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Geotechnical Analysis Report for July 2002 – June 2003

March 2004

Waste Isolation Pilot Plant

Geotechnical Analysis Report for July 2002 – June 2003
DOE/WIPP 04-3177, Vol. 1

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Foreword and Acknowledgments

This report contains an assessment of the geotechnical status of the Waste Isolation Pilot Plant (WIPP). During the excavation of the principal underground access and experimental areas, the status was reported quarterly. Since 1987, when the initial construction phase was completed, reports have been published annually. This report presents and analyzes data collected from July 1, 2002, to June 30, 2003.

This Geotechnical Analysis Report (GAR) was written to meet the needs of several audiences. This report satisfies the requirements presented in the WIPP Hazardous Waste Permit[1] and the Certification of Compliance[2] with Subparts Band C, Title 40 *Code of Federal Regulations (CFR)* Part 191, "Environmental Radiation Protection for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes." It focuses on the geotechnical performance of the various components of the underground facility, including the shafts, shaft stations, access drifts, and waste disposal areas. The results of investigations of excavation effects and other geologic studies are also included. The report compares the geotechnical performance of the repository to the design criteria. It describes the techniques that were used to acquire the data and the performance history of the instruments. The depth and breadth of the evaluation of the different components of the underground facility vary according to the types and quantities of data available and the complexity of the recorded geotechnical responses. Graphic documentation of data and tabular documentation of instrument history can be provided upon request.

This GAR was prepared by Washington TRU Solutions LLC (WTS) for the U.S. Department of Energy (DOE), Carlsbad Field Office (CBFO), Carlsbad, New Mexico. Work was supported by the DOE under Contract No. DE-AC29-01AL66444.

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[1] New Mexico Environment Department (NMED), 1999, "Waste Isolation Pilot Plant Hazardous Waste Facility Permit," NM4890139088-TSDF, Santa Fe, New Mexico
[2] Federal Register, Vol. 63, No. 95, pp. 27354, May 18, 1998

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Acronyms and Abbreviations

b.p.	before present
bsc	below shaft collar
CAO	Carlsbad Area Office
CBFO	Carlsbad Field Office
cfi	closure from initial
CFR	Code of Federal Regulations
CH	contact-handled
cm	centimeter(s)
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
GAR	Geotechnical Analysis Report
GIS	geomechanical instrumentation system
in.	inch(es)
kPa	kilopascal(s)
kVA	kilovolt amp(s)
LANL	Los Alamos National Laboratory
lb	pound(s)
m	meter(s)
Ma	million years ago
MB	marker bed
NMED	New Mexico Environment Department
OMB	orange marker bed
psi	pound(s) per square inch
RH	remote-handled
SDD	system design description
SNL/NM	Sandia National Laboratories/New Mexico
SPDV	Site and Preliminary Design Validation
TRU	transuranic
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WTS	Washington TRU Solutions LLC
yr(s)	year(s)

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1.0 Introduction

This Geotechnical Analysis Report (GAR) presents and interprets the geotechnical data from the underground excavations at the Waste Isolation Pilot Plant (WIPP). The data, which are obtained as part of a regular monitoring program, are used to characterize conditions, to compare actual performance to the design assumptions, and to evaluate and forecast the performance of the underground excavations.

GARs have been available to the public since 1983. During the Site and Preliminary Design Validation (SPDV) Program, the architect/engineer for the project produced these reports on a quarterly basis to document the geomechanical performance during and immediately after excavation of the underground facility. Since the completion of the construction phase of the project in 1987, the management and operating contractor for the facility has prepared these reports annually. This report describes the performance and condition of selected areas from July 1, 2002, to June 30, 2003. It is divided into ten chapters. Chapter 1 provides background information on WIPP, its mission, and the purpose and scope of the Geomechanical Monitoring Program. Chapter 2 describes the local and regional geology of the WIPP site. Chapters 3 and 4 describe the geomechanical instrumentation located in the shafts and shaft stations, present the data collected by that instrumentation, and provide interpretation of these data. Chapters 5, 6, and 7 present the results of geomechanical monitoring in the three main portions of the WIPP underground facility (the access drifts, the Northern Experimental Area, and the Waste Disposal Area). Chapter 8 discusses the results of the Geoscience Program, which include fracture and stratigraphic mapping and borehole observations. Chapter 9 summarizes the results of the geomechanical monitoring and compares the current excavation performance to the design requirements. Chapter 10 lists the references and bibliography.

1.1 Location and Description

WIPP is located in southeastern New Mexico, 26 miles (42 kilometers [km]) east of Carlsbad (Figure 1-1). The surface facilities were built on the flat to gently rolling hills that are characteristic of the Los Medaños area. The underground facility is being excavated approximately 2,150 feet [ft] (655 meters [m]) beneath the surface in the Salado Formation. Figure 1-2 shows a plan view of the current underground configuration of WIPP.

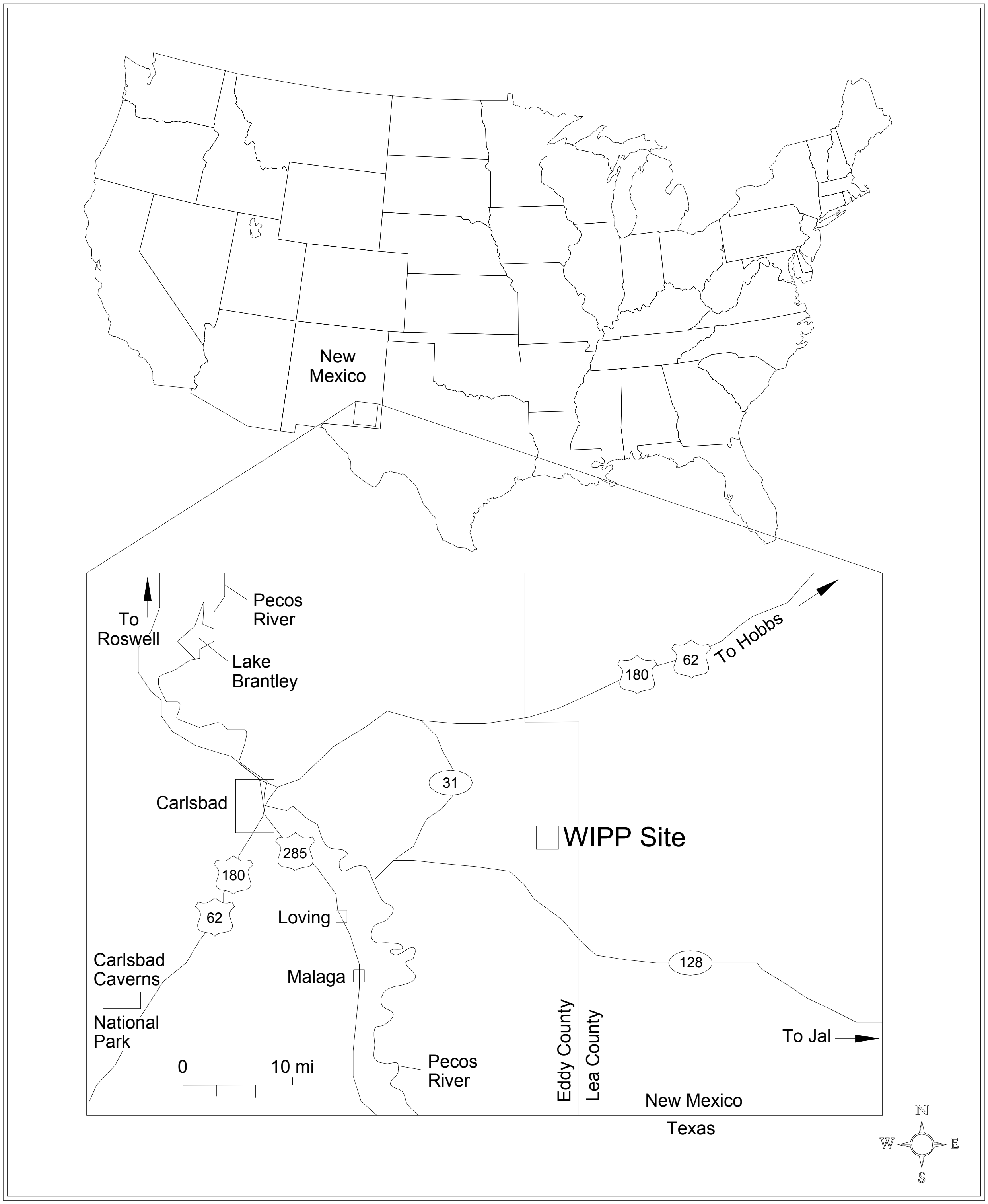

Figure 1-1
WIPP Location

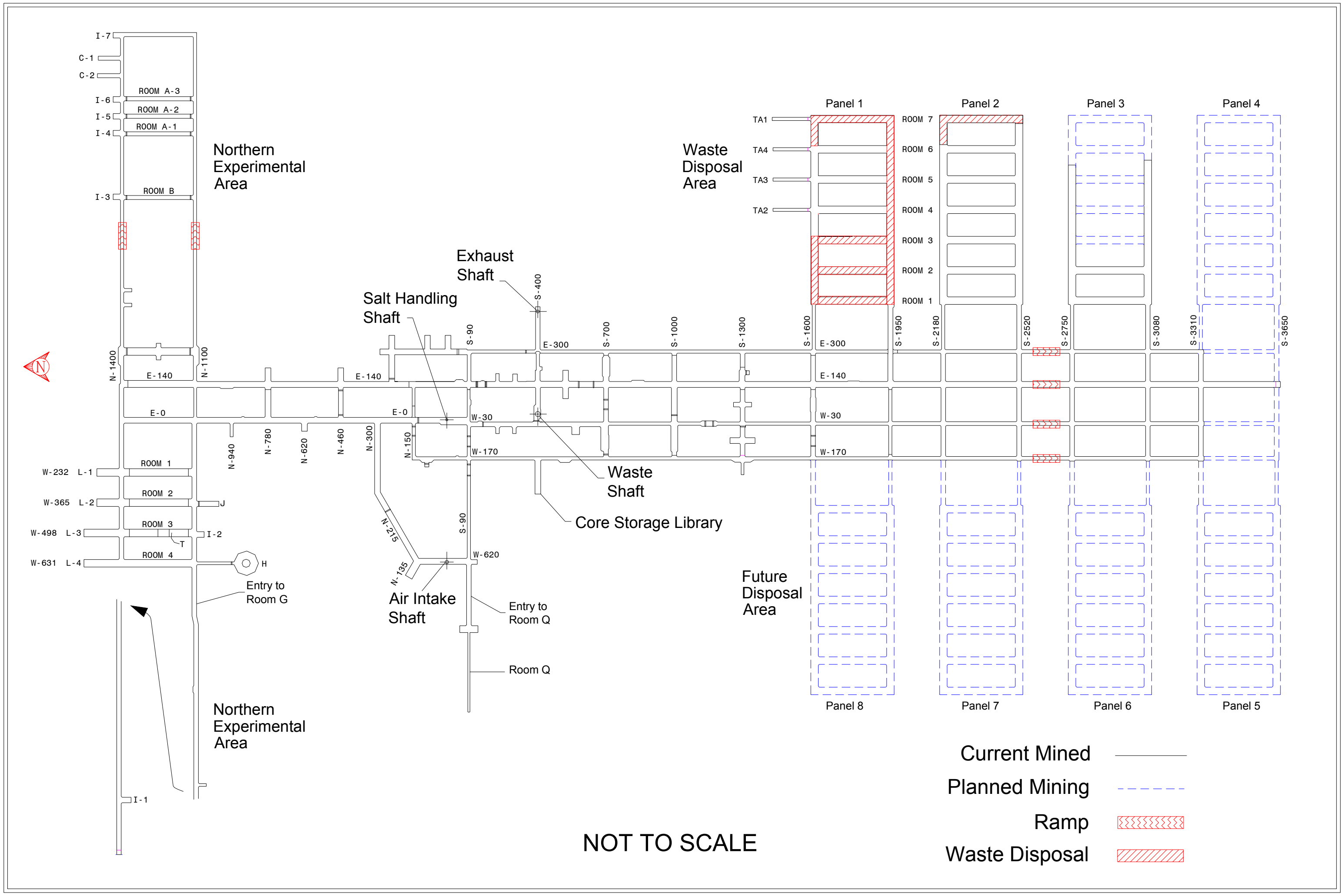

Figure 1-2
Underground Mining and Waste Disposal Configuration as of 6/30/03

1.2 Mission

In 1979 Congress authorized WIPP (Public Law 96-164) to provide ". . . a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." WIPP is intended to receive, handle, and permanently dispose of transuranic (TRU) waste and TRU mixed waste. To fulfill this mission, the U.S. Department of Energy (DOE) constructed a full-scale facility to demonstrate both technical and operational principles of the permanent disposal of TRU and TRU mixed wastes. Technical aspects are those concerned with the design, construction, and performance of the subsurface excavations. Operational aspects refer to the receiving, handling, and emplacement of TRU wastes in the facility. The facility was also used for *in situ* studies and experiments without the use of radioactive waste.

1.3 Development Status

To fulfill its mission, the DOE developed WIPP in a phased manner. The goal of the SPDV phase, begun in 1980, was to characterize the site and obtain *in situ* geotechnical data from underground excavations to determine whether site characteristics and the *in situ* conditions were suitable for a permanent disposal facility. During this phase, the Salt Handling Shaft, a ventilation shaft, a drift to the southernmost extent of the proposed waste disposal area, a four-room experimental panel, and access drifts were excavated. Surface-based geological and hydrological investigations were also conducted. The data obtained from the SPDV investigations were reported in the "Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program" (DOE, 1983).

