occluded boreholes were drilled between 1992 and 1995. Holes in Panel 1 are no more than 25% occluded, but as pointed out above, these holes are relatively young having been drilled in 1999.

The trigger value for displacement of deformation features is the observation of a fully occluded borehole. *To date, 23 offsets, representing about 10% of all the offsets being monitored, meet or exceed the trigger value.* In addition, several other offsets will likely exceed the trigger value in future reporting periods. Exceedance of the trigger value, in and of itself, is not necessarily a cause for concern, particularly when the result is having no significant impact on safety or performance given current ground-control techniques. However, in view of the current assessment and the likelihood that many or all of the offsets will exceed the trigger value in the future, a re-evaluation of the trigger value for displacement of deformation features may be warranted. The recent excavation and instrumentation of Panel 2 may provide the information needed for the re-evaluation.

Displacement of Deformation Features - 2001:

Trigger Value Derivation				
COMP Title:	Displacement of Deformation Features			
COMP Units:	Length			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g. number, observation)	Compliance Baseline Value	
Geotechnical	Delta D/D_o	Observational	Not established	
COMP Derivation Procedure				
Observational – Lateral deformation across boreholes.				
Performance and Compliance Element				
Element Title	Parameter Type & ID or Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Not directly related to PA	N/A	N/A	N/A	N/A
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Borehole diameter closure	Obscured observational borehole.	If lateral displacement is sufficient to close diameter of observational borehole, technical evaluation of consequences will be initiated.		

2.2.5 Subsidence

Subsidence is currently monitored via elevation determination of 51 existing monuments and 14 of the National Geodetic Survey's vertical control points. To address EPA monitoring requirements, the most recent survey results (DOE 2000a) are reviewed and compared to possible trigger values. Because of the low extraction ratio and the relatively deep emplacement horizon (650 m), subsidence over the WIPP is expected to be much lower and slower than over potash mines. Maximum observed subsidence over potash mines near the WIPP is 1.5 m, occurring over a time period of months to a few years. Calculations show that the maximum subsidence predicted directly above the WIPP waste emplacement panels is 0.62 m assuming emplacement of CH-TRU waste and no backfill (Backfill Engineering Analysis Report [BEAR; WID 1994]). Further considerations, such as calculations of room closure, suggest that essentially all surface subsidence would occur during the first few centuries following construction of the WIPP so the average vertical displacement rates would be approximately 0.002 m/yr (0.006 ft/yr). Obviously, these predicted rates could be higher or lower depending on mining activities as well as other factors such as time. Because the annual vertical elevation changes are very small, survey accuracy, expressed as the vertical closure of an individual loop times the square root of the loop length, is of primary importance. For the current annual subsidence surveys, a Second-Order Class II loop closure accuracy of $8\text{ mm} \times \sqrt{\text{km}}$ (or $0.033\text{ ft} \times \sqrt{\text{mile}}$) or better was achieved in all cases.

Over the years, different data sets have been included in the annual surveys. In general, the data sets have included:

- 29 monuments surveyed from 1986 to 2000
- 2 monuments surveyed from 1989 to 2000
- 19 monuments surveyed from 1992 to 2000
- 1 monument surveyed from 1993 to 2000
- 14 National Geodetic Survey vertical control points surveyed from 1996 to 2000.

Four other monuments have also been included in various annual surveys, but were not included in the current surveys because the monuments no longer exist or have been physically disturbed. Historically, the surveys were conducted by private companies under subcontract to DOE; however, since 1993, the WIPP M&OC has conducted the surveys using a set of standardized methods.

The current annual surveys comprise ten leveling loops containing as few as two to as many as eleven monuments/control points per loop as shown in Figure 2.3. Elevations are referenced to Monument S-37 located approximately 7700 feet north of the most northerly boundary of the WIPP underground excavation. This location is considered to be far enough from the WIPP facility to be unaffected by excavation-induced subsidence expected directly above and near the WIPP underground. Survey accuracy for all loops was 0.005 ft × √mi or better which exceeds the Second-Order Class II closure accuracy by more than an order of magnitude. Adjusted elevations are determined for every monument/control point by proportioning the vertical closure error for each survey loop to the monuments/control points comprising the loop. The proportions are based on the number of instrument setups and distance between adjacent points within an individual loop.

The adjusted elevations for each monument/control point are plotted as functions of time to assess subsidence trends. Figures 2.4 through 2.7 provide, respectively, elevations for selected monuments including those located (1) directly above the northern experimental area, (2) near the salt handling shaft, (3) directly above the first waste emplacement panel, and (4) well outside the repository footprint of the WIPP underground excavation. As expected, subsidence is occurring directly above the underground openings (Figures 2.4 through 2.6); however the magnitude of the subsidence is small ranging from -0.10 feet to -0.17 feet. In contrast, little elevation change (e.g., -0.06 feet) is observed for Monuments S-48 and S-49 located outside the repository footprint (Figure 2.7) and, in fact, data from the last 7 annual surveys suggest the elevations of these monuments have increased slightly. Most of the observed subsidence has occurred in the period of time between 1987 and 1993, but as discussed above, consistent surveying practices were not implemented until 1993 so some of the observed elevation changes may be related to differences in methodology rather than subsidence. In general, the measured changes in elevations of the WIPP monuments/control points have been small since 1993 even though Panel 2 mining was initiated in 1999 and completed in October 2000. Based on three-dimensional modeling conducted by Patchet et al. [2001], the convergence rates within Panel 1 are predicted to increase by as much as 60 to 96 percent as a result of the mining of Panel 2. A likely manifestation of these higher

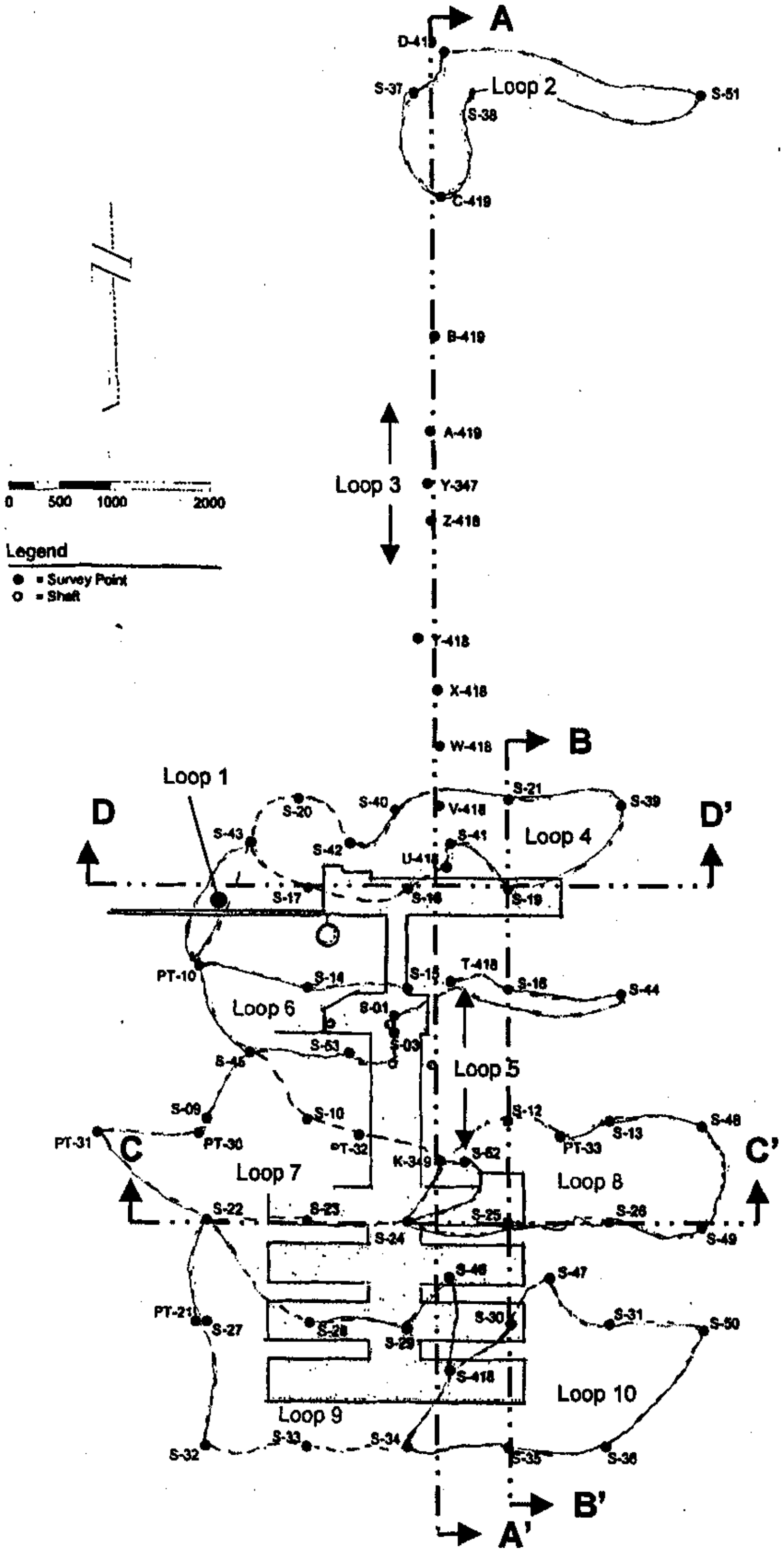


Figure 2.3 Monuments and Vertical Control Points Comprising WIPP Subsidence Survey Loops.

convergence rates is higher subsidence rates at the surface, particularly above Panel 1. Although the elevations of the monuments directly above Panel 1 (i.e., S-24 and S-25) have generally remained constant since 1993, Figure 2.6 does show small decreases in the elevations of S-24 and S-25 over the past 2 years that may be related to Panel 2 mining activities. These trends were expected in view of the just completed mining activities, but will be evaluated further after the results of the next annual survey become available. In general, results on a point-by-point basis are identical to the survey of one year ago with the exceptions discussed above

As time passes, subsidence is expected to be most pronounced directly above the WIPP underground excavations and will be less distinctive away from the repository footprint. Early results suggest this pattern is already occurring as shown in Figures 2.8 through 2.11 for the following subsidence profiles (shown in plan view in Figure 2.3):

- Section A-A', North-South section extending through the WIPP site
- Section B-B', North-South section extending from the north experimental area through the south emplacement panels
- Section C-C', East-West section extending through Panel 1
- Section D-D', East-West section extending through the northern experimental area.

The elevation changes of individual monuments shown in these figures are referenced to the elevations determined from the first annual surveys that incorporated the monument so direct temporal comparisons between pairs of monuments cannot be made in all cases. For example, only 29 monuments were included in the 1987 survey, while 50 and 65 monuments were included in the 1992 and 1996 surveys, respectively. Although direct comparisons cannot be made, several observations are possible including:

1. Monuments D-419 and S-38 located in the vicinity of the Reference Monument, S-37, are stable (Section A-A', Figure 2.8) showing very little change in elevation with time. This observation suggests the reference monument is stable and located outside the influence of any WIPP-induced subsidence.
2. The most significant subsidence (approximately – 0.15 ft) occurs directly above the northern experimental area (Monument S-18) and also above Panel 1 (Monuments S-24 and S-25) with slightly less subsidence near the Salt Handling Shaft (Monuments S-01 and S-03).
3. The highest subsidence rate is $6x10^{-3}$ m/yr and occurs at only one monument.
4. The effects of subsidence extend away from the repository footprint approximately 1,000 to 1,500 ft (e.g., S-26, Figure 2.10).
5. Ground surface elevation between the north experimental area and the Reference Monument, S-37 (Figure 2.8), appears to be rising slightly (< 0.05 ft).
6. Generally, subsidence magnitudes were largest for the 1992 survey but then were reduced in subsequent annual surveys. An exception is in the Panel 1 area where current data (2000 annual surveys) suggest subsidence magnitudes have returned to their 1992 levels probably resulting from the Panel 2 mining activities.

Furthermore, total subsidence and subsidence rates are small, and are approximately at the resolution level of the survey accuracy. These minor amounts of subsidence and low subsidence rates are expected and are well within normal ranges. *Based on the survey data available, subsidence rates of the ground surface at the WIPP are low and meet the trigger value requiring rates to be less than* $1x10^{-2}$ *m/yr.*

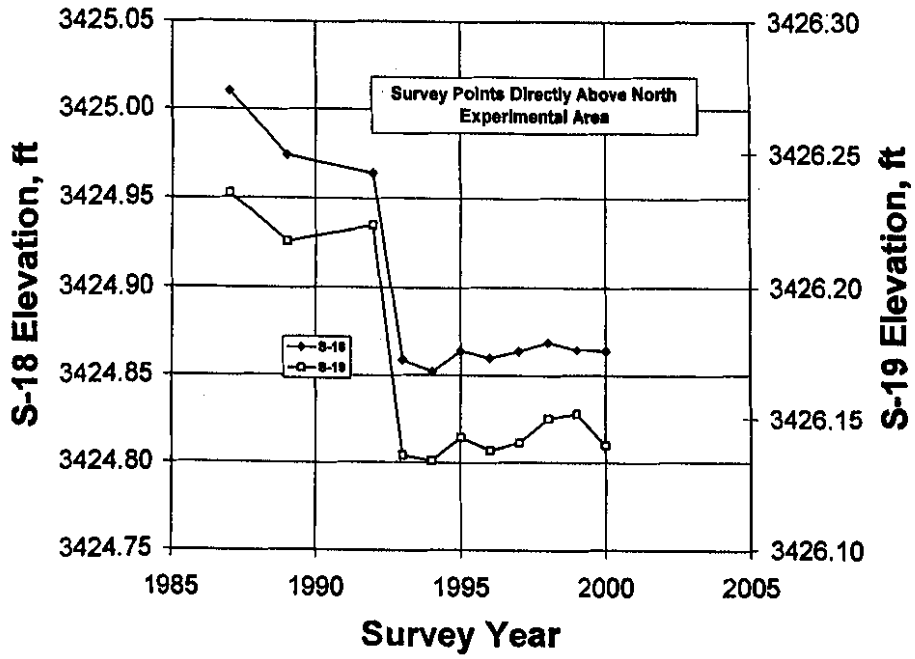


Figure 2.4. Elevations of WIPP Monuments S-18 and S-19 Located Directly Above North Experimental Area.

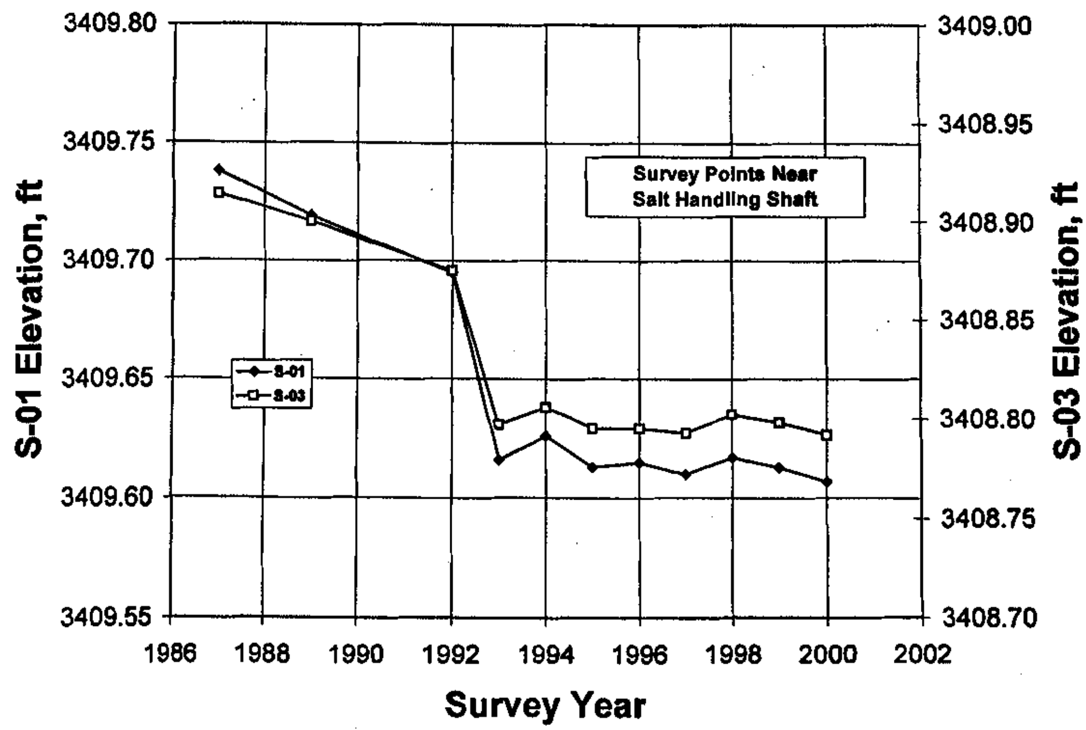


Figure 2.5 Elevations of WIPP Monuments S-01 and S-03 Located Near the Salt Handling Shaft.

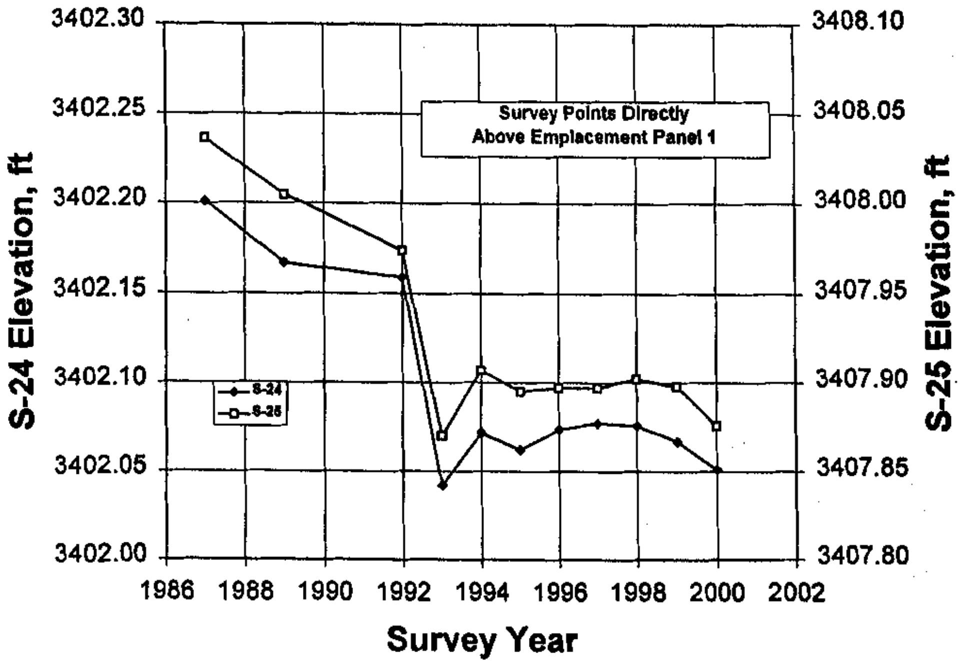


Figure 2.6 Elevations of WIPP Monuments S-24 and S-25 Located Directly Above Waste Emplacement Panel 1.

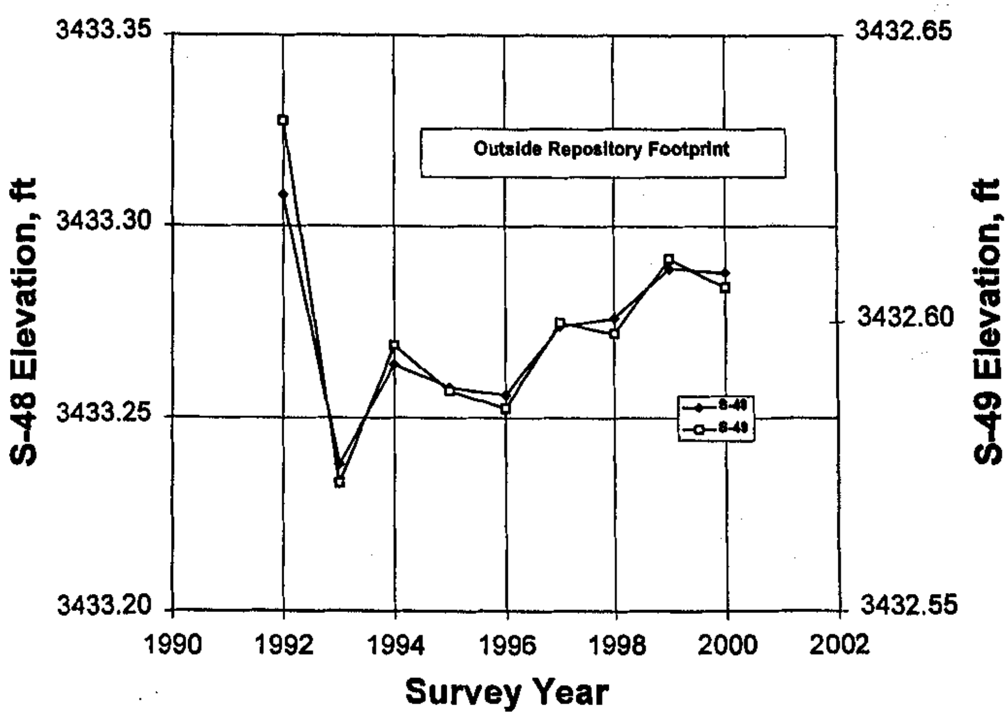


Figure 2.7 Elevations of WIPP Monuments S-48 and S-49 Located Outside the Repository Footprint.