Based upon the favorable results of the SPDV investigations, additional activities were initiated in 1983. These included the construction of surface structures, conversion of the ventilation shaft for use as the waste shaft, excavation of the Exhaust Shaft, development of additional access drifts to the waste disposal area, excavation of the Air Intake Shaft, and excavation of additional experimental rooms to support research and development activities. Geotechnical data acquired during this phase were used to evaluate the performance of the excavations in the context of established design criteria (DOE, 1984). Results of these evaluations were reported in Geotechnical Field Data Reports (DOE, 1985; DOE, 1986a) and were summarized in the Design Validation Final Report (DOE, 1986b).

The Design Validation Final Report concluded that the facility, including waste disposal areas, could be developed and operated to fulfill the long-term mission of WIPP (DOE, 1986b). However, some modifications to the reference design were proposed so that the requirements could be met for the anticipated life of the waste disposal rooms and the demonstration phase while the waste remained retrievable. The information from these studies validated the design of underground openings to safely accommodate the permanent disposal of waste under routine operating conditions.

Panel 1 mining began in 1986 and was completed in 1988. Panel 1 was intended to receive waste for an initial operations demonstration and pilot plant phase that was scheduled to start in October 1988. During this reporting period, waste disposal operations in Panel 1 were completed and panel closures were constructed.

In October 1996, the DOE submitted to the U.S. Environmental Protection Agency (EPA) a compliance certification application in accordance with Title 40 CFR Parts 191 and 194, which addressed the long-term (10,000-year) performance criterion for the disposal system. On May 18, 1998, the EPA published final certification that allowed for the receipt of TRU waste at WIPP. Immediately prior to this certification, the DOE Carlsbad Area Office (CAO) completed the WIPP Operational Readiness Review, which was required before the start-up of a nuclear waste repository. As a result of the review, the CAO notified the Energy Secretary on April 1, 1998, that WIPP was operationally ready to receive waste. On October 27, 1999, WIPP received the Hazardous Waste Facility Permit (HWFP). On March 26, 1999, the first shipment of TRU waste was received from Los Alamos National Laboratory (LANL). At the end of June 2003, shipments of TRU waste were received at the WIPP site from LANL, Savannah River Site, Hanford Site, Rocky Flats Environmental Technology Site, Idaho National Engineering and Environmental Laboratory, and Argonne National Lab-East.

Mining of Panel 2 began in September 1999 and was completed in August 2000. The south mains (entry drifts) for Panel 3 were completed in June, 2002. Mining of Panel 3 began on January 31, 2003. As of June 30, 2003, Rooms 1 and 2 are mined and South 2750 and South 3080 drifts are rough cut east of Room 5 of Panel 3.

1.4 Purpose and Scope of Geomechanical Monitoring Program

As specified in the WIPP HWFP (NMED, 1999), the purpose of the geomechanical monitoring program is to obtain *in situ* data to support the continuous assessment of the design for underground facilities.

Specifically, the program provides for:

- Early detection of conditions that could affect operational safety.
- Evaluation of disposal room closure that ensures adequate access.
- Guidance for design modifications and remedial actions.
- Data for interpreting the behavior of underground openings, in comparison with established design criteria.

Polling of the geomechanical instrumentation is performed at least monthly. Data taken by the geomechanical instrumentation system (GIS) are evaluated and reported in this GAR. This annual report fulfills the requirements set forth in Section IV.F.1 and Attachment M2, Section M2-5b(2) of the WIPP Hazardous Waste Facility Permit (NMED, 1999), and 40 CFR §191.14, "Assurance Requirements," implemented through the certification criteria, 40 CFR Part 194.

The Geomechanical Monitoring Program generates the data for four of the compliance monitoring parameters: creep closure and stresses, extent of deformation, initiation of brittle deformation, and displacement of deformation features. Convergence measurements and borehole extensometers provide monitoring data and observations on salt creep closure and stress changes induced by rock excavation. Data on the extent of deformation are generated through borehole extensometers and borehole observations. Fracture mapping of the excavation surface and borehole observations are used to provide data on the initiation of brittle deformation. Displacement of deformation features in the underground facility are monitored by comparing the results of geologic mapping in newly mined areas to the expected stratigraphy.

The GIS provides data that are collected, processed, and stored for analysis. The following subsections briefly describe the major components of the GIS.

1.4.1 Instrumentation

Instrumentation installed for measuring the geomechanical response of the shafts, drifts, and other underground openings include convergence points, convergence meters, extensometers, rock bolt load cells, pressure cells, strain gauges, piezometers, and joint meters. Table 1-1 lists a summary of the geomechanical instrumentation specifications.

Table 1-1
Geomechanical Instrumentation System

Instrument Type	Measures	Range[a]	Resolution[a]
Sonic probe borehole extensometer	Cumulative deformation	0–2 in.	0.001 in.
Convergence points (Tape Extensometer)	Cumulative deformation	2–50 ft	0.001 in.
Wire convergence meters	Cumulative deformation	0–3.5 ft	0.001 in.
Sonic probe convergence meters	Cumulative deformation	0–25 ft	0.001 in.
Embedded strain gauges	Cumulative strain	0–3000 μin./in.	1 μin./in.
Spot-welded strain gauges	Cumulative strain	0–2500 μin./in.	1 μin./in.
Rock bolt load cells	Load	0–50 tons	40 lb
Earth pressure cells	Pressure	0–1000 psi	1 psi
Piezometers	Fluid pressure	0–500 psi	0.5 psi
Joint Meters	Cumulative deformation	0–4 in.	0.001 in.
Vibrating wire borehole extensometer	Cumulative deformation	0–4 in.	0.001 in.
Wire borehole extensometer	Cumulative deformation	0–20 in.	0.001 in.
Linear potentiometric borehole extensometer	Cumulative deformation	0–6 in.	0.001 in.

[a] Manual readout boxes for the instruments were manufactured to output measurements in English units. Range and resolution measurement units have not been converted to metric units. Measurements from these instruments have been converted for presentation elsewhere in this report.

ft = foot (feet)
in. = inch(es)
μin. = 10^{-6} inch(es)
psi = pound(s) per square inch
lb = pound(s)

1.4.2 Data Acquisition

The individual geomechanical instruments are read either manually using portable devices or remotely by electronically polling the stations from the surface in accordance with approved operating procedures. Remotely read instruments are connected to one of the data loggers located underground and readings are collected by initiating the appropriate polling routine. Upon completion of a verification process, the data are transferred to a computer database. The manual readout devices are taken to the instrument locations underground. The data are recorded on a data sheet and later entered into an electronic database along with the remotely acquired data.

The underground data acquisition system consists of instruments, polling devices, and a communications network. One or more instruments are connected to a polling device. The polling devices are installed in electrical enclosures near the location of the instrument to facilitate queries of each individual instrument. Polling devices are connected by a datalink to a surface computer.

Whether acquired manually or remotely, geomechanical data are entered into the database files of the GIS data processing system. The data processing system consists of computer programs that are used to enter, reduce, and transfer the data to permanent storage files. Additional routines allow access to these permanent storage files for numerical analysis, tabular reporting, and graphical plotting. Copies of the instrumentation database and data plots are available upon request[3].

1.4.3 Data Evaluation

Closure measurements are acquired manually from convergence point anchors and remotely from convergence meters. The data are presented in plots as closure versus time. Rate data are calculated and presented as part of the data analysis.

Borehole extensometers provide relative displacement data from instrumented rods anchored at various depths in the rock strata. Displacement is measured relative to a fixed point. The deepest anchor is fixed in what is assumed to be undisturbed ground and is used as the reference point. Plots of displacement versus time for individual anchors relative to the reference point are presented. Typically, the plots show greater relative ground movement near the collar (i.e., the opening of the hole). Rate data for the hole collar relative to the deepest anchor are presented in the data analysis.

The annualized closure rate is calculated as follows:

$$rate(inches/year) = (cfi_2 - cfi_1)/(date_2 - date_1) \times 365.25\, days/year$$
$$where\ cfi = the\ change\ from\ the\ initial\ reading\ (inches)$$
$$cfi_1 = cfi\ reading\ closest\ to\ the\ beginning\ of\ the\ reporting\ period$$
$$cfi_2 = cfi\ reading\ closest\ to\ the\ end\ of\ the\ reporting\ period$$

Rock bolt load cells are used to determine bolt loading. Plots show load versus time for each instrumented bolt.

[3] Instrumentation data and data plots are presented in "Geotechnical Analysis Report for July 2002-June 2003 Supporting Data." The document is available upon request from the National Technical Information Service. See the back side of this document's cover sheet for details and addresses.

Earth pressure cells and strain gages are used to determine the stresses and deformations in and around the shaft liners, and data are depicted in time-based plots.

Piezometers used to measure the gage pressure of groundwater are installed in the shafts at varying elevations to monitor the hydraulic head acting on the shaft liners. Data from piezometers are plotted as pressure versus time.

Joint meters, installed perpendicular to a crack, monitor the dilation of the crack with time. Data from these are typically presented as displacement versus time.

1.4.4 Data Errors

As described above, GIS data are processed through a comprehensive database management system. Whether acquired manually or remotely, GIS data are processed and permanently stored according to approved procedures. On occasion, erroneous readings can occur. There are several possible explanations for erroneous readings, including the following:

- The measuring device was misread.
- The reading was recorded incorrectly.
- The measuring device was not functioning within specifications.

When a reading is believed to be erroneous, an immediate evaluation of the previous reading is performed, and a second reading is collected. If the second reading falls in line with the instrument trend, the first reading is discarded and the second reading is entered in the database. If the second reading and subsequent readings remain out of the instrument trend, the ground conditions in the vicinity of the instrument are assessed to determine the reason for the discrepancy. In addition, reading frequency may be increased. This process to correct erroneous readings is documented and filed for future reference.

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2.0 Geology

This chapter provides a summary of the stratigraphy of the WIPP region and the facility stratigraphy. Readers desiring further geologic information may consult the "Geological Characterization Report, WIPP Site, Southeastern New Mexico" (Powers et al., 1978). This report was developed as a source document on the geology of the WIPP site for individuals, groups, or agencies seeking basic information on geologic history, hydrology, geochemistry, or detailed information, such as physical and chemical properties of repository rocks. A more recent survey of WIPP stratigraphy is included in Holt and Powers (1990).

2.1 Regional Stratigraphy

The stratigraphy in the vicinity of the WIPP site includes rocks and sediments of Permian (286 to 245 million years ago [Ma]), Triassic (245 to 208 Ma), and Quaternary (1.6 Ma to present) ages. The generalized descriptions of formations provided in this section are given in order of deposition (oldest to youngest), beginning with the Castile Formation (Figure 2-1).

The Permian system in the United States is divided into four series. The last of these, the Ochoan Series, contains the host rock in which the WIPP facility is located. The Ochoan Series is of mostly marine origin and consists of four formations: three evaporite formations (the Castile, the Salado, and the Rustler) and one redbed formation (the Dewey Lake). The Ochoan evaporites overlie marine limestones and sandstones of the Guadalupian Series (Delaware Mountain Group). The younger redbeds represent a transition from the lower evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. Fluvial deposits of the Triassic and Quaternary periods complete the stratigraphic column.

2.1.1 Castile Formation

The Castile Formation, lowermost of the four Ochoan formations, is approximately 1,250 ft (380 m) thick in the WIPP vicinity. Lithologically, the Castile is the least complex of the evaporite formations and is composed chiefly of interbedded anhydrite and halite, with limestone present in minor amounts.

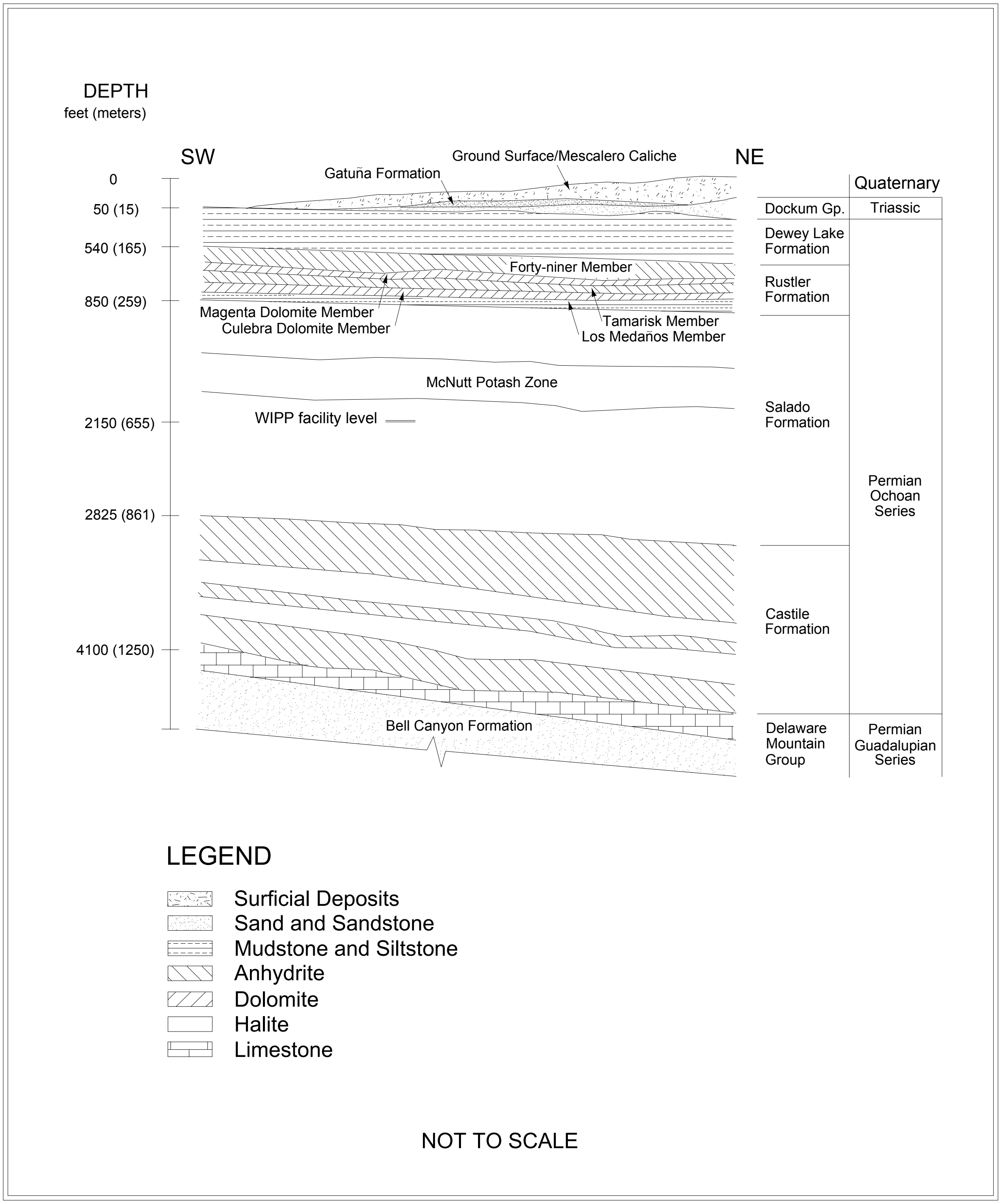

Figure 2-1
Regional Geology

2.1.2 Salado Formation

The Salado Formation comprises nearly 2,000 ft (610 m) evaporites (primarily halite). The formation is subdivided into three informal members: the unnamed lower member, the McNutt potash zone, and the unnamed upper member. Each member contains similar amounts of halite, anhydrite, and polyhalite and is differentiated on the basis of soluble potassium and magnesium-bearing minerals. The WIPP disposal horizon is located within the unnamed lower member, 2,150 ft (655 m) below the surface.

2.1.3 Rustler Formation

The Rustler Formation is the uppermost of the three Ochoan evaporite formations and contains the largest proportion of clastic material of the three. The Rustler is subdivided into five members as follows (from the base): the Los Medaños Member, the Culebra Dolomite Member, the Tamarisk Member, the Magenta Dolomite Member, and the Forty-niner Member.

In the vicinity of the WIPP site, the Rustler is approximately 310 ft (95 m) thick and thickens to the east. The lower portion (Los Medaños Member) contains primarily fine sandstone to mudstone with lesser amounts of anhydrite, polyhalite, and halite. Bedded and burrowed siliciclastic sedimentary rocks with cross-bedding and fossil remains signify the transition from the strongly evaporitic environments of the Salado to the brackish lagoonal environments of the Rustler (Holt and Powers, 1990).

The upper portion of the Rustler contains interbeds of anhydrite, dolomite, and mudstone. The Culebra Dolomite member is generally brown, finely crystalline and locally argillaceous. The Culebra contains rare to abundant vugs with variable gypsum and anhydrite filling and is the most transmissive hydrologic unit within the Rustler. The Tamarisk Member consists of lower and upper sulfate units separated by a unit that varies laterally from mudstone to mainly halite. The Magenta Dolomite Member is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features. The Forty-niner Member consists of lower and upper sulfate units separated by a mudstone that displays sedimentary features and bedding. East of the site area, halite correlates with the mudstone. The Culebra and Magenta Dolomite members are persistent and serve as important marker units.

2.1.4 Dewey Lake Redbeds

The Dewey Lake Redbeds are the uppermost of the Ochoan Series formations in the WIPP vicinity. Within the series, the Dewey Lake represents a transition from the lower marine-influenced evaporite deposition to fluvial deposition on a broad, low-relief, fluvial plain. The redbeds, approximately 475 ft (145 m) thick, consist of predominantly reddish-brown interbedded fine-grained sandstone, siltstone, and claystone. The formation is differentiated from other formations by its lithology and distinctive color (both of which are remarkably uniform), and sedimentary structures, including horizontal- and cross-laminae and ripple marks. The redbeds also contain locally abundant greenish-gray reduction spots and gypsum-filled fractures. The formation thickens from west to east due to eastward dips and erosion to the west.

2.1.5 Dockum Group

The Dockum Group consists of fine-grained floodplain sediments and coarse alluvial debris of the Triassic age. At the WIPP site, the Dockum Group pinches out near the center of the site and thickens eastward as an erosional wedge. Local subdivisions of the Dockum Group are the Santa Rosa Sandstone and the Chinle Formation; however, only the Santa Rosa occurs in the vicinity of the site. The Santa Rosa consists primarily of poorly sorted sandstone with conglomerate lenses and thin mudstone partings and contains impressions and remnants of fossils. These rocks have more variegated hues than the underlying uniformly colored Dewey Lake.

2.1.6 Gatuña Formation, Mescalero Caliche, and Surficial Sediments

Quaternary Period deposits include the Gatuña Formation, Mescalero Caliche, and surficial sediments. The Gatuña Formation (ranging in age from approximately 13 Ma to 600,000 years before present [b.p.] [Powers and Holt, 1993]) is a stream-laid deposit overlying the Dockum Group in the WIPP vicinity. At the site center the formation consists of approximately 13 ft (4 m) of poorly consolidated sand, gravel, and silty clay. The Gatuña Formation is light red and mottled with dark stains. The unit contains abundant calcium carbonate, but is poorly cemented. Sedimentary structures are abundant (Powers and Holt, 1993, 1995).

The Mescalero Caliche (approximately 500,000 years b.p.) is approximately 4 ft (1.2 m) thick in the WIPP vicinity. The Mescalero is a hard, resistant soil horizon that lies beneath a cover of wind-blown sand. The horizon is petrocalcic, or very strongly cemented with calcium carbonate. Petrocalcic horizons form slowly beneath a stable landscape at the average depth of infiltration of soil moisture and are an indicator of stability and integrity of the land surface. Many of the surface buildings at WIPP are founded on top of the Mescalero Caliche.

Surficial sediments include sandy soils developed from eolian material and active dune areas. The Berino Series (a soil type) covers about 50 percent of the site and consists of deep sandy soils that developed from wind-worked material of mixed origin. Based on sample analyses, the Berino soil from the WIPP site formed 330,000 ± 75,000 years ago.

2.2 Underground Facility Stratigraphy

The WIPP disposal horizon lies in the approximate center of the Salado Formation. The Salado was deposited in a shallow saline lagoon environment, which progressed through numerous inundation and desiccation cycles that are reflected in the formation. An "ideal" cycle progresses upward as follows: a basal layer consisting predominantly of claystone, followed by a layer of sulfate, which is in turn followed by a layer of halite. The entire sequence is capped by a bed of argillaceous (clay-rich) halite accumulated during a period of mainly subaerial exposure.

A regional system used for numbering the more significant sulfate beds within the Salado designates these beds as marker beds (MB) 100 (near the top of the formation) to MB144 (near the base). The repository is located between MB138 and MB139 (Figure 2-2) within a sequence of laterally continuous depositional cycles as described above. Within this sequence, layers of clay and anhydrite that are locally designated (as shown) can have a significant impact on the geomechanical performance of the excavations. Clay layers provide surfaces along which slip and separation can occur, whereas anhydrite acts as a brittle unit that does not deform plastically.

2.2.1 Disposal Horizon Stratigraphy (Panels 1, 2, 7, and 8)

This disposal horizon contains panels 1, 2, 7, and 8, all the shaft areas, the shop areas, most of the north experimental areas, and all the access drifts to South 2620. The four main entries that extend south ramp-up starting at South 2620 and complete at South 2740.

Most underground excavations are located within this disposal horizon (see Figure 2-2). In this horizon, the Orange Marker Bed (OMB) typically occurs near mid-rib. The OMB is a laterally consistent unit of moderately to light reddish-orange halite, typically about 6 in. (15 cm) thick, that is used as a point of reference for disposal area excavation.

MB139 typically lies approximately 5 ft (1.5 m) below the excavation floor. MB139 is a 20-to-32 in. (50-to-80 cm) thick layer of polyhalitic anhydrite. The top of the anhydrite undulates up to 15 in. (38 cm) while the bottom is subhorizontal and is underlain by clay "E." Above MB139 is a unit of halite that terminates at the base of the OMB. Within this unit, polyhalite is locally abundant and decreases upward, while argillaceous material increases upward.

Above the OMB, a thin sequence of argillaceous halite gives way to a thick sequence of clear halite that becomes increasingly argillaceous upward and is capped by clay "F." Clay "F" occurs as a thin layer occasionally interrupted by partings and breaks and is readily visible in the upper ribs of disposal horizon excavations, usually approxmiately 24 in. (60 cm) below the roof.

Above clay "F," another sequence of halite begins that, as in lower sequences, becomes increasingly argillaceous upward. This sequence terminates at the clay "G"/Anhydrite "b" interface, approximately 6.5 ft (2 m) above the roof of most disposal horizon excavations, forming a roof beam that typically acts as a unit. The roof of some disposal horizon excavations (e.g., East 140 drift between South 1000 and South 1950), has been excavated to the upper contact of Anhydrite "b." In this case, a roof beam is formed by the next depositional sequence beginning with Anhydrite "b" and progressing upward to the clay "H"/Anhydrite "a" interface, typically approxmiately 6.5 ft (2 m) above the upper contact of Anhydrite "b."

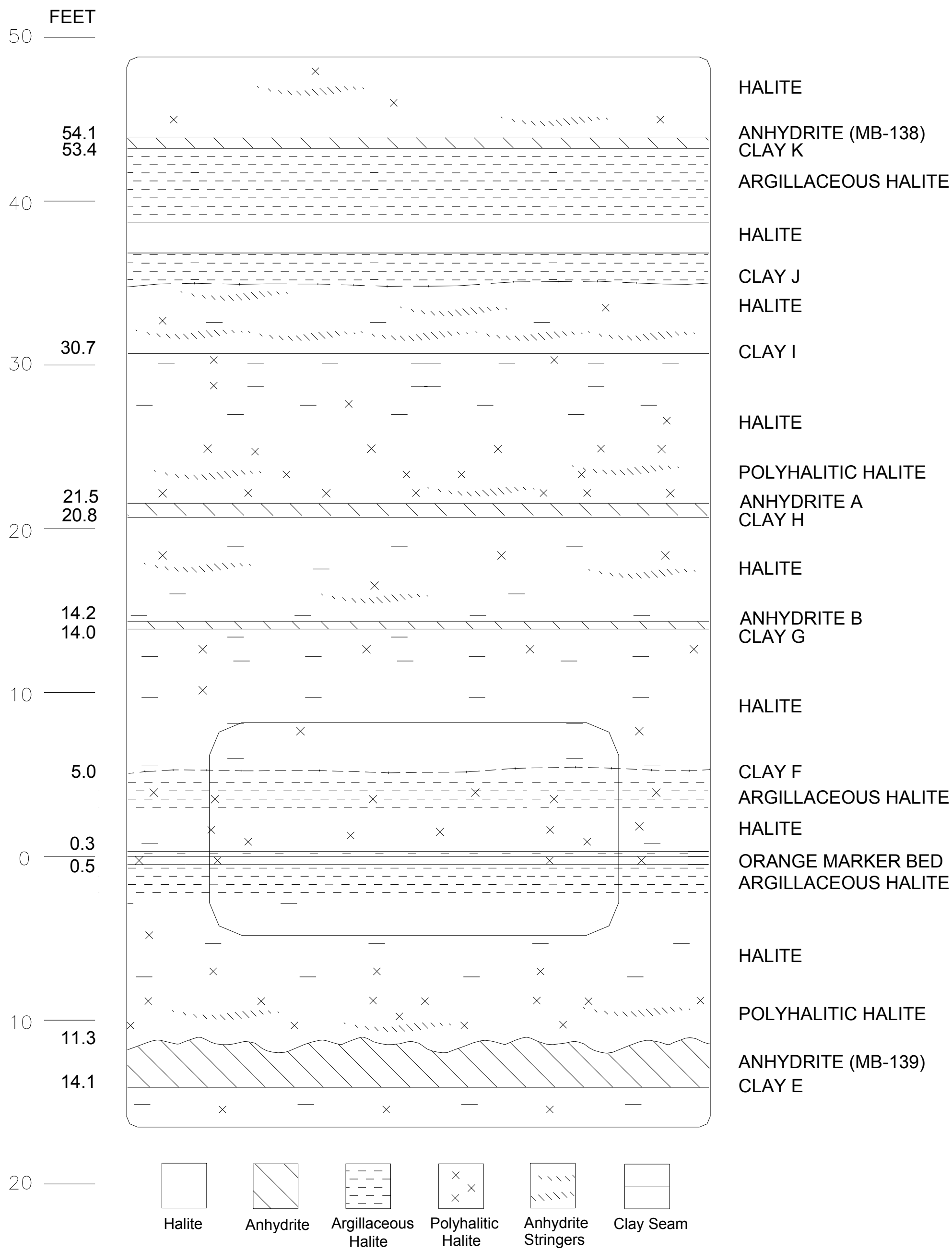

Figure 2-2
Repository Level Stratigraphy (Panels 1, 2, 7, and 8)

2.2.2 Disposal Horizon Stratigraphy (Panels 3, 4, 5, and 6)

This disposal horizon contains panels 3, 4, 5, and 6, all the access drifts south of South 2740. The rise in elevation from South 2620 to South 2740 is approximately 6 ft.

In this horizon (see Figure 2-3), the OMB typically occurs at or below the floor. MB139 typically lies about 12 feet (3.7 m) below the excavation floor. This sequence terminates at the clay "G"/Anhydrite "b" interface. The roof is immediately above Anhydrite "b." Clay "G"/Anhydrite "b" is used as the mining reference at this disposal horizon.