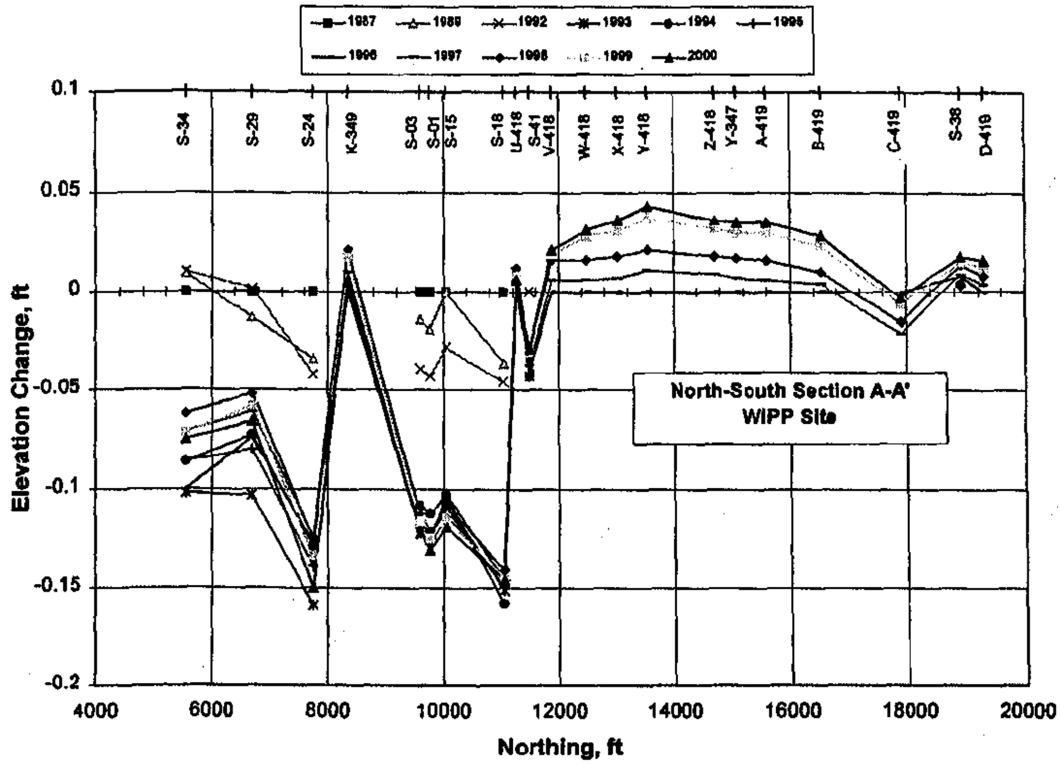


Figure 2.8 North-South Subsidence Profile A-A'

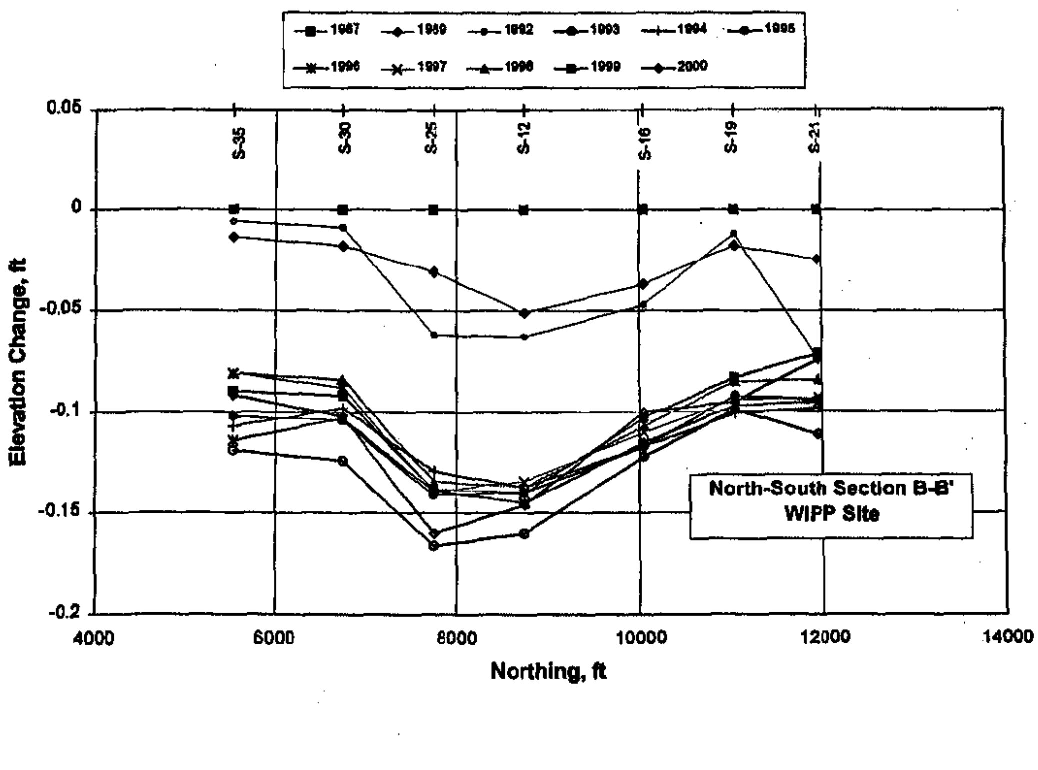


Figure 2.9 North-South Subsidence Profile B-B'.

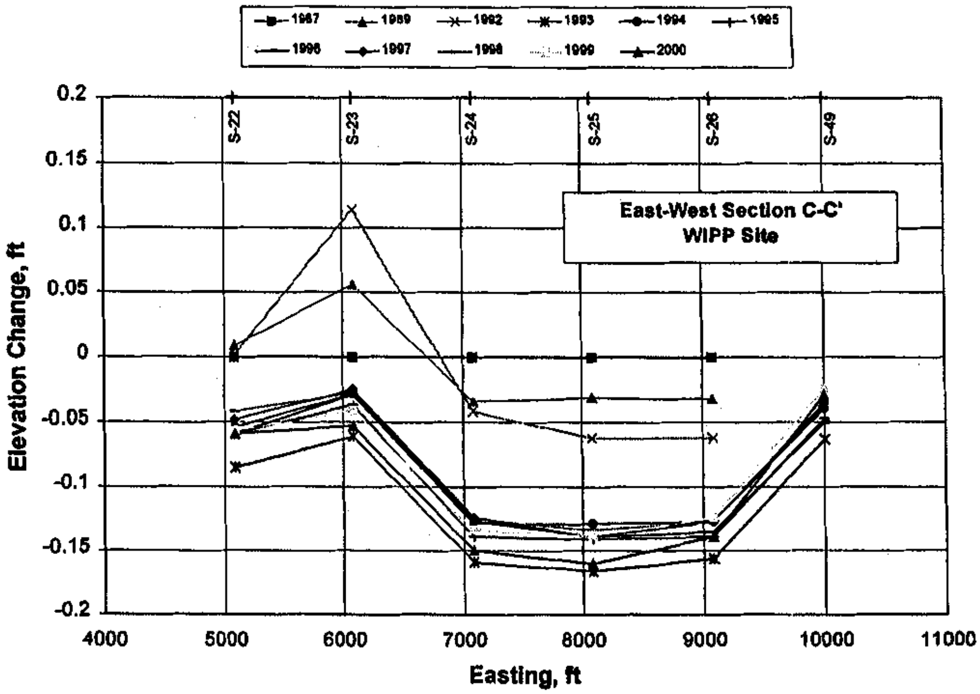


Figure 2.10 East-West Subsidence Profile C-C'.

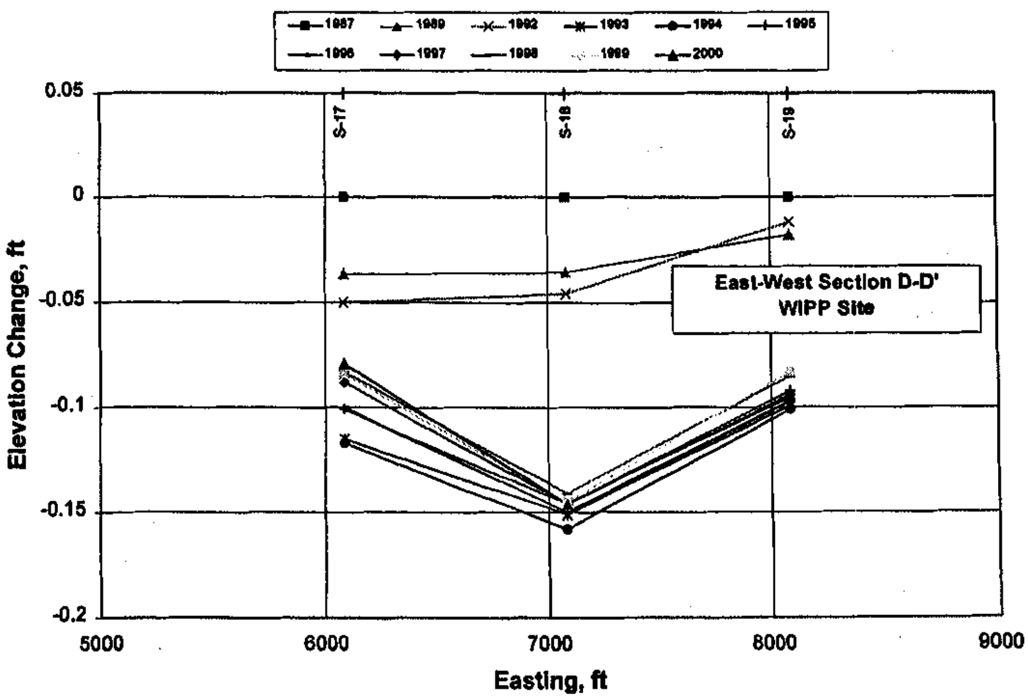


Figure 2.11 East-West Subsidence Profile D-D'.

Subsidence - 2001:

Trigger Value Derivation				
CMPMP Title:	Subsidence			
CMPMP Units:	Change in surface elevation in meters per year			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Subsidence Monitoring Leveling Survey (SMP)	Elevation of 51 monitoring monuments	Decimal (meters)	—	
SMP	National Geodetic Survey (NGS) results	Decimal (meters)	—	
SMP	Change in elevation over year	Decimal (meters)	—	
SMP	Total change in elevation since excavation of the WIPP	Decimal (meters)	—	
COMP Derivation Procedure				
Survey data from annual WIPP Subsidence Monument Leveling are evaluated. Elevations of 51 monitoring monuments are compared to determine annual change.				
Performance and Compliance Elements				
Element Title	Parameter Type & ID of Model Description	Derivation Procedure	Compliance Baseline	Impact of Change
Subsidence	NA	Predictions are of low consequence to the calculated performance of the disposal system – based on WID (1994) analysis and EPA treatment of mining.	Maximum total subsidence of 0.62 m above the WIPP.	Predicted subsidence will not exceed existing surface relief of 3 m – i.e., it will not affect drainage. Predicted subsidence may cause an order of magnitude rise in Culebra hydraulic conductivity (CCA Appendix SCR , Section 2.3.4) – this is within range modeled in the PA. Predicted WIPP subsidence is below that predicted for the effects of potash mining (0.62 m vs.1.5 m; EPA 1996).
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Change in elevation per year	1.0×10^{-2} m per year subsidence	Based on the most conservative prediction by analyses referenced in the CCA.		

2.3 Hydrological COMPs

The CCA lists ten monitoring parameters that the DOE is required to monitor and assess during the WIPP operational period. Two of these parameters are considered "Hydrological" in nature and include:

- Change in Culebra Water Composition
- Changes in Culebra Groundwater Flow

The SA has reviewed the data collected by the M&OC in 2000 under the Groundwater Surveillance Program (GSP). The GSP has two components: the Water Quality Sampling Program (WQSP) and Water-Level Monitoring Program (WLMP). WQSP and WLMP data are reported in the Waste Isolation Pilot Plant 2000 Site Environmental Report (ASER; DOE 2001b) and WLMP data are also reported in monthly memoranda from the M&OC to the SA.

2.3.1 Change in Culebra Water Composition

Water Quality Sampling Program (WQSP)
Under the WQSP, WTS collected water samples twice (sampling rounds 10 and 11) in 2000 from seven wells, denoted WQSP-1 through 6 and WQSP-6A. WQSP-1 through 6 are completed to the Culebra Dolomite Member of the Rustler Formation and WQSP-6A is completed to the Dewey Lake Redbeds. Flow and transport in the Dewey Lake are not modeled in PA because FEP screening showed them to be unimportant. Nevertheless, the Dewey Lake water quality is monitored because it might help to increase the understanding of Dewey Lake hydrology. The water samples were analyzed in duplicate for major and minor elements and hazardous constituents per the WIPP Ground Water Monitoring Program Plan (GWMP; WID 1999a).

The Culebra is not a source of drinking water, so Culebra water quality is not of concern in an immediate health sense. Instead, Culebra water quality is important because of what it implies about the nature of the flow system. Solute concentrations differ widely among wells across the WIPP site, reflecting local equilibrium, diffusion, and, perhaps most importantly, slow transport. The conceptual model for the Culebra presented in the CCA and implemented in PA numerical models is that of a confined aquifer with solute travel times across the WIPP site on the order of tens of thousands of years. In such a system, no changes in water quality at an individual well outside the range of normal analytical uncertainty and noise should be observed during the WIPP operational phase of a few decades duration. If sustained and statistically significant changes in the concentrations of major ionic species (Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^-) were observed, this would imply that water was moving faster through the Culebra than was consistent with our models. Stability of major ion concentrations, on the other hand, is consistent with and supports the SA's models. Thus, this evaluation of the water-quality data focuses on the stability of major ion concentrations.

In this evaluation, stability is defined as a condition where the concentration of an ion remains within the 95% confidence interval (C.I.) (mean +/- two standard deviations) established from the baseline measurements at a well, assuming a normal distribution of concentrations. The baseline was revised in 2000, expanding from the first five rounds of sampling in the WQSP wells to the first ten rounds of sampling, which were performed between 1995 and 2000 before the first receipt of RCRA-regulated waste at WIPP. The baseline data are presented in the Waste Isolation Pilot

Plant RCRA Background Groundwater Quality Baseline Report (Crawley and Nagy 1998) and in Addendum 1 to that report (IT Corporation 2000). For the purposes of this evaluation, a small number of measurements have been eliminated from the baselines for WQSP-3, 5, 6, and 6A for reasons discussed below. Eliminating these values is always conservative in that it reduces the "stable" range of concentrations for the affected parameters.

A charge-balance error, defined as the difference between the positive and negative charges from the ions in solution divided by the sum of the positive and negative charges, was also calculated for each analysis (Freeze and Cherry 1979). Charge-balance errors are useful in evaluating the reliability of an analysis because water must be electrically neutral. Charge-balance errors are rarely zero because of inherent inaccuracy in analytical procedures, but a reliable analysis should not have a charge-balance error exceeding five percent (Freeze and Cherry 1979). Charge-balance errors in excess of five percent imply either that the analysis of one or more ions is inaccurate (most common) or that a significant ion has been overlooked (rare). The variation between the values obtained for the "sample" and "duplicate" analyses are also considered. Generally speaking, this variation should be less than 10%. Greater variation indicates a potential problem with one or both analyses. Analytical results and charge-balance errors for rounds 10 and 11 of sampling are presented in Table 2.7 with the 95% confidence intervals derived from the baseline data.

In the 1998 COMPs Assessment Report (SNL 2000c), It was noted that round 7 potassium concentrations exceeded the 95% confidence intervals (from five rounds of sampling) at WQSP-1, 2, 4, 5, and 6A. In the 1999 COMPs Assessment Report (SNL 2000d), it was noted that all potassium concentrations from rounds 8 and 9 from all seven WQSP wells exceeded the same 95% confidence intervals. Because no other ion concentrations in any of the wells were showing a systematic change, and because this change was occurring in the same ion in all wells, the speculation was that it represented an analytical effect (e.g., a change in analytical procedure) and not an actual change in water quality. The rounds 10 and 11 analyses show that potassium concentrations continue to be high in all wells except WQSP-6A. In the case of WQSP-3, potassium concentrations from rounds 1 through 7 appear to constitute a separate population from the concentrations from rounds 8 through 10, with no overlap of the 95% C.I.s (1200 to 1730 versus 2060 to 3150 mg/L). A similar situation is seen at WQSP-4 with respect to potassium, except the two populations are comprised of rounds 1 through 6 and rounds 7 through 10 with slight overlap of the 95% C.I.s (627 to 805 mg/L versus 784 to 1600 mg/L). The greatest variation between concentrations of an ion between rounds 10 and 11 also concerned potassium, in both WQSP-1 and WQSP-2 (see Table 2.7). Thus, the potassium analyses remain problematic.

WQSP-1

Concentrations of all major ions were within the 95% C.I.s for round 10 sampling at WQSP-1 except for calcium, which was at the upper 95% C.I. for one analysis and above for the duplicate (Table 2.7). Sodium concentrations in round 10 were the lowest ever observed at WQSP-1, and would be below the lower 95% C.I. were they not included in the baseline definition. As a result of these low values, the charge-balance error for round 10 was an unacceptable -9.7%. For round 11, all concentrations were within the 95% C.I.s and the charge-balance error was an acceptable -3.3%. At the present time, the water quality is believed to be stable at WQSP-1.

Table 2.7. Rounds 10 and 11 Ion Concentrations and Baseline 95% Confidence Intervals.

Well	Sample	Cl^- Conc. (mg/L)	SO_4^{2-} Conc. (mg/L)	HCO_3^- Conc. (mg/L)	Na^+ Conc. (mg/L)	Ca^{2+} Conc. (mg/L)	Mg^{2+} Conc. (mg/L)	K^+ Conc. (mg/L)	Charge-Balance Error (%)
WQSP-1	Round 10	36000/36000	4800/4700	49/49	16450/16230	2030/**2160**	1110/1100	442/441	-9.7
	Round 11	36000/34000	4800/4700	50/52	19000/18600	1760/1680	1200/1120	717/687	-3.3
	95% C.I.	31100-39600	4060-5600	45-54	15850-21130	1380-2030	940-1210	322-730	
WQSP-2	Round 10	37000/37000	5900/6000	44/46	15370/16400	1840/1730	1030/1110	333/380	-14.2
	Round 11	37000/36000	5800/5600	51/48	19800/20300	1460/1530	982/1040	**815/823**	-4.5
	95% C.I.	31800-39000	4550-6380	43-53	14060-22350	1230-1730	852-1120	318-649	
WQSP-3	Round 10	123000/123000	7500/7200	**55/54**	75200/75200	1390/1440	2110/2140	2700/2700	-0.5
	Round 11	130000/130000	7000/6800	35/36	77900/77800	1410/1420	2120/2140	2880/3030	-1.4
	95% C.I.	113900-145200	6420-7870	23-51	62600-82700*	1090-1620	1730-2500	2060-3150*	
WQSP-4	Round 10	59000/61000	6700/7300	41/39	34000/35200	1610/1670	1180/1210	1350/1350	-3.4
	Round 11	*60000/54000*	6700/6300	*36/40*	*30700/26100*	1560/1550	1190/1180	1320/1320	-9.4
	95% C.I.	53400-63000	5620-7720	31-46	28100-37800	1420-1790	973-1410	784-1600*	
WQSP-5	Round 10	16000/16000	5400/5200	48/46	8470/**7880**	1170/1070	*500/450*	*450/400*	-9.9
	Round 11	16000/16000	5200/4800	46/48	9040/8750	1020/1010	454/462	395/410	-6.8
	95% C.I.	13400-17600	4060-5940	42-54	7980-10420*	902-1180	389-535	171-523	
WQSP-6	Round 10	5600/5500	4700/4800	45/45	*4280/4740*	707/774	222/**240**	184/200	+0.2
	Round 11	5500/5500	4800/4700	48/50	4120/4280	747/766	226/**236**	224/227	-1.9
	95% C.I.	5470-6380*	4240-5120*	41-54	3610-5380*	586-777	189-233*	113-245	
WQSP-6A	Round 10	530/510	2100/2000	108/103	279/291	681/664	167/162	5.2/5.4	+0.5
	Round 11	480/480	1900/1900	108/102	258/**250**	655/658	187/179	3.3/3.0	+3.6
	95% C.I.	433-764*	1610-2440	97-111	253-354	554-718	146-185	1.8-9.2	

Bold signifies outside 95% confidence interval
Italics signifies sample and duplicate analyses differ by more than 10%
*see text for baseline definition

WQSP-2

Concentrations of all major ions were within the 95% C.I.s for round 10 sampling at WQSP-2 except for calcium, which was at the upper 95% C.I. for one analysis and above for the duplicate (Table 2.7). As was the case with WQSP-1, sodium concentrations in round 10 were the lowest ever observed at WQSP-2, and would be below the lower 95% C.I. were they not included in the baseline definition. As a result of these low values, the charge-balance error for round 10 was an unacceptable -14.2%. In round 11, concentrations of all major ions except for potassium were within the 95% C.I.s. Possible reasons for the high potassium concentrations are discussed above. The round 11 charge-balance error was an acceptable -4.5%. In general, the water quality appears to be stable at WQSP-2.