2.2.3 Experimental Area Stratigraphy

Some excavations located in the eastern portion of the Northern Experimental Area (deactivated and closed during this reporting period) lie at a higher stratigraphic level than the disposal excavations. These excavations typically have floors excavated at Anhydrite "b." As in the lower units, the halite intervals between the clay seams/anhydrite beds contain relatively pure halite that becomes increasingly argillaceous upward. Above clay "I," two more halite intervals complete the underground facility stratigraphy. Clay "J," at the top of the first of these intervals, may occur as a distinct seam or merely an argillaceous zone. Clay "K" tops the second interval and is overlain by anhydrite MB138.

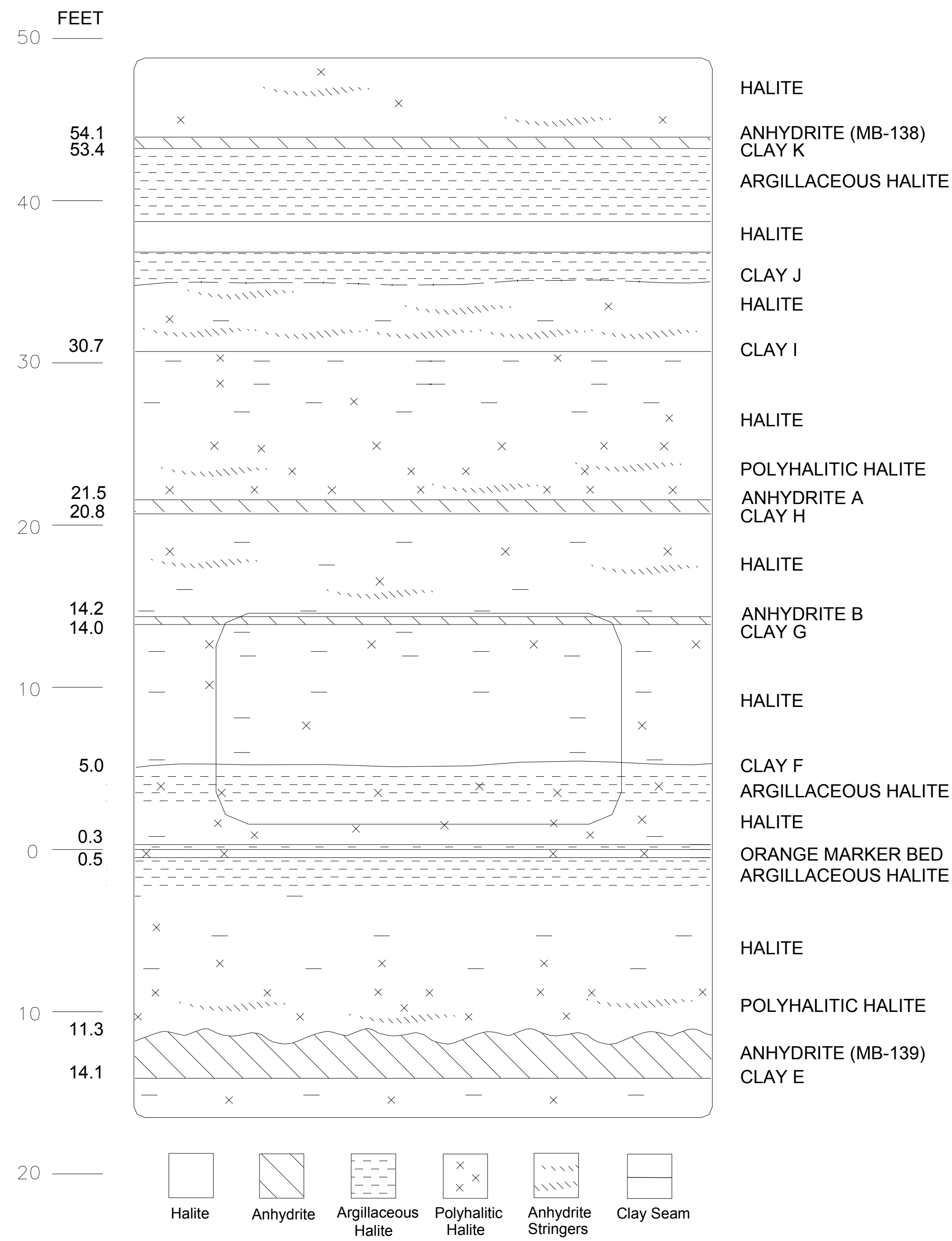

Figure 2-3
Repository Level Stratigraphy (Panels 3, 4, 5, and 6)

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3.0 Performance of Shafts and Keys

Four shafts connect the surface with the WIPP underground facility. The four shafts are: the Salt Handling Shaft, which is primarily used for removing excavated salt from the underground; the Waste Shaft, which is the primary shaft for transporting men and materials and is used for transporting TRU waste to the underground; the Exhaust Shaft, which is used to exhaust the ventilation air from the underground; and the Air Intake Shaft, which is the primary source of fresh air ventilation to the underground. This chapter describes the geomechanical performance of these shafts.

Although through the years some of the shaft instrumentation has failed, there are no plans to replace failed instrumentation installed in any of the shafts. The project currently has a good understanding of the expected movements in the shafts. The monitoring results, up to the point of instrument failure, did not indicate any unusual shaft movements or displacements. Continued periodic visual inspections confirm the expected shaft performance and provide necessary observations to evaluate shaft performance. It is anticipated that replacement of the failed instrumentation will not provide significant additional information.

3.1 Salt Handling Shaft

The first construction activity undertaken during the SPDV Program was the excavation of the Exploratory Shaft. This shaft was subsequently referred to as the Construction and Salt Handling Shaft and is currently designated the Salt Handling Shaft (see Figure 1-2). The shaft was drilled from July 4 to October 24, 1981, and geologic mapping was conducted in the spring of 1982 (DOE, 1983). Figure 3-1 presents the stratigraphy at the Salt Handling Shaft.

The Salt Handling Shaft is lined with steel casing and has a 10-ft (3-m) inside diameter from the ground surface to a depth of 846 ft (257.9 m). The steel liner has a thickness of 0.62 in. (1.6 cm) at the top, increasing with depth to a thickness of 1.5 in. (3.8 cm), including external stiffener rings, at the key. Cement grout is placed between the liner and rock face. The 10-ft (3-m) diameter extends through the concrete shaft key to a depth of 880 ft (268.2 m). The shaft key is a 37.5-ft (11.4-m) long, reinforced-concrete structure that begins 3.5 ft (1.07 m) above the bottom of the steel liner. The shaft from the key to the bottom of the shaft, at a depth of 2,298 ft (700 m), has a nominal diameter of 12 ft (4 m).

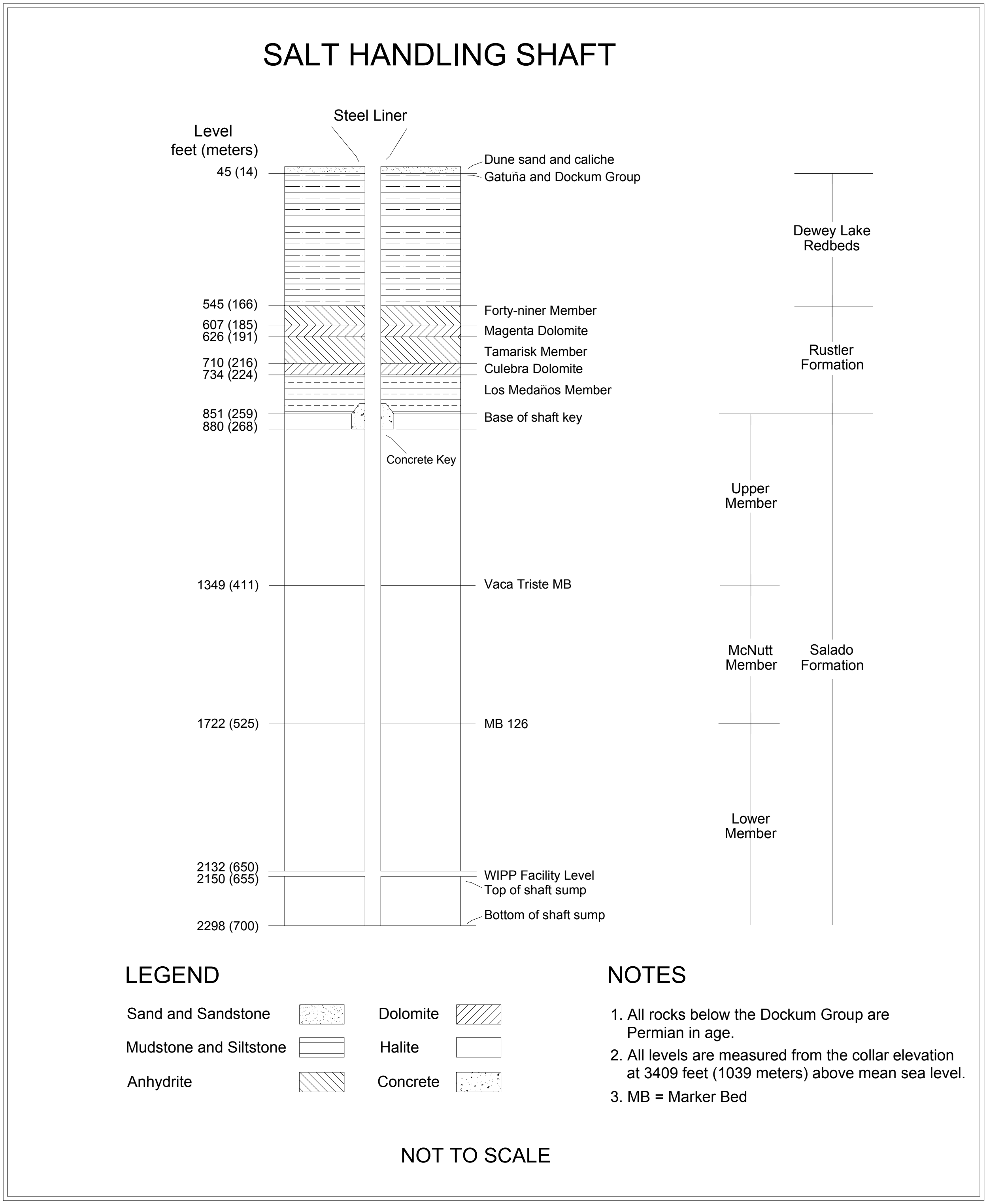

Figure 3-1
Salt Handling Shaft Stratigraphy

Wire mesh anchored by rock bolts is installed in this portion as a safety screen to contain rock fragments that may become detached. The shaft extends approximately 140 ft (43 m) below the facility horizon in order to accommodate the skip loading equipment and to act as a sump.

3.1.1 Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections. These inspections are performed principally to assess the condition of the hoisting and mechanical systems, but they also include examining the shaft walls for water seepage, loose rock, or sloughing. The visual shaft inspections during this reporting period found that the Salt Handling Shaft was in satisfactory condition. Only routine ground control activities were required in the Salt Handling Shaft during this reporting period.

3.1.2 Instrumentation

Geomechanical instruments (extensometers, piezometers, and radial convergence points) were installed at various levels in the Salt Handling Shaft during April and July of 1982 (Figure 3-2). In the shaft key, instruments included strain gages, pressure cells, and piezometers (Figure 3-3). All of the extensometers in the Salt Handling Shaft are nonfunctional.

All 12 piezometers continue to provide data. The fluid pressures recorded at the end of this reporting period range from approximately 74 pounds per square inch (psi) (510 kilopascals [kPa]) at the 580-ft (177-m) level in the Forty-niner Member to 149 psi (1,027 kPa) at the 691-ft (211-m) level in the Tamarisk Member. The recorded pressure of 90 psi (620 kPa) at the Magenta Dolomite Member represents a 46-psi increase and the recorded pressure of 105 psi (723 kPa) at the Los Medaños Member represents an 11-psi decrease from the recorded pressure in the same location at the end of the previous reporting period. The pressure for the shaft liner will continue to be monitored on a regular basis.

Four earth pressure cells were installed in the key section of the Salt Handling Shaft during concrete emplacement at the 860-ft (262-m) level. These instruments measure the normal stress between the concrete key and the Salado Formation as the creep effects load on the key structure. Three of the four earth pressure cells continue to provide data, although all three indicate negative pressure. These instruments have essentially indicated no contact pressure since their installation (readings resemble instrument drift at a zero pressure).