WQSP-3

For definition of the baseline 95% C.I.s for sodium at WQSP-3, both round 8 analyses were excluded. The concentrations reported were roughly twice as high as all other reported values, causing a charge-balance error of +27.1%. For round 10 sampling at WQSP-3, both alkalinity concentrations exceeded the upper 95% C.I. by less than 10% (Table 2.7). All potassium concentrations were high for rounds 10 and 11. As discussed above, potassium concentrations from rounds 1 through 7 appear to constitute a separate population from the concentrations from rounds 8 through 10, with no overlap of the 95% C.I.s (1200 to 1730 versus 2060 to 3150 mg/L). Therefore, the potassium concentrations from rounds 10 and 11 are consistent with analytical results since round 8, but not before. For the round 11 sampling, all other ion concentrations were within the 95% C.I.s. Charge-balance errors were acceptable for both rounds 10 and 11 at -0.5% and -1.4%, respectively. At the present time, the water quality is believed to be stable at WQSP-3.

WQSP-4

For rounds 10 and 11 sampling at WQSP-4, potassium concentrations were again high (Table 2.7). As discussed above, potassium concentrations from rounds 1 through 6 appear to constitute a separate population from the concentrations from rounds 7 through 10, with only slight overlap of the 95% C.I.s (627 to 805 versus 784 to 1600 mg/L). Therefore, the potassium concentrations from rounds 10 and 11 are consistent with analytical results since round 7, but not before. All other ion concentrations from round 10 were within the 95% C.I.s, and the charge-balance error was an acceptable -3.4%. In round 11, one sodium analysis was both below the lower 95% C.I. and greater than 10% lower than the other analysis. Discrepancies of approximately 10% were also noted between the duplicate analyses of chloride and alkalinity from round 11. The charge-balance error for round 11 was an unacceptable –9.4% because of the low sodium result. At the present time, the water quality appears stable at WQSP-4.

WQSP-5

For definition of the baseline 95% C.I.s for sodium at WQSP-5, one of the round 4 duplicate analyses was excluded. The concentration reported for this analysis was 32% lower than that of the other duplicate, and nearly five standard deviations below the mean defined by the remaining nineteen baseline analyses. For round 10, all ion concentrations were within the 95% C.I.s except for one sodium analysis, which was below the lower 95% C.I. (Table 2.7). Discrepancies of approximately 10% were noted between the duplicate analyses of magnesium and potassium from round 10. Concentrations of all ions were within the 95% C.I.s for round 11. Despite the consistency of the analytical results with baseline values, however, the charge-balance errors for rounds 10 and 11 were both unacceptable at -9.9% and -6.8%, respectively. This may reflect the cumulative effect of a number of minor analytical inaccuracies. The water quality at WQSP-5 is believed to be stable.

WQSP-6

For definition of the baseline 95% C.I.s for chloride, sulfate, sodium, and magnesium at WQSP-6, both round 1 analyses were excluded. The concentrations of those ions reported for the round 1 analyses were all higher than any values reported since, and three to 43 standard deviations above the means defined by the remaining eighteen baseline analyses. Even with the narrowing of the confidence intervals caused by excluding those round 1 analyses, all reported ion concentrations for both rounds 10 and 11 fell within the 95% C.I.s except for individual magnesium analyses from both rounds, which were within 3% of the upper C.I. (Table 2.7). A discrepancy of approximately 10% was noted between the duplicate analyses of sodium from round 10. The charge-balance

errors for rounds 10 and 11 were very good at +0.2% and -1.9%, respectively. Overall, the WQSP-6 water quality appears to be extremely stable.

WQSP-6A

For definition of the baseline 95% C.I.s for chloride at WQSP-6A, both round 1 and round 3 analyses were excluded. The reported round 3 chloride concentrations appear to be an order of magnitude too high, leading to a charge-balance error of -60%. The reported round 1 chloride concentrations were over five standard deviations higher than the mean defined by the remaining sixteen baseline analyses. For round 10, all ion concentrations were within the 95% C.I.s (Table 2.7). For round 11, one sodium concentration was 1% below the lower 95% C.I. and one magnesium concentration was 1% above the upper 95% C.I. Charge-balance errors were only +0.5% and +3.6% for rounds 10 and 11, respectively. Water quality appears to be very stable at WQSP-6A.

Change in Groundwater Composition - 2001:

<table>
<tr><th colspan="5">Trigger Value Derivation</th></tr>
<tr><td>COMP Title</td><td colspan="4">Groundwater Composition</td></tr>
<tr><td>COMP Units</td><td colspan="4">Various – mg/L pCi/L</td></tr>
<tr><th colspan="5">Related Monitoring Data</th></tr>
<tr><th>Monitoring Program</th><th>Monitoring Parameter ID</th><th>Characteristics (e.g. number, observation)</th><th colspan="2">Compliance Baseline Value</th></tr>
<tr><td>Groundwater Monitoring</td><td>Composition</td><td>Semi-annual chemical and radionuclide analysis</td><td colspan="2">RCRA Background Water Quality Baseline</td></tr>
<tr><th colspan="5">COMP Derivation Procedure</th></tr>
<tr><td colspan="5">Annually evaluate ASER data and compare to previous years and baseline information</td></tr>
<tr><th colspan="5">Related PA Elements</th></tr>
<tr><th>Element Title</th><th>Type & ID</th><th>Derivation Procedure</th><th>Compliance Baseline</th><th>Impact of Chang</th></tr>
<tr><td>Groundwater conceptual model, brine chemistry, actinide solubility</td><td>Indirect</td><td>Conceptual models</td><td>Indirect – The average Culebra brine composition is not used.</td><td>Provides validation of the various CCA models, potentially significant with respect to flow, transport, and solubility and redox assumptions.</td></tr>
<tr><th colspan="5">Monitoring Data Trigger Values</th></tr>
<tr><th>Monitoring Parameter ID</th><th>Trigger Value</th><th colspan="3">Basis</th></tr>
<tr><td>Change in Culebra groundwater composition</td><td>TBD</td><td colspan="3"></td></tr>
</table>

2.3.2 Changes in Groundwater Flow (Water Level)

Assessment of the COMP "Changes in Groundwater Flow" involves trigger values derived from the steady-state freshwater heads estimated for Culebra flow modeling in the CCA. The Culebra transmissivity (T) fields that were subsequently used to simulate the transport of radionuclides through the Culebra were considered calibrated when, among other things, the modeled heads at 32 wells fell within the ranges of uncertainty estimated for steady-state freshwater heads at those wells. If monitoring shows that heads at these wells are outside the ranges used for T-field calibration (hereafter called the "CCA range"), the cause(s) and ramifications of the deviations must be determined.

The freshwater head is the elevation of the column of freshwater (density = 1.0 g/cm^3) that would exert the same pressure at the midpoint of the Culebra as that exerted by the column of fluid actually in the well. Thus, once the ground-surface elevation at a well site is surveyed, determination of freshwater head requires two sets of information: the height of the water column in the well above the midpoint of the Culebra and the density of the water in that column.

Under the Water-Level Monitoring Program (WLMP) in 2000, WTS made monthly water-level measurements in 41 Culebra wells, and quarterly water-level measurements in 17 "redundant" Culebra wells located on the same drilling pads as eight of the wells monitored monthly. Pressure-density surveys were performed in 29 of the Culebra wells in 1987 (Crawley 1988). Fluid-density data from the other wells come from water samples collected over a range of years. Thus, the density of the water in the Culebra wells is not well characterized at the present time. WTS began an annual program of pressure-density surveys in all of the monitoring wells in 2000, but the survey data are not yet available.

Water levels were also measured in wells completed to other horizons. No trigger values have been established for heads (or water levels) from these other units because they have no direct significance to performance assessment. The water-level measurements in these units do, however, provide information used in development of our conceptual model of site hydrology. Water levels in the Magenta Member of the Rustler Formation were measured monthly in nine wells. Water levels in Los Medaños Member of the Rustler and across the Rustler-Salado contact were measured monthly in one well. Dewey Lake water levels were measured in two wells, water levels in the Bell Canyon were measured in two wells, and water levels in the Forty-niner Member of the Rustler were measured in a single well, all monthly.

Culebra Data

Table 2.8 provides a comparison of Culebra water levels in feet above mean sea level (ft amsl) from December 1999 to December 2000 at the 41 wells monitored monthly(DOE 2001b). Water levels in 28 of the wells rose in 2000. In all but two of those wells, water levels rose by less than 2 ft. Water levels rose by 3.4 ft in CB-1 and by 2.5 ft in P-15. The high and changing heads in CB-1 appear to reflect a problem with the well (perhaps plugged perforations combined with a leaking packer) and are not thought to reflect conditions in the Culebra. The rise in water levels in P-15 may be caused by leaks in the well casing. The water level rose 1.8 ft in P-18, continuing a

Table 2.8. Summary of 2000 Culebra Water-Level Changes and Freshwater Heads

Well	12/99 w.l. (ft amsl)	12/00 w.l. (ft amsl)	2000 change (ft)	12/00 fwh (ft amsl)	CCA Range (ft amsl)	Outside CCA Range?
AEC-7	3038.70	3038.22	-0.48	3061.17	3055.1-3060.4	Y
CB-1	3242.45	3245.85	3.40	3257.90	2986.9-2991.5	**Y**
DOE-1	2974.68	2975.04	0.36	3003.38	2992.5-3013.8	N
DOE-2	3057.50	3040.80	-16.70	3053.58	3061.7-3071.5	**Y**
ERDA-9	3007.08	3007.53	0.45	3022.93	NA	NA
H-1	3035.95	3035.57	-0.38	3036.22	3017.1-3030.2	**Y**
H-2b2	3036.12	3036.63	0.41	3038.97	3033.8-3040.0	N
H-3b2	2997.61	2997.81	0.20	3009.11	2995.1-3007.5	Y
H-4b	3000.27	3000.30	0.03	3003.87	2988.2-2992.1	**Y**
H-5b	3028.14	3028.30	0.16	3073.17	3060.4-3069.6	Y
H-6b	3051.30	3051.70	0.40	3063.85	3054.5-3061.0	**Y**
H-7b2	2997.08	2997.56	0.48	2997.47	2994.1-2996.1	**Y**
H-9b	2990.71	2990.20	-0.51	2990.45	2973.4-2977.7	**Y**
H-10b	2993.79	2994.49	0.70	3026.59	3015.4-3029.9	N
H-11b4	2983.57	2983.61	0.04	3003.65	2990.2-3003.3	Y
H-12	2969.58	2968.94	-0.64	3006.13	2993.1-3001.0	**Y**
H-14	3008.98	3008.98	0.00	3011.85	3007.9-3021.0	N
H-15	2961.62	2961.86	0.24	3015.05	3005.2-3019.4	N
H-17	2960.39	2960.56	0.17	3009.55	2985.9-2991.8	**Y**
H-18	3059.51	3059.60	0.09	3074.87	3055.4-3067.3	**Y**
H-19b0	2988.42	2988.52	0.10	3010.21	NA	NA
P-15	3013.39	3015.89	2.50	3016.67	3008.5-3013.8	**Y**
P-17	2982.82	2983.47	0.65	2997.65	2981.0-2985.6	**Y**
P-18	3160.60	3162.44	1.84	3233.94	NA	NA
WIPP-12	3031.76	3031.51	-0.25	3068.25	3062.7-3070.2	N
WIPP-13	3058.43	3057.57	-0.86	3068.15	3059.1-3068.2	N
WIPP-18	3033.16	3033.55	0.39	3071.01	3048.9-3062.7	Y
WIPP-19	3038.85	3038.93	0.08	3076.63	NA	NA
WIPP-21	3014.94	3015.17	0.23	3039.25	NA	NA
WIPP-22	3028.76	3029.15	0.39	3060.14	NA	NA
WIPP-25	3059.02	3057.46	-1.56	3054.42	3043.6-3050.2	**Y**
WIPP-26	3020.41	3021.71	1.30	3021.84	3013.1-3014.8	**Y**
WIPP-27	3080.73	3081.22	0.49	3087.28	3075.5-3080.1	**Y**
WIPP-29	2966.62	2967.37	0.75	2970.59	NA	NA
WIPP-30	3066.73	3061.22	-5.51	3068.11	3060.4-3067.6	Y
WQSP-1	3053.31	3053.00	-0.31	3069.65	NA	NA
WQSP-2	3059.44	3059.11	-0.33	3078.84	NA	NA
WQSP-3	3011.75	3011.21	-0.54	3068.25	NA	NA
WQSP-4	2985.83	2986.23	0.40	3011.27	NA	NA
WQSP-5	3001.23	3001.69	0.46	3008.72	NA	NA
WQSP-6	3014.19	3014.19	0.00	3017.89	NA	NA

Bold **Y** signifies determination is independent of density uncertainty

NA = not applicable; data from well not used in CCA T-field calibration

trend dating back to 1977. The speculation is that the casing in P-18 may not be well cemented, and that the measured water levels reflect leakage from horizons above the Culebra.

Water levels were unchanged in one well (H-14), and decreased in twelve wells. In nine of the twelve wells, water levels decreased by less than 1 ft and, in three of those (WQSP-1, 2, and 3), the decreases can be directly related to pumping for water-quality samples. The 1.6-ft and 5.5-ft water-level decreases in WIPP-25 and WIPP-30, respectively, were caused by replacement of the packers between the Culebra and Magenta and are dissipating. The 16.7-ft decrease in water level in DOE-2 is thought to be related to a packer problem. The packer in question will be replaced in 2001.

Table 2.8 also compares the December 2000 freshwater heads (fwh) to the CCA ranges for the 28 wells used in generation of the CCA T fields that were monitored in 2000. Freshwater heads in 21 of the 28 wells appear to be outside the CCA ranges at the end of 2000, 20 higher and one lower than expected. The heads at CB-1, DOE-2, and probably P-15 can be discounted for the reasons discussed above. The Culebra heads in H-1 are also considered nonrepresentative because of continuing problems with the well casing and attempts to repair it, leaving 17 wells with unexpectedly high freshwater heads.

For 11 of these 17 wells (AEC-7, H-3b2, H-5b, H-6b, H-11b4, H-12, H-17, H-18, P-17, WIPP-18, and WIPP-30), freshwater heads could be within the CCA range if a lower fluid density was used to convert the measured water levels to freshwater heads. The fluid densities used to calculate the freshwater heads in Table 2.8 are those estimated by Cauffman et al. (1990) from data collected in 1989 or earlier. Fluid densities may have changed since that time because of things such as hydraulic tests and well rehabilitation. Thus, current fluid density information is needed before it is known with confidence that the freshwater heads in these 11 wells exceed the CCA range. As mentioned above, WTS began an annual program of pressure-density surveys in all of the monitoring wells in 2000.

For the remaining six of the 17 wells (H-4b, H-7b2, H-9b, WIPP-25, WIPP-26, and WIPP-27), the measured water levels exceed the CCA range before being converted to freshwater head. In these cases, conversion to freshwater head using any feasible density can only increase the deviation from the CCA range. WIPP-25, 26, and 27 are located in Nash Draw where they may be affected by discharge of effluent from potash mines and mills. Changes in heads in Nash Draw might then propagate to the other wells but, at the present time, this is just speculation. None of these six wells are on or near the offsite-transport pathways through the Culebra modeled for the CCA. Thus, changes at these wells alone should have little or no effect on the CCA compliance calculations. The cause(s) of the changes, however, needs to be understood, particularly if new pressure-density surveys show that the freshwater heads of other wells exceed the CCA range. The SA began an investigation of possible causes of the high heads in 2000 that will continue in succeeding years (SNL 2001b).

Data from Other Units

Table 2.9 provides a comparison of water levels from units other than the Culebra from December 1999 to December 2000. Water levels in the Magenta changed by less than 1 ft in all wells monitored except for H-1, H-2b1, and WIPP-25 in 2000. A variety of activities were conducted in H-1 in 2000 in an attempt to repair a leak in the casing. These activities caused water levels to fluctuate over approximately 43 ft, but were unsuccessful in repairing the leak. H-1 will

be plugged and abandoned and replaced with a new well in 2001. The leak has caused historically high Magenta heads at H-1 that have propagated to H-2b1 and H-3b1, where water levels rose by approximately 2.1 ft and 0.6 ft, respectively, in 2000. These water-level rises should dissipate once H-1 is plugged and abandoned, and are of no significance to PA. The packer separating the Culebra and Magenta in WIPP-25 was replaced in 2000, causing water-level fluctuations from which the well is still recovering.

Table 2.9 Summary of 2000 Water-Level Changes in Units Other than the Culebra.

Well	12/99 w.l. (ft amsl)	12/00 w.l. (ft amsl)	2000 change (ft)
Magenta Wells			
H-1	3216.46	3229.17	12.71
H-2b1	3144.47	3146.54	2.07
H-3b1	3151.14	3151.71	0.57
H-4c	3143.28	3143.93	0.65
H-5c	3156.62	3156.91	0.29
H-6c	3063.82	3064.40	0.58
H-8a	3027.20	3027.07	-0.13
H-10a	3159.97	3160.18	0.21
WIPP-25	3058.29	3048.23	-10.06
Dewey Lake Wells			
H-3d	3072.52	3073.01	0.49
WQSP-6A	3199.06	3198.25	-0.81
Los Medaños Well			
H-8c	2979.20	2979.12	-0.08
Forty-niner Well			
H-3d	3087.12	3089.45	2.33
Bell Canyon Wells			
AEC-8	3010.37	3026.09	15.72
CB-1	3014.30	3014.65	0.35

Water levels were stable within 1 ft in both Dewey Lake wells and in the Los Medaños/Rustler-Salado well (H-8c). The water level in the Forty-niner well, H-3d, increased by 2.3 ft in 2000.

The Bell Canyon water level in AEC-8 increased by approximately 15.7 ft in 2000, continuing a rise of unknown origin dating back to 1993. The cause of this rise is currently under investigation. Water-level monitoring of the Bell Canyon began again in well Cabin Baby-1 in September 1999 after a 13-year hiatus. The water level was extremely stable in 2000, oscillating within a 0.6-ft

range. At the end of 2000, the water level was approximately 5 ft lower than it had been in 1986, which may be attributed to differences in the density of the fluid in the well related to drilling-brine contamination.

Changes in Groundwater Flow - 2001:

Trigger Value Derivation				
COMP Title	Changes in Groundwater Flow			
COMP Units	Inferred from water-level data			
Related Monitoring Data				
Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value	
Groundwater Monitoring	Head and Topography	Monthly water-level measurements; annual pressure-density surveys.	Indirect	
COMP Derivation Procedure				
Annual assessment from ASER data.				
Related PA Elements				
Element Title	Type & ID	Derivation Procedure	Compliance Baseline	Impact of Change
Groundwater conceptual model, Transmissivity fields	NA	NA	NA	Provides validation of the various CCA models - T-field assumptions and groundwater basin model.
Monitoring Data Trigger Values				
Monitoring Parameter ID	Trigger Value	Basis		
Change in Culebra Groundwater Flow	CCA range; see Table 2.8	Annual comparisons with ranges of undisturbed steady-state freshwater heads used to calibrate Culebra T fields for CCA.		

2.3.3 Hydrological Geotechnical COMPs: Concluding Remarks

The evaluation of the water-quality data collected in 2000 shows that major ion concentrations are generally stable at all seven sampled wells. Most of the reported concentrations that fall outside the baseline 95% confidence intervals appear random and probably reflect analytical problems. Calcium concentrations at WQSP-1 and 2, alkalinity at WQSP-3, sodium concentrations at WQSP-4, 5, and 6A, magnesium concentrations at WQSP-6, and potassium concentrations at all wells will be observed in coming years to determine if the data from WQSP rounds 10 and 11 reflect actual trends, analytical problems, or just measurement anomalies.

Of the 28 Culebra wells monitored in 2000 for which steady-state freshwater head ranges were established for CCA modeling, 20 had apparent freshwater heads higher than the CCA range and one (DOE-2) had an apparent freshwater head lower than the CCA range. The high heads in

CB-1, H-1, and P-15 appear to reflect problems with the wells and are not thought to reflect conditions in the Culebra. Similarly, the low heads in DOE-2 are thought to be caused by a packer problem, not the Culebra. Freshwater heads in 11 other wells need confirmation from pressure-density surveys performed by WTS in 2000 before it can be determined with certainty that they exceed the CCA range. Freshwater heads in six of the wells, however, are clearly above the CCA range. Causes and potential ramifications of these high heads are under investigation by the SA. No significant water-level changes were observed in wells completed to the Magenta, Forty-niner, or Los Medaños Members of the Rustler Formation or to the Dewey Lake. Bell Canyon water levels in AEC-8 are continuing to rise.