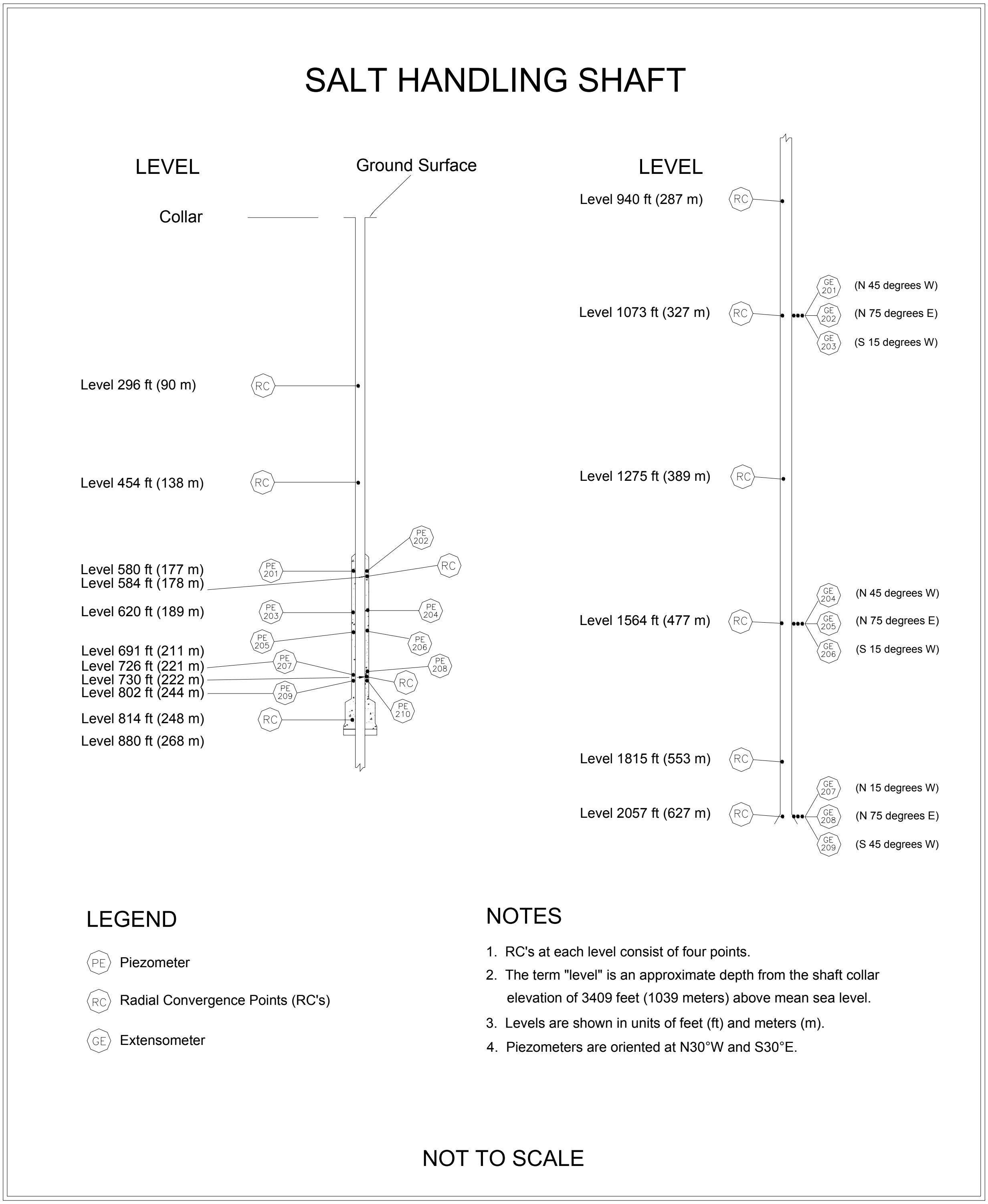

Figure 3-2
Salt Handling Shaft Instrumentation (Without Shaft Key)

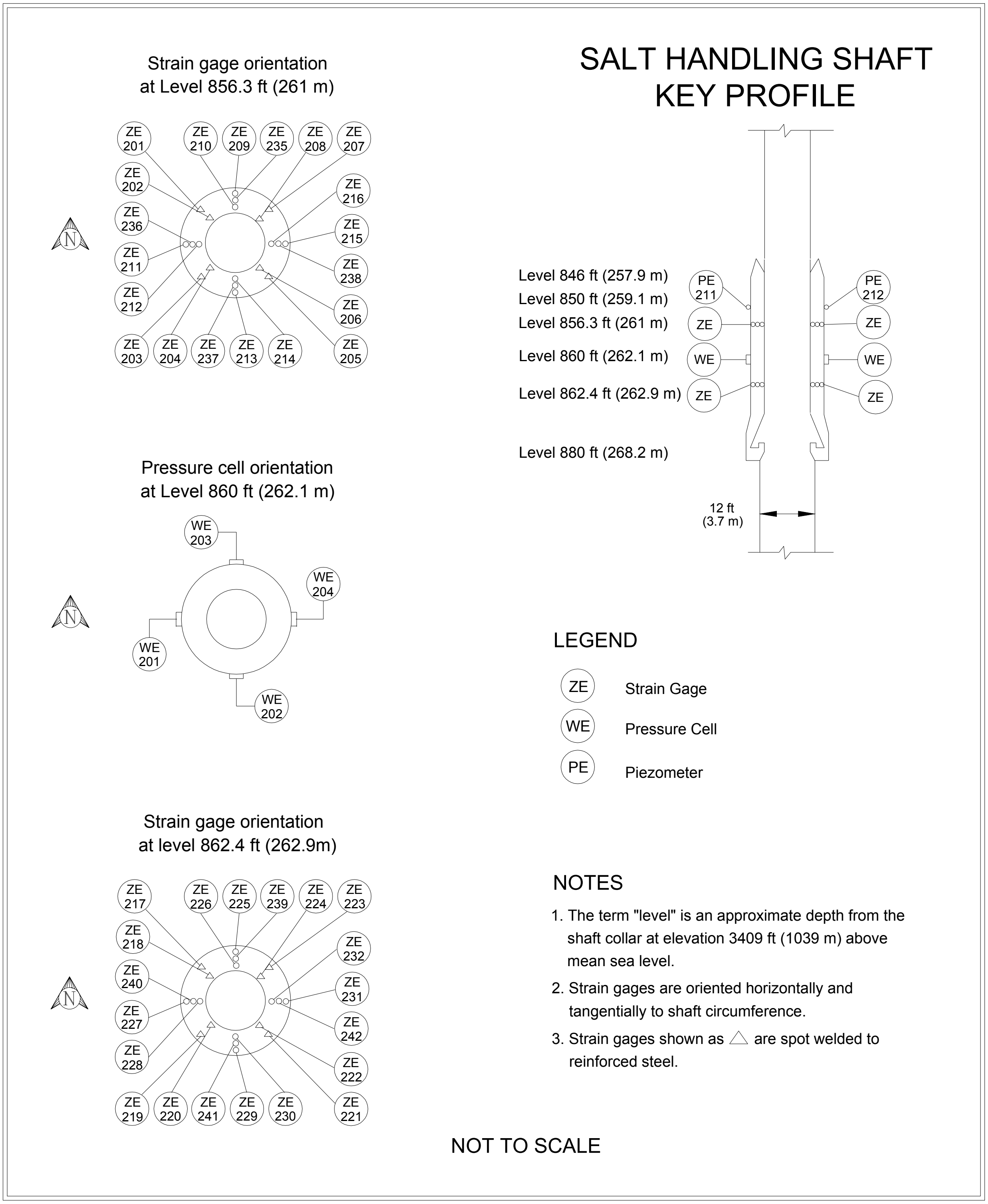

Figure 3-3
Salt Handling Shaft Key Instrumentation

The contact pressures recorded by the instruments for this reporting period ranged from -21.1 to 0.6 psi (-145 to 4 kPa). Sixteen spot-welded and 24 embedment strain gages were installed on and in the shaft key concrete at both the 856.3-ft (261-m) level and at the 862.4-ft (262.9-m) level. There are four functioning spot-welded strain gages located at these levels. The reported strains at the 856.3-ft (261-m) level were 652 and 748 microstrain. The reported strains at the 862.4-ft (262.9-m) level were 507 and 784 microstrain. The strains reported for this reporting period from the 12 embedment strain gages located at the 856.3-ft (261-m) level range from -676 microstrain to 977 microstrain. The strains reported for this reporting period from the two embedment strain gages located at the 862.4-ft (262.9-m) level were 161 microstrain to 297 microstrain. The strains recorded from the spot-welded strain gages and the embedment strain gages are very similar to the recorded strains from these instruments at the end of the previous reporting period.

3.2 Waste Shaft

As part of the SPDV Program, a 6-ft (2-m) diameter ventilation shaft, now referred to as the Waste Shaft, was excavated from December 1981 through February 1982 (see Figure 1-2). This shaft, in combination with the Salt Handling Shaft, provided a two-shaft underground air circulation system. From October 11, 1983, to June 11, 1984, the shaft was enlarged to a diameter of 20 to 23 ft (6 to 7 m) and lined above the key. Stratigraphic mapping (Figure 3-4) was conducted during shaft enlargement from December 9, 1983, to June 5, 1984 (Holt and Powers, 1984).

The Waste Shaft is lined with nonreinforced concrete and has a 19 ft (6 m) inside diameter from the ground surface to the top of the Waste Shaft key at 837 ft (255 m). Liner thickness increases with depth from 10 in. (25 cm) at the surface to 20 in. (51 cm) at the key. The Waste Shaft key is 63 ft (19 m) long and 4.25 ft (1.3 m) thick and is constructed of reinforced concrete. The bottom of the key is 900 ft (274 m) below the surface. The diameter of the shaft is 20 ft (6 m) at the point below the key and increases to 23 ft (7 m) just above the shaft station. The shaft below the key is lined with wire mesh anchored by rock bolts. The diameter of 23 ft (7 m) extends to a depth of approximately 2,286 ft (697 m) with the shaft sump comprising the lower 119 ft (36 m) of that interval.

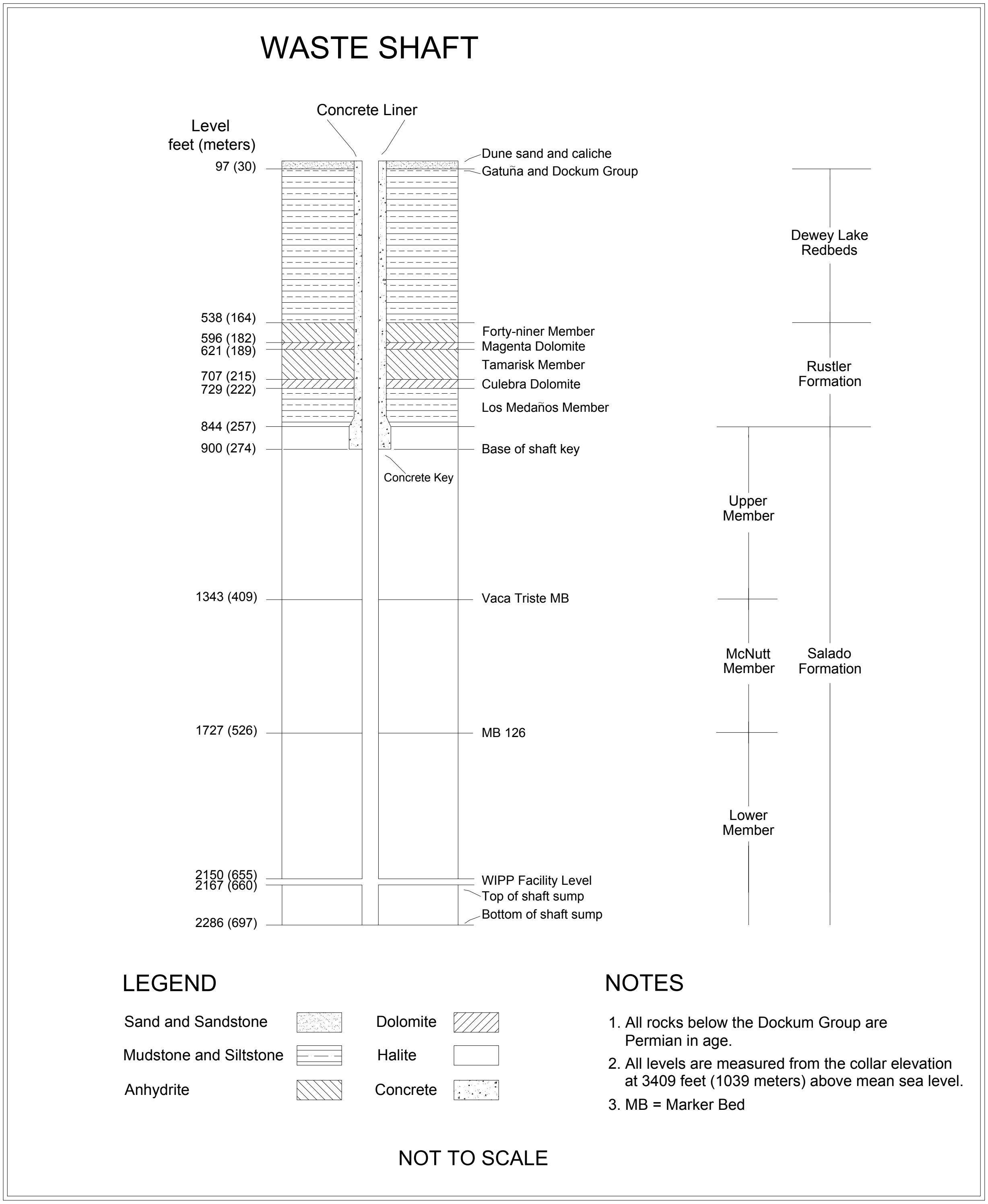

Figure 3-4
Waste Shaft Stratigraphy

3.2.1 Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections. These inspections are performed principally to assess the condition of the hoisting and mechanical systems, but also include observation of the shaft walls for water seepage, loose rock, or sloughing. The visual shaft inspections during this reporting period found that the Waste Shaft was in satisfactory condition. No ground control activities other than routine maintenance were required in the Waste Shaft during this reporting period.

3.2.2 Instrumentation

Extensometers, piezometers, earth pressure cells, and radial convergence points were installed in the Waste Shaft between August 27 and September 10, 1984. Figures 3-5 and 3-6 illustrate the instrumentation configurations in the shaft and shaft key.

Nine multiposition borehole extensometers were installed in arrays at 1,071 ft (326 m), 1,566 ft (477 m), and 2,059 ft (628 m) below the surface as shown in Figure 3-5. Each array consists of three extensometers. Currently, six out of nine extensometers remain functional. Table 3-1 summarizes information regarding collar displacement measurements from these extensometers.