2.4 Waste Activity

Only a limited amount of waste has been emplaced in the WIPP as of September, 2001. A total of 10,851 55-gallon drums, 137 Standard Waste Boxes (SWBs), one 85 gallon over-pack and 161 dunnage drums of CH TRU are currently stored at WIPP. No RH waste has been emplaced in WIPP. Panel 1 is currently filled to 16.5% of the total waste capacity. As discussed in the trigger value Derivation Report, Waste Activity COMPs assessments are not performed until half of a panel is filled since small quantities do not yield statistically valid assessments. There are no trigger values for CH activity, only RH. There are no recognized reportable issues associated with this COMP. No changes to the monitoring program are recommended.

Totals for actinide content (listed in grams and curries), number of drums/SWBs, and kilograms of cellulosics, plastics and rubber (CPR) emplaced in Panel 1 are found in Appendix A of this document.

Waste Activity - 2001:

Trigger Value Derivation	
CMPMP Title	Waste Activity
CMPMP Units	Curies

Related Monitoring Data

Monitoring Program	Monitoring Parameter ID	Characteristics (e.g., number, observation)	Compliance Baseline Value
WWIS	Radionuclide activity per container and volume	Curies per container. Container volume.	Appendix P of CCA Appendix BIR (DOE 1996) by waste stream.
Waste emplacement records	Location of waste in panels	Coordinates and number of containers (or volume in cubic meters).	None.

COMP Derivation Procedure
Map of waste activity distribution in each panel. Total curie content of emplaced CH-TRU and RH-TRU waste. *[Total radionuclide inventories reported annually by WWIS]*

Year 2001 COMP Assessment Value
No assessment is made until ½ a panel is filled. Panel 1 is currently 16.5% full of waste. Actinide totals and CPR totals are found in Appendix A of this document.

Element Title	Type and ID	Derivation Procedure	Compliance Baseline	Impact of Chang
Radionuclide inventories	Parameter	Product of waste stream content and volume scaled up to the LWA limits.	Table PAR-41 and Table 4-8 of the CCA.	May affect direct brine releases for those radionuclides that become inventory-limited during a PA simulation.
Activity of waste intersected for cuttings and cavings releases.	Parameter	Function of waste stream volumes and activities	Figure 6-31 of the CCA	Cuttings are a significant contributor to releases. Therefore, an increase in activity of intersected waste is potentially significant.
WIPP-scale average activity for spallings releases	Parameter	Average of all CH-TRU waste only.	NA	Spallings are a significant contributor to releases. Therefore, an increase in average activity of intersected waste is potentially significant.

Monitoring Data Trigger Values

Monitoring Parameter ID	Trigger Value	Basis
Waste emplacement records	Panel half-full	Check that PA assumptions about waste activity will remain valid as remainder of panel is filled and verify random emplacement assumptions.
Total emplaced RH-TRU waste activity	5.1 million curies	LWA emplacement limit reached. Administrative controls address these limits.

3 COMPs Assessment Conclusion

The WIPP became operational in 1999 when it received its first shipment of TRU waste. This event initiated the operational period monitoring program designed to meet the assurance requirements of the EPA radioactive waste certification decision. This monitoring program was designed to further validate the assumptions and conceptual models that were used to predict WIPP performance. The monitoring program was intended to identify conditions that could potentially cause radioactive release above the allowable 40 CFR 191 release limits. Since releases above these limits cannot occur during the operational period of WIPP, the monitoring program looks at monitorable aspects of the disposal system and compares them to performance expectations. Ten monitoring parameters are assessed and compared annually to these expectations. The results of this year's assessment are documented in this report and, with the exception of the Culebra ground water monitoring wells, the SA concludes that there are no COMPs data or results that indicate a reportable event or condition adverse to predicted performance. Freshwater heads in several Culebra wells are above the ranges used in the CCA. A program has been initiated by the SA to investigate the long-term changes in the Culebra water levels. The general investigation approach is described in the SNL test plan titled, *Examining Culebra Water Levels* (SNL 2001b). Preliminary findings indicate that Culebra water levels are generally rising across the entire monitoring region. Water-level data compiled from various sources and dating back to 1977 indicate that regional water levels were rising when Culebra monitoring began and that this trend continues today.

The water-level data are currently being used to construct a Geographic Information System (GIS) database that will allow the generation of various types of maps to aid in this investigation. These maps will include regional variations in the rates of water-level changes as a function of time. The GIS data base will also allow simple deconvolution to be applied to selected hydrographs, permitting differentiation between shaft-construction induced water-level variations associated with known WIPP activities and naturally occurring variations (or non-WIPP related variations). The first status report for Culebra water level investigations is scheduled to be published in the spring of 2002.

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Appendix A

2001 WWIS COMPs Waste report

Waste Isolation Pilot Plant

WWIS

Report	RP0380	Nuclide Report
Filename		
Run by	MIKUSK	
Report Date	09/17/2001 11:03	
Total Pages	3	

Selection Criteria

Module :	*RP0380*
Version :	*1.0*
Site id :	*%*
Nuclide :	*%*
Panel Number :	*%*
Room Number :	*%*
Handling Code :	*%*
Show Uncertainty :	*YES*
TRU Nuclides Only :	*%*
EPA Tracked Nuclides Only:	*%*

Panel Number: 1 Room Number: 6

Radionuclide	Activity (Ci)	Activity Uncert (Ci)	Mass(G)	Mass Uncert(G)
AC-227 - ACTINIUM	3.8430E-04	1.3324E-04	4.9741E-06	1.8173E-06
AM-241 - AMERICIUM 241	7.6749E+03	5.9974E+02	2.2118E+03	1.7284E+02
AM-243 - AMERICIUM 243	3.6230E-04	9.8714E-05	1.7918E-03	4.8917E-04
CS-137 - CESIUM 137	6.8759E-06	3.5925E-06	7.5728E-07	7.2003E-07
K-40 - POTASSIUM-40	1.6160E-06	5.7390E-07	2.8610E-01	1.0150E-01
NP-237 - NEPTUNIUM 237	4.6715E-02	2.6662E-03	6.5519E+01	3.7393E+00
PA-231 - PROTACTINIUM 231	4.7302E-04	1.7283E-04	9.8980E-03	3.6173E-03
PU-238 - PLUTONIUM 238	1.0635E+02	7.1391E+01	6.1475E+00	4.1266E+00
PU-239 - PLUTONIUM 239	4.2007E+03	2.2051E+02	6.6785E+04	3.5061E+03
PU-240 - PLUTONIUM 240	9.2704E+02	2.0818E+02	4.0306E+03	9.0514E+02
PU-241 - PLUTONIUM 241	8.2007E+03	7.0327E+02	7.8853E+01	6.7623E+00
PU-242 - PLUTONIUM 242	6.5781E-02	3.6962E-02	1.6565E+01	9.3103E+00
TH-230 - THORIUM	2.4100E-05	3.6276E-06	1.1800E-03	1.7806E-04
U-233 - URANIUM 233	2.1814E-03	2.3446E-03	2.2350E-01	2.4023E-01
U-234 - URANIUM 234	2.5842E-02	1.7499E-02	4.0906E+00	2.7683E+00
U-235 - URANIUM 235	2.2187E-03	1.7566E-03	1.0131E+03	8.0211E+02
U-238 - URANIUM 238	1.0762E-01	9.2466E-02	3.1654E+05	2.7196E+05
Totals:	2.1110E+04	1.8032E+03	3.9075E+05	2.7737E+05

Panel Number: 1 Room Number: 7

Radionuclide	Activity (Ci)	Activity Uncert (Ci)	Mass(G)	Mass Uncert(G)
AM-241 - AMERICIUM 241	2.7844E+04	5.7614E+03	8.0252E+03	1.6603E+03
AM-243 - AMERICIUM 243	2.2362E-03	5.1028E-04	1.1140E-02	7.3833E-03
CO-60 - COBALT 60	3.4696E-07	4.9614E-08	3.0400E-10	4.3000E-11
CS-137 - CESIUM 137	2.4119E-04	1.0217E-04	2.7401E-06	1.1607E-06
K-40 - POTASSIUM-40	1.8587E-05	7.7348E-06	3.2901E+00	1.3692E+00
NA-22 - SODIUM 22 (NA-22)	5.3435E-06	1.9794E-07	8.4500E-10	3.1000E-11
NP-237 - NEPTUNIUM 237	9.3755E-02	2.3458E-02	1.3149E+02	3.1981E+01
PA-231 - PROTACTINIUM 231	6.1146E-06	1.1650E-05	1.3003E-05	2.4784E-05
PU-238 - PLUTONIUM 238	1.4362E+03	6.9960E+02	8.3073E+01	4.0455E+01
PU-239 - PLUTONIUM 239	2.7257E+04	3.0028E+03	4.3332E+05	4.7741E+04
PU-240 - PLUTONIUM 240	6.1924E+03	1.4491E+03	2.6925E+04	6.3001E+03
PU-241 - PLUTONIUM 241	8.6568E+04	2.3525E+04	8.3333E+02	7.6263E+03
PU-242 - PLUTONIUM 242	6.8228E-01	2.9626E-01	1.7200E+02	7.3616E+01
TH-232 - THORIUM 232	2.6073E-06	1.9759E-06	2.3846E+01	1.7854E+01

Nuclide Report

Radionuclide		Activity (Ci)	Activity Uncert (Ci)	Mass(G)	Mass Uncert(G)
U-233 - URANIUM 233		1.3393E-01	9.4639E-02	1.3722E+01	9.6966E+00
U-234 - URANIUM 234		1.6387E-01	1.0530E-01	2.5948E+01	1.6667E+01
U-235 - URANIUM 235		1.3687E-02	9.9701E-03	6.2499E+03	4.5525E+03
U-238 - URANIUM 238		4.8689E-01	4.1726E-01	1.4312E+06	1.2271E+06
	Totals:	1.4930E+05	3.4439E+04	1.9070E+06	1.2954E+06
	Grand Totals:	1.7041E+05	3.6242E+04	2.2978E+06	1.5727E+06

Waste Isolation Pilot Plant

WWIS

Report	RP0380 Nuclide Report
Filename	
Run by	MIKUSK
Report Date	09/17/2001 09:18
Total Pages	3