Table 3-1
Collar Displacement at Waste Shaft Extensometers

Field Tag	Location Shaft Level	Date of Last Reading	Collar Displacement Relative to Deepest Anchor inches (cm)	Displacement Rate 2002-2003 inches/year (cm/yr)	Displacement Rate 2001-2002 inches/year (cm/yr)	Rate Change Percent %
31X-GE-00203	1071	04/28/03	0.207 (0.526)	0.003 (0.008)	0.002 (0.005)	50%
31X-GE-00204	1566	04/28/03	0.781 (1.984)	0.019 (0.048)	0.018 (0.046)	6%
31X-GE-00205	1566	04/28/03	0.661 (1.679)	0.016 (0.041)	0.016 (0.041)	0%
31X-GE-00206	1566	04/28/03	0.791 (2.009)	0.021 (0.053)	0.021 (0.053)	0%
31X-GE-00208	2059	04/28/03	1.860 (4.724)	0.055 (0.140)	0.047 (0.119)	17%
31X-GE-00209	2059	04/28/03	2.115 (5.372)	0.072 (0.183)	0.067 (0.170)	7%

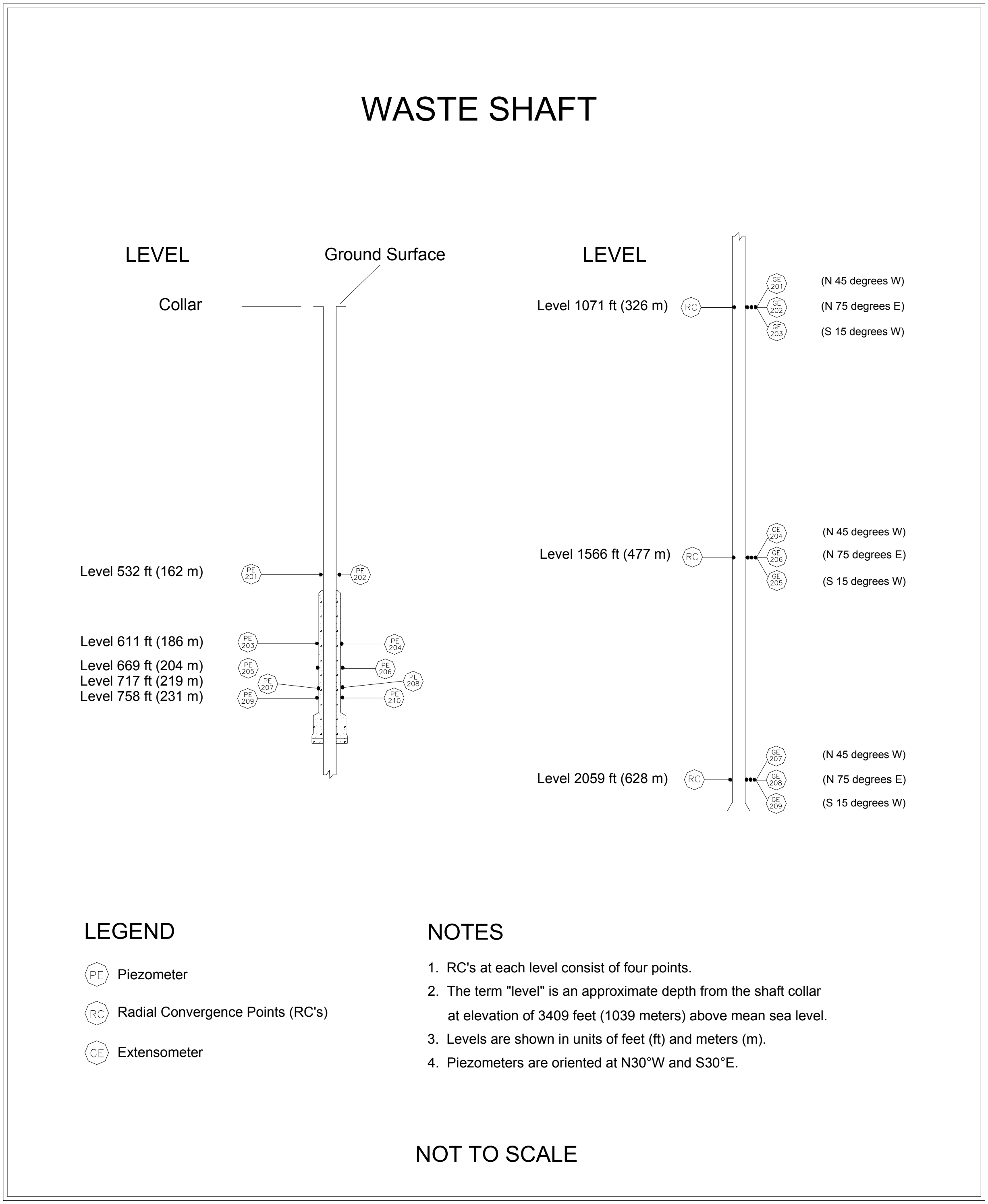

Figure 3-5
Waste Shaft Instrumentation (Without Shaft Key)

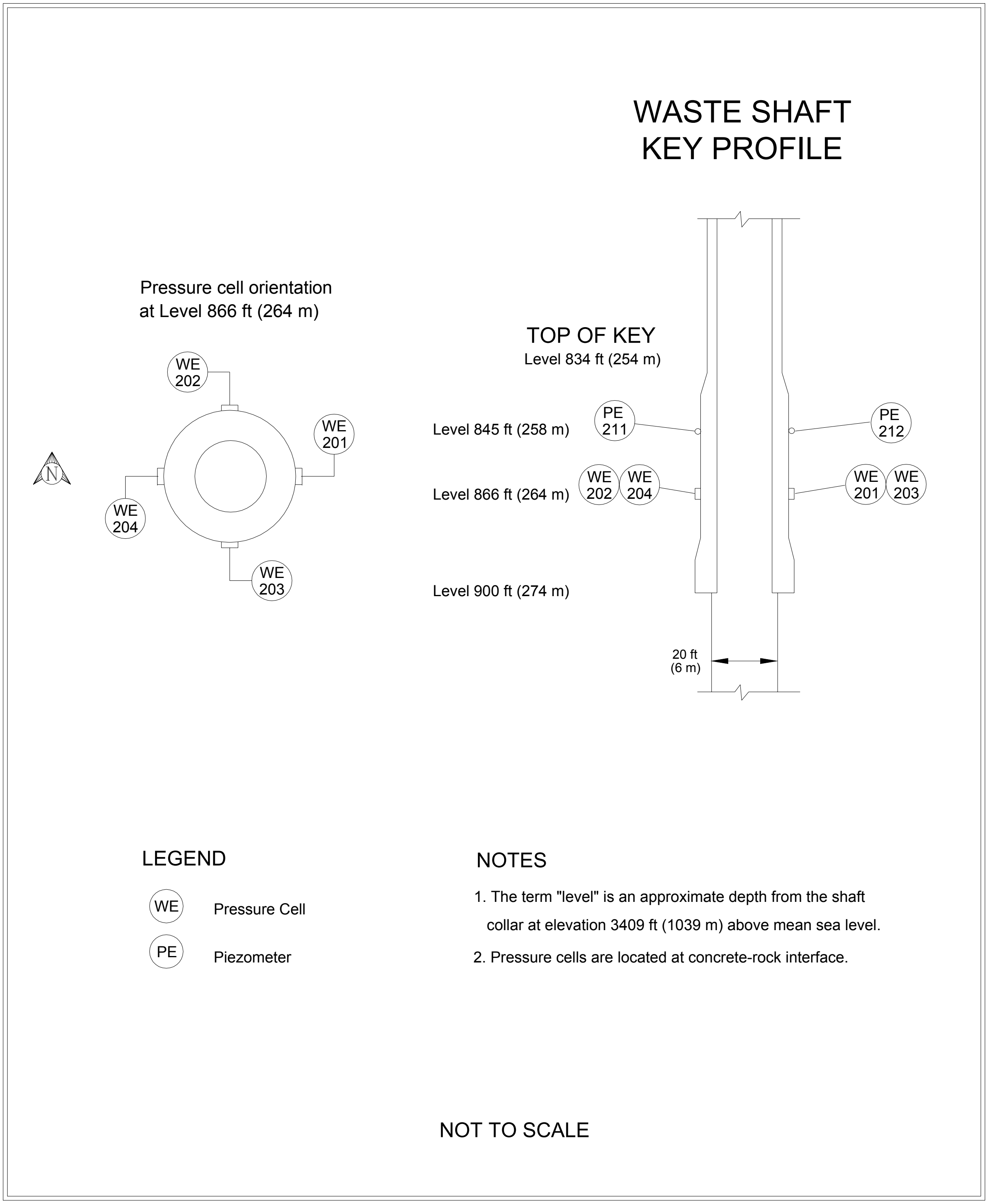

Figure 3-6
Waste Shaft Key Instrumentation

The collar displacement for the one working extensometer at the 1,071-ft (326-m) level indicates virtually no movement. Its annual displacement rate[4] is 0.003 in./yr (0.008 cm/yr). Overall, this displacement rate shows a slight increase over the previous reporting period.

The collar displacement rates at the 1,566-ft (477-m) level have remained similar relative to the rates from the previous reporting period. The annualized displacement rate change for the three extensometers is calculated at 0, 0, and 6 percent. At the 2,059-ft (628-m) level, the collar displacement rate changes varied from 7 to 17 percent. There were no data from the third extensometer because of a instrument failure. Again, these rates are considered acceptable. There is no indication of shaft instability from routine inspections.

Twelve piezometers were installed in the lined section of the Waste Shaft on September 7 and 8, 1984, to monitor pressure behind the shaft liner and key section in the shaft. Data continue to be received from all 12 piezometers, although 5 of the 12 report zero or near zero fluid pressure. The recorded positive fluid pressures from the remaining 7 piezometers at the end of the reporting period range from 34 psi (234 kPa) at the Magenta Dolomite Member (611-ft [186-m] depth) up to greater than 144 psi (992 kPa) at the level where the shaft intersects the Culebra Dolomite Member (717-ft [218.5-m] depth).

Four earth pressure cells were installed in the key section of the Waste Shaft during concrete emplacement between March 23 and April 3, 1984. These instruments measure the normal stress between the concrete key and the Salado Formation as the salt creep loads the key structure. The contact pressure recorded by these four instruments has remained fairly constant over the past five years. The pressures of record during this reporting period are between 74 and 101 psi (510 and 696 kPa).

3.3 Exhaust Shaft

The Exhaust Shaft was drilled from September 22, 1983, to November 29, 1984, to establish a route from the underground facility to the surface for exhaust air (see Figure 1-2). Stratigraphic mapping was conducted from July 16, 1984, to January 18, 1985 (DOE, 1986c). Figure 3-7 illustrates the Exhaust Shaft Stratigraphy.

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[4] Annual displacement rates are calculated as the difference in collar displacement readings from the first reading of the previous reporting period to the final reading of this reporting period divided by the time between those two readings, usually approximately one year.

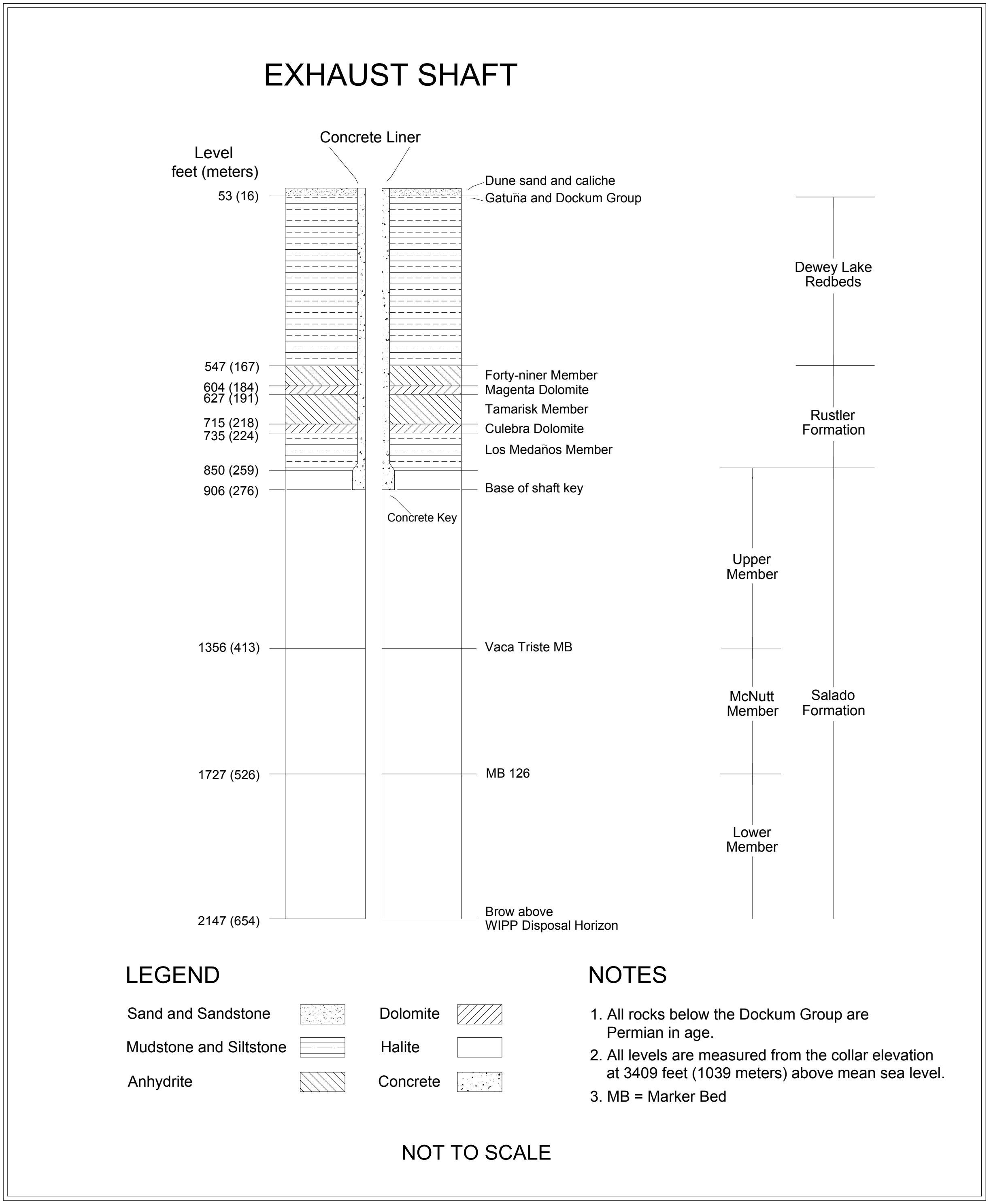

Figure 3-7
Exhaust Shaft Stratigraphy

The Exhaust Shaft is lined with nonreinforced concrete from the surface to the top of the shaft key at a depth of 844 ft (257 m). The liner thickness increases from 10 to 16 in. (25 to 41 cm) over that interval. The Exhaust Shaft key is 63 ft (19 m) long and 3.5 ft (1 m) thick. The shaft diameter below the key is 15 ft (5 m) and the interval below the key is lined with wire mesh anchored by rock bolts. The shaft terminates at the facility horizon, at a depth of approximately 2,150 ft (655 m). There is no excavated shaft sump.

3.3.1 Exhaust Shaft Observations

Quarterly Exhaust Shaft video inspections are conducted following approved WIPP procedures. Inspections are performed to evaluate the condition and to verify the integrity of the shaft. The shaft is examined for cracks, corrosion, salt buildup, leaks, and debris. In addition, inspections examine the condition of anchors, brackets, and down-hole equipment. Between June 2002 and July 2003, four shaft inspections were conducted. Inspections were conducted on August 15, 2002; November 13, 2002; February 11, 2003; and May 15, 2003.

3.3.1.1 Video Camera

Video inspections of the Exhaust Shaft were conducted by the Washington TRU Solutions LLC (WTS) Geotechnical Engineering Section using a custom-designed vertical-drop camera. The system consists of a color camera with pan, tilt, and zoom capability. The camera is housed in an aerodynamic housing and suspended by a dual-armored cable. The cable consists of five copper conductors and two multimode optical fibers. The cable is reeled out by a winch mounted in a control van. The video inspections are recorded on VHS tape.

3.3.1.2 Shaft Inspection Observations

Quarterly video inspection observations concentrate on four major areas: air monitoring systems, shaft liner, shaft walls, and equipment support and cabling. The air monitoring components consist of one air-velocity and three air-monitoring devices in the Exhaust Shaft, as shown in Figure 3-8. The video inspection includes examination of each device, including the transport assembly, guide tubes, the sample intake, and the support brackets that extend from Station A located above the shaft to the Exhaust Shaft collar. From the Exhaust Shaft collar, the air monitoring components extend down 21 ft and into the shaft.

Video inspections indicate that the air-sampling components may typically accumulate salt buildup of up to several inches.

The Exhaust Shaft liner is examined for cracks, seepage, and general shaft stability. Currently, there are two principal zones of seepage in the shaft. The first is at a depth of about 50 to 55 feet below the shaft collar (bsc). The second is at a depth of about 80 to 85 ft bsc, as shown in Figure 3-9. Monitoring of these seepage horizons dates back prior to 1995. Water entering the shaft through these cracks is believed to originate from a perched anthropogenic water-bearing horizon at the base of the Santa Rosa Formation. The fluid level in the Santa Rosa near the shaft is at about 42 feet below ground surface. Based on examination of the inspection videos the flow rate into the shaft is estimated at about 1 to 3 gallons per minute.

Conditions in the shaft change as a function of several variables, including airflow, humidity, temperature, and underground mining activities (dust). The seepage cracks noted above are confined primarily to the eastern side of the shaft wall. During this reporting period, there did not appear to be any significant change in the quantity of fluid entering the shaft. This is confirmed by comparing annual records of the volume of fluid accumulating in the Exhaust Shaft catch basin at the bottom of the Exhaust Shaft.

When fluid was detected seeping into the Exhaust Shaft in 1995, a catch basin was designed and installed at the base of the Exhaust Shaft to intercept and prevent water from draining into the Waste Shaft Sump. Fluid has been removed on an as-needed basis from the catch basin since March 1996. Table 3-2 presents the volume of fluid removal from the catch basin from July 1997 through June 2003. Between July 2002 and June 2003, the volumes of fluid removed from the catch basin ranged from 55 gallons to 660 gallons (Table 3-2). The largest reported volumes are typically associated with periods of reduced ventilation and increased humidity. For a discussion of the factors affecting the quantity of fluid entering the Exhaust Shaft catch basin, refer to DOE/WIPP 00-2000, "*Brine Generation Study*."

The shaft walls were examined for cracks, moisture, and encrustation, with particular attention paid to three water rings located at the base of the Magenta and Culebra members of the Rustler Formation and the bottom of the shaft key. As noted earlier, the condition of the shaft wall varies depending on the airflow, humidity, temperature, and underground mining activities. During this reporting period, there was significant mining activity in the south main drifts and Panel 3. The only areas in the shaft with significant salt buildup were the three water rings located at the Magenta, the Culebra, and the key.

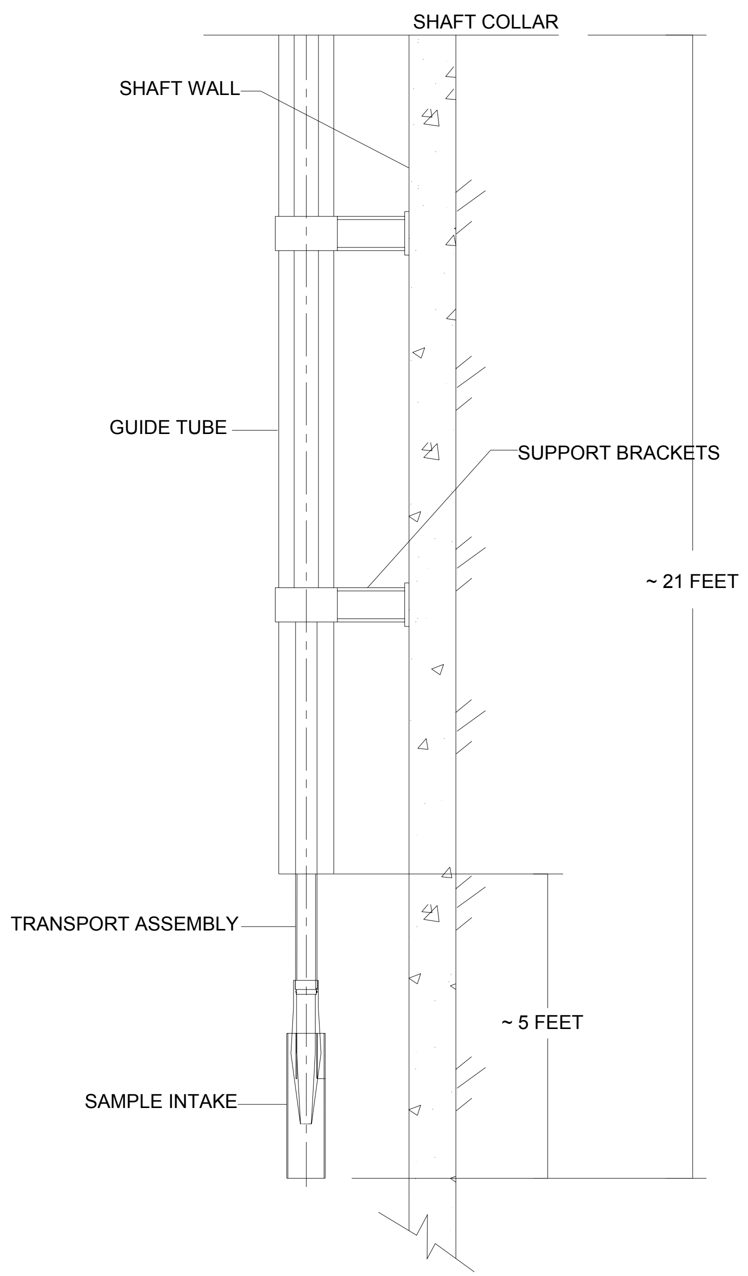

Figure 3-8
Sample Intake Air Monitoring System

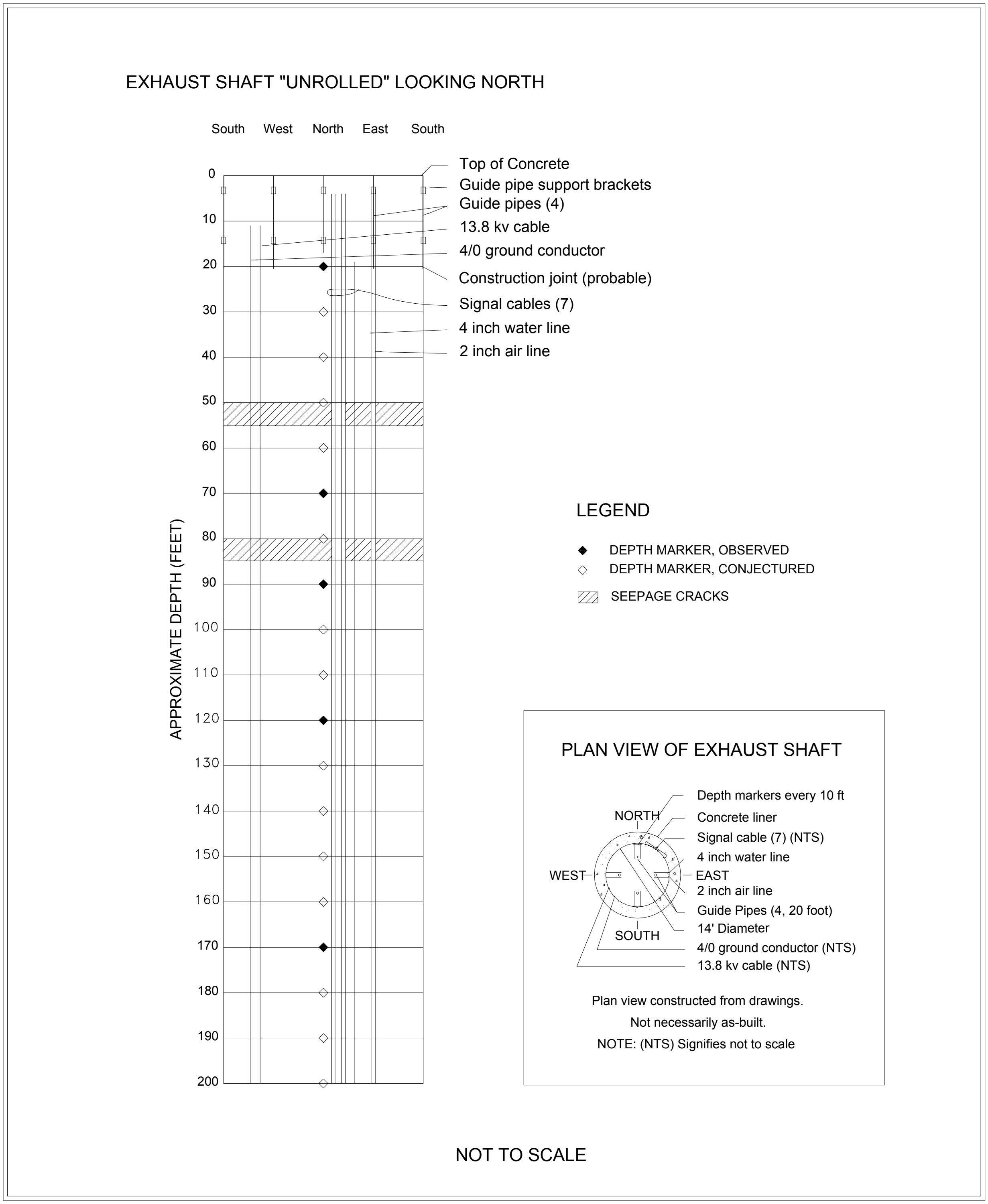

Figure 3-9
Diagram of Exhaust Shaft Fixtures (200 ft Upper Portion)

Though the Magenta and Culebra water rings are encrusted with salt buildup, there does not appear to be any water emanating from the liner or water rings. Most of the seepage was observed along the east face of the shaft wall near the instrumentation cables and the air and waterlines in the upper section of the shaft. Though the presence of water is an inconvenience requiring periodic disposal, at this time it does not appear to have created any hazard or compromised the structural integrity of the shaft. There are no visible signs of dissolution of the salt below the key.

The video inspection also concentrated on the installed utilities and support brackets. This included the 13.8 kilovolt amp (kVA) power cable and the grounding cable located on the west wall of the shaft, the instrumentation cables located on the northeast wall of the shaft, and the 4-in. airline and the 2-in. water line located on the east wall of the shaft. Video inspection of the 13.8 kVA cable and the grounding cable show no visible signs of damage. There is sporadic salt buildup on the cables. Currently, long-term implications of salt buildup on the cables is unknown. The 4-in. compressed air line and the 2-in. water line extend from the ground surface to the bottom of the shaft. At present, neither line is being used. Inspection of the integrity of the brackets holding the air line and water line is difficult to assess because of salt buildup. However, there does not appear to be any indication that the brackets, which hold the air line and water line in place, are broken. Currently broken instrumentation cables were observed at eight locations from about 500 to 1300 ft (152 to 396 m) below the shaft collar. However, only one of the instrumentation cables was in use and therefore should have minimal impact on shaft monitoring or shaft operations.