Selection Criteria

Module :	*RP0380*
Version :	*1.0*
Site id :	*%*
Nuclide :	*%*
Panel Number :	*%*
Room Number :	*%*
Handling Code :	*%*
Show Uncertainty :	*NO*
TRU Nuclides Only :	*%*
EPA Tracked Nuclides Only:	*%*

Panel Number : 1   Room Number : 6

Radionuclide	Activity (Ci)	Mass(G)
AC-227 - ACTINIUM	3.6430E-04	4.9741E-06
AM-241 - AMERICIUM 241	7.6749E+03	2.2118E+03
AM-243 - AMERICIUM 243	3.6230E-04	1.7918E-03
CS-137 - CESIUM 137	6.8759E-08	7.5728E-07
K-40 - POTASSIUM-40	1.8160E-06	2.8810E-01
NP-237 - NEPTUNIUM 237	4.6715E-02	6.5519E+01
PA-231 - PROTACTINIUM 231	4.7302E-04	9.8980E-03
PU-238 - PLUTONIUM 238	1.0635E+02	6.1475E+00
PU-239 - PLUTONIUM 239	4.2007E+03	6.6785E+04
PU-240 - PLUTONIUM 240	9.2704E+02	4.0306E+03
PU-241 - PLUTONIUM 241	8.2007E+03	7.8853E+01
PU-242 - PLUTONIUM 242	6.5781E-02	1.6565E+01
TH-230 - THORIUM	2.4100E-05	1.1800E-03
U-233 - URANIUM 233	2.1814E-03	2.2350E-01
U-234 - URANIUM 234	2.5842E-02	4.0908E+00
U-235 - URANIUM 235	2.2187E-03	1.0131E+03
U-238 - URANIUM 238	1.0762E-01	3,1654E+05
Totals:	2.1110E+04	3.9075E+05

Panel Number : 1   Room Number : 7

Radionuclide	Activity (Ci)	Mass(G)
AM-241 - AMERICIUM 241	2.7844E+04	8.0252E+03
AM-243 - AMERICIUM 243	2.2362E-03	1.1140E-02
CO-60 - COBALT 60	3.4896E-07	3.0400E-10
CS-137 - CESIUM 137	2.4119E-04	2.7401E-06
K-40 - POTASSIUM-40	1.8587E-05	3.2901E+00
NA-22 - SODIUM 22 (NA-22)	5.3435E-06	8.4500E-10
NP-237 - NEPTUNIUM 237	9.3755E-02	1.3149E+02
PA-231 - PROTACTINIUM 231	6.1146E-06	1.3003E-05
PU-238 - PLUTONIUM 238	1.4362E+03	8.3073E+01
PU-239 - PLUTONIUM 239	2.7257E+04	4.3332E+05
PU-240 - PLUTONIUM 240	6.1924E+03	2.6925E+04
PU-241 - PLUTONIUM 241	8.6568E+04	8.3333E+02
PU-242 - PLUTONIUM 242	6.8228E-01	1.7200E+02
TH-232 - THORIUM 232	2.6073E-06	2.3648E+01

Nuclide Report

Radionuclide	Activity (Ci)	Mass(G)
U-233 - URANIUM 233	1.3393E-01	1.3722E+01
U-234 - URANIUM 234	1.6387E-01	2.5948E+01
U-235 - URANIUM 235	1.3687E-02	6.2499E+03
U-238 - URANIUM 238	4.8689E-01	1.4312E+06
Totals:	1.4930E+05	1.9070E+06
Grand Totals:	1.7041E+05	2.2978E+06

Waste Isolation Pilot Plant
WWIS

Report	*RP0530 Repository Report*
Filename	
Run by	*MIKUSK*
Report Date	*09/17/2001 10:31*
Total Pages	*8*

Report Criteria

Module *RP0530*

Version *1.0*

Repository Report

Waste Isolation Pilot Plant

Containers

Container Type	Description	Emplaced	Total
001	55 GAL DRUM	3963	5296
001	Dunnage: 55 GAL DRUM	52	711
1	55 GAL DRUM	3088	3179
1	Dunnage: 55 GAL DRUM	109	308
2	SWB	137	139
5	55 GALLON PIPE OVERPACK - 12 INCH PIPE OVERPACK	3626	3859
7	55 GAL DRUM - 1 TRIP	68	69
8	55 GALLON DRUM - GALVANIZED	106	106
9	Overpacked: 85 GALLON DRUM - OVERPACK	1	1

Repository Report

WIPP Waste
Information System

Waste Isolation Pilot Plant

Containers by Site

Site Id :	AE	Name :	ARGONNE NATIONAL LABORATORY
Site Id :	AL	Name :	AMES LABORATORY
Site Id :	AW	Name :	ARGONNE NATIONAL LABORATORY WE
Site Id :	BC	Name :	BATTELLE COLUMBUS LABORATORY
Site Id :	BP	Name :	BATTELLE - PACIFIC NORTHWEST L
Site Id :	BT	Name :	BETTIS ATOMIC POWER LABORATORY
Site Id :	C1	Name :	CCP AT SRS
Site Id :	C2	Name :	CCP AT ANL-E
Site Id :	C3	Name :	CCP AT NTS
Site Id :	ET	Name :	ENERGY TECHNOLOGY ENGINEERING
Site Id :	HF	Name :	HANFORD(2)
Site Id :	IN	Name :	IDAHO NATIONAL ENGINEERING LAB

Specific Container Information

Container Type	Description	Container Status	Dunnage	Total Containers
001	55 GAL DRUM	Approved Certification		1134
001	55 GAL DRUM	Approved Characterization		2
001	55 GAL DRUM	Approved Shipment		190
001	55 GAL DRUM	Emplaced Container		3832
001	55 GAL DRUM	Dunnage - Emplaced	*	52
001	55 GAL DRUM	Dunnage	*	658
1	55 GAL DRUM	Dunnage - Emplaced	*	72
1	55 GAL DRUM	Dunnage	*	102

Repository Report

WIPP Waste
Information System

Waste Isolation Pilot Plant

Containers by Site

Site Id : IN Name : IDAHO NATIONAL ENGINEERING LAB

Container Status Totals

Container Status	Total Containers
Approved Characterization	2
Approved Certification	1134
Approved Shipment	190
Dunnage - Emplaced	124
Emplaced Container	3832

Site Id : IT Name : INHALATION TOXICOLOGY RESEARCH

Site Id : KA Name : KNOLLS ATOMIC POWER LABORATORY

Site Id : LA Name : LOS ALAMOS NATIONAL LABORATORY

Specific Container Information

Container Type	Description	Container Status	Dunnage	Total Containers
001	55 GAL DRUM	Approved Certification		8
001	55 GAL DRUM	Emplaced Container		27
1	55 GAL DRUM	Emplaced Container		1
2	SWB	Approved Certification		2
2	SWB	Emplaced Container		137
2	SWB	Dunnage	*	1

Container Status Totals

Container Status	Total Containers
Approved Certification	10
Emplaced Container	165

Site Id : LB Name : LAWRENCE BERKELEY LABORATORY

Site Id : LL Name : LAWRENCE LIVERMORE NAT'L LAB

Repository Report

Waste Isolation Pilot Plant

Containers by Site

Site Id :	MD	Name :	MOUND PLANT
Site Id :	MU	Name :	UNIVERSITY OF MISSOURI
Site Id :	NR	Name :	NAVAL REACTORS FACILITY
Site Id :	NT	Name :	NEVADA TEST SITE
Site Id :	OR	Name :	OAK RIDGE NATIONAL LABORATORY
Site Id :	PA	Name :	PADUCAH GASEOUS DIFFUSION PLAN
Site Id :	PX	Name :	PANTEX SITE(3)
Site Id :	RF	Name :	ROCKY FLATS

Specific Container Information

Container Type	Description	Container Status	Dunnage	Total Containers
1	55 GAL DRUM	Approved Certification		20
1	55 GAL DRUM	Emplaced Container		2730
1	55 GAL DRUM	Dunnage - Emplaced	*	35
1	55 GAL DRUM	Dunnage	*	81
5	55 GALLON PIPE OVERPACK - 12 INCH PIPE OVERPACK	Approved Certification		131
5	55 GALLON PIPE OVERPACK - 12 INCH PIPE OVERPACK	Approved Shipment		84
5	55 GALLON PIPE OVERPACK - 12 INCH PIPE OVERPACK	Emplaced Container		3626
5	55 GALLON PIPE OVERPACK - 12 INCH PIPE OVERPACK	Pending Certification		18

Container Status Totals

Container Status	Total Containers
Pending Certification	18
Approved Certification	151
Approved Shipment	84

Repository Report

Waste Isolation Pilot Plant

Containers by Site

Site Id : RF Name : ROCKY FLATS

Container Status Totals

Container Status	Total Containers
Dunnage - Emplaced	35
Emplaced Container	6356

Site Id : RL Name : RICHLAND (HANFORD) SITE

Specific Container Information

Container Type	Description	Container Status	Dunnage	Total Containers
001	55 GAL DRUM	Dunnage	*	1
1	55 GAL DRUM	Emplaced Container		315
1	55 GAL DRUM	Pending Characterization		19
1	55 GAL DRUM	PreSubmit Certification		10
1	55 GAL DRUM	Dunnage - Emplaced	*	2
1	55 GAL DRUM	Dunnage	*	6
7	55 GAL DRUM - 1 TRIP	Emplaced Container		68
7	55 GAL DRUM - 1 TRIP	PreSubmit Certification		1

Container Status Totals

Container Status	Total Containers
Pending Characterization	19
PreSubmit Certification	11
Dunnage - Emplaced	2
Emplaced Container	383

Site Id : SA Name : SANDIA NATIONAL LABORATORIES -

Site Id : SQ Name : NATIONAL TRU CERT TEAM

Site Id : SR Name : SAVANNAH RIVER SITE

Repository Report

WIPP Waste
Information System

Waste Isolation Pilot Plant

Containers by Site

Site Id : SR Name : SAVANNAH RIVER SITE

Specific Container Information

Container Type	Description	Container Status	Dunnage	Total Containers
001	55 GAL DRUM	Emplaced Container		104
1	55 GAL DRUM	Approved Shipment		42
1	55 GAL DRUM	Emplaced Container		42
8	55 GALLON DRUM - GALVANIZED	Emplaced Container		106

Container Status Totals

Container Status	Total Containers
Approved Shipment	42
Emplaced Container	252

Site Id : WI Name : WASTE ISOLATION PILOT PLANT

Repository Report

WIPP Waste
Information System

Waste Isolation Pilot Plant

Material Parameter Totals

Material Parameter	Description	Weight(Kg)
6	CELLULOSICS	150427.99
7	RUBBER	1216.44
8	PLASTICS	52356.4