Table 3-2
Water Removed from the Exhaust Shaft Catch Basin

July 1997 – June 1998		July 1998 – June 1999		July 1999 – June 2000		July 2000 – June 2001		July 2001 – June 2002		July 2002 – June 2003	
Date	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**	**Date**	**Gallons**
7/18/97	275	7/1/98	770	7/19/99	110	7/3/00	220	7/31/01	165	07/02/2002	165
7/28/97	660	7/7/98	330	12/13/99	165	7/15/00	110	8/21/01	1595	07/08/2002	440
8/1//97	550	7/14/98	220	2/21/00	110	9/18/00	330	9/13/01	330	07/09/2002	495
8/4/97	715	7/16/98	275	5/16/00	715	10/24/00	110	10/15/01	770	07/10/2002	660
8/8/97	770	7/23/98	165	6/7/00	165	3/7/01	110	10/30/01	220	07/30/2002	220
8/11/97	660	7/24/98	220	6/12/00	275	3/21/01	165	4/29/02	275	09/17/2002	165
8/15/97	475	7/27/98	825	6/19/00	440	4/10/01	220	6/11/02	550	09/24/2003	
8/18/97	330	7/28/98	330	6/22/00	330	4/17/01	220	6/22/02	330	Sludge	330
8/22/97	330	8/3/98	495	6/30/00	165	4/24/01	110	**Total**	**4235**	03/25/2003	
8/25/97	1045	8/10/98	1265	**Total**	**2475**	5/22/01	110			Sludge	220
Sludge	110	8/21/98	330			Sludge	440			05/27/2003	55
9/2/97	220	8/24/98	990			6/12/01	1100			06/03/2003	220
9/15/97	605	8/27/98	1155			6/13/01	110			06/25/2003	330
9/22/97	550	9/1/98	330			Sludge	110			**Total**	**3300**
10/13/97	825	10/5/98	385			**Total**	**3465**				
10/20/97	220	10/26/98	660								
11/3/97	275	11/23/98	110								
11/10/97	385	2/1/99	385								
11/17/97	385	2/10/99	110								
11/24/97	330	5/4/99	330								
12/10/97	440	5/11/99	110								
12/12/97	550	5/24/99	605								
1/2/98	220	5/26/99	165								
1/12/98	605	6/1/99	165								
2/2/98	660	6/4/99	165								
2/16/98	605	6/10/99	165								
3/16/98	605	Sludge	165								
5/4/98	660	6/16/99	165								
5/11/98	550	6/21/99	1705								
5/18/98	495	6/23/99	275								
5/20/98	110	6/30/99	605								
6/1/98	330	**Total**	**14135**								
6/10/98	90										
6/15/98	385										
6/22/98	165										
Total	**16185**										

3.3.2 Instrumentation

The Exhaust Shaft was equipped with geomechanical instrumentation in two stages. Earth pressure cells were installed behind the liner key in November 1984. Piezometers and nine multiposition borehole extensometers were installed during November and December 1985. Figures 3-10 and 3-11 illustrate the instrumentation configuration.

The extensometers at the 1,573-ft (480-m) level indicate annual collar displacement rates ranging from 0.016 to 0.019 in/yr. (0.047 to 0.048 cm/yr.) These rates have not significantly changed from the previous reporting periods. At the 2,066-ft (630-m) level, the annualized collar displacement rate was 0.072 in/yr (0.183 cm/yr) from the one functioning extensometer. These displacements indicate continued deformation into the shaft; however, there is no indication of accelerated movement. Table 3-3 summarizes information regarding collar displacement measurements from these extensometers.

Table 3-3
Collar Displacement at the Exhaust Shaft Extensometers

Field Tag	Location Shaft Level	Date Last Reading	Collar Displacement Relative to Deepest Anchor in. (cm)	Displacement Rate 2002 to 2003 in/yr (cm/yr)	Displacement Rate 2001 to 2002 in/yr (cm/yr)	Rate Change Percent	Comments
35X-GE-00204	1573	06/02/03	0.363 (0.922)	0.016 (0.041)	0.019 (0.048)	-16%	
35X-GE-00205	1573	06/02/03	0.380 (0.965)	0.017 (0.043	0.023 (0.058)	-26%	
35X-GE-00206	1573	06/02/03	0.393 (0.998)	0.019 (0.048)	0.024 (0.061)	-21%	
35X-GE-00207	2066	06/02/03	1.754 (4.455)	0.072 (0.183)	0.080 (0.203)	-10%	
35X-GE-00209	2066	07/03/02	1.244 (3.160)	N/A	0.059 (0.150)	N/A	Cable Failure

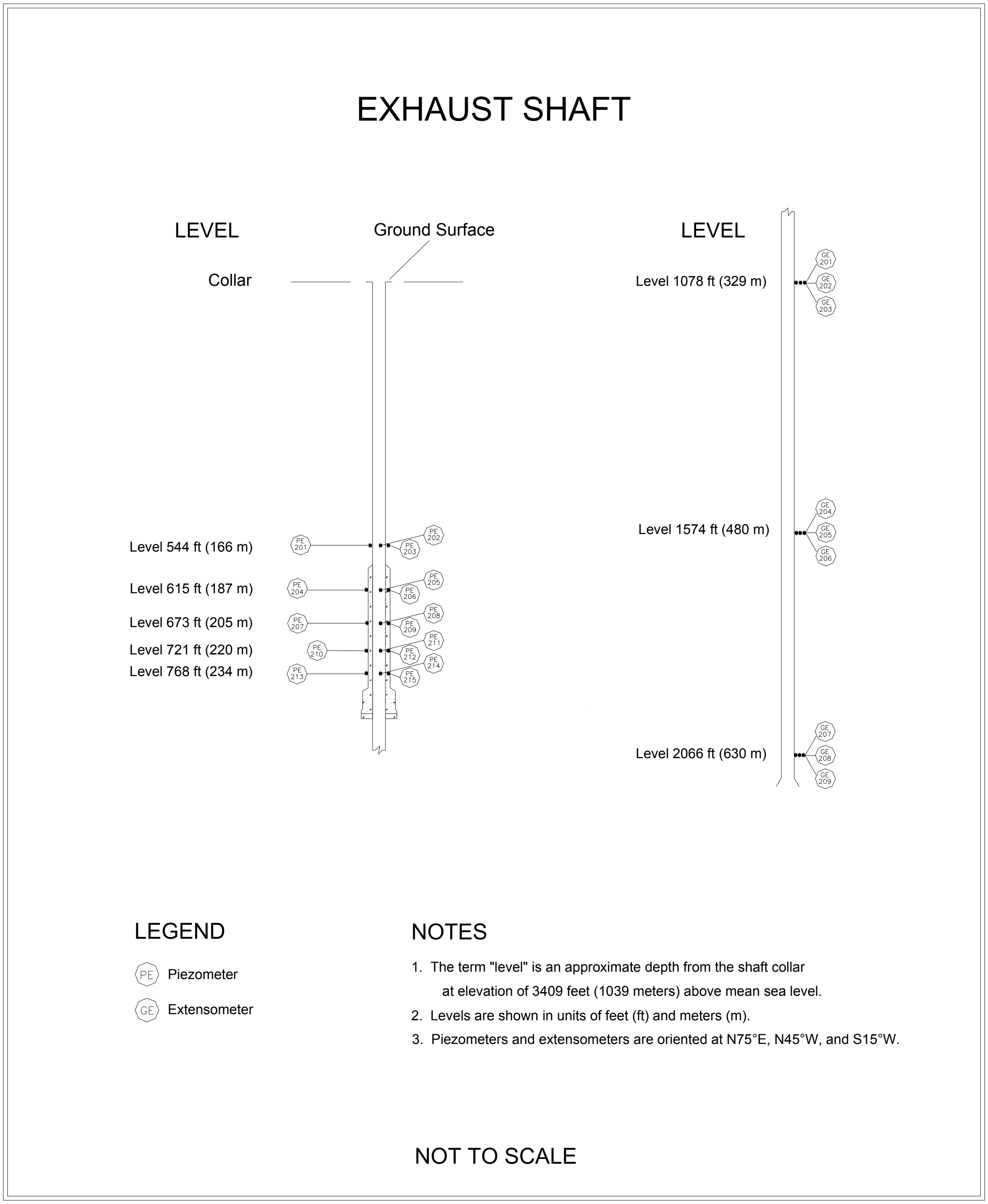

Figure 3-10
Exhaust Shaft Instrumentation (Without Shaft Key)

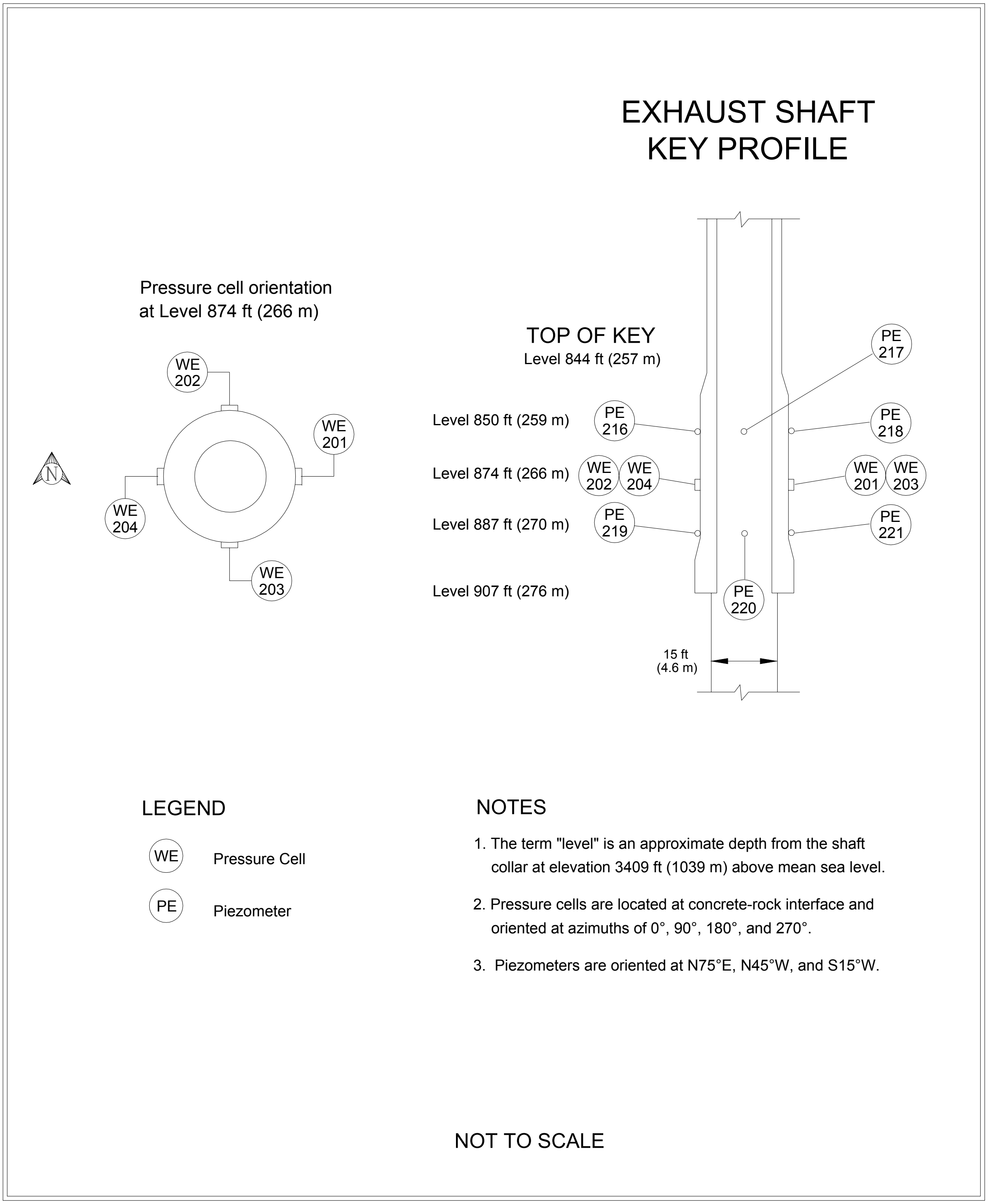

Figure 3-11
Exhaust Shaft Key Instrumentation

Thirteen of the 21 piezometers installed remain in working condition. The fluid pressure readings from the working piezometers at the end of the reporting period range from -3.5 psi (-24.1 kPa) at the 544-ft (165-m) level to 141 psi (971 kPa) at the 721-ft (219-m) level. Maximum pressure readings from the working piezometers during this reporting period were consistent with maximum readings from the previous reporting period with some of the recorded pressures having decreased slightly.

Four earth pressure cells were installed in the key section of the Exhaust Shaft during concrete emplacement. Currently, only two of these earth pressure cells are functional. During this reporting period, the pressure cell readings indicated changes of –0.3 and 0.4 percent. The recorded pressures during this period are 53.2 and 43.6 psi (367 and 300 kPa).

3.4 Air Intake Shaft

The Air Intake Shaft was drilled from December 4, 1987, to August 31, 1988, to establish a primary route for surface air to enter the repository (see Figure 1-2). Stratigraphic mapping was conducted from September 14, 1988, to November 14, 1989 (Holt and Powers, 1990). Figure 3-12 illustrates the Air Intake Shaft stratigraphy.

The Air Intake Shaft is lined with nonreinforced concrete from the surface to the bottom of the shaft key at a depth of 903 ft (275 m). The Air Intake Shaft key is 81 ft (25 m) long with an inside diameter of 16 ft (5 m). The diameter below the shaft key is 20 ft (6 m), and the shaft is unlined below the key to the facility horizon at a depth of 2,150 ft (655 m). The shaft walls are bolted and meshed from just below the key all the way down to the shaft station. The Air Intake Shaft has no sump.

3.4.1 Shaft Performance

Weekly visual inspections were performed on the Air Intake Shaft during this reporting period and the shaft was found to be in satisfactory condition. No ground control activities other than routine maintenance were required during this reporting period.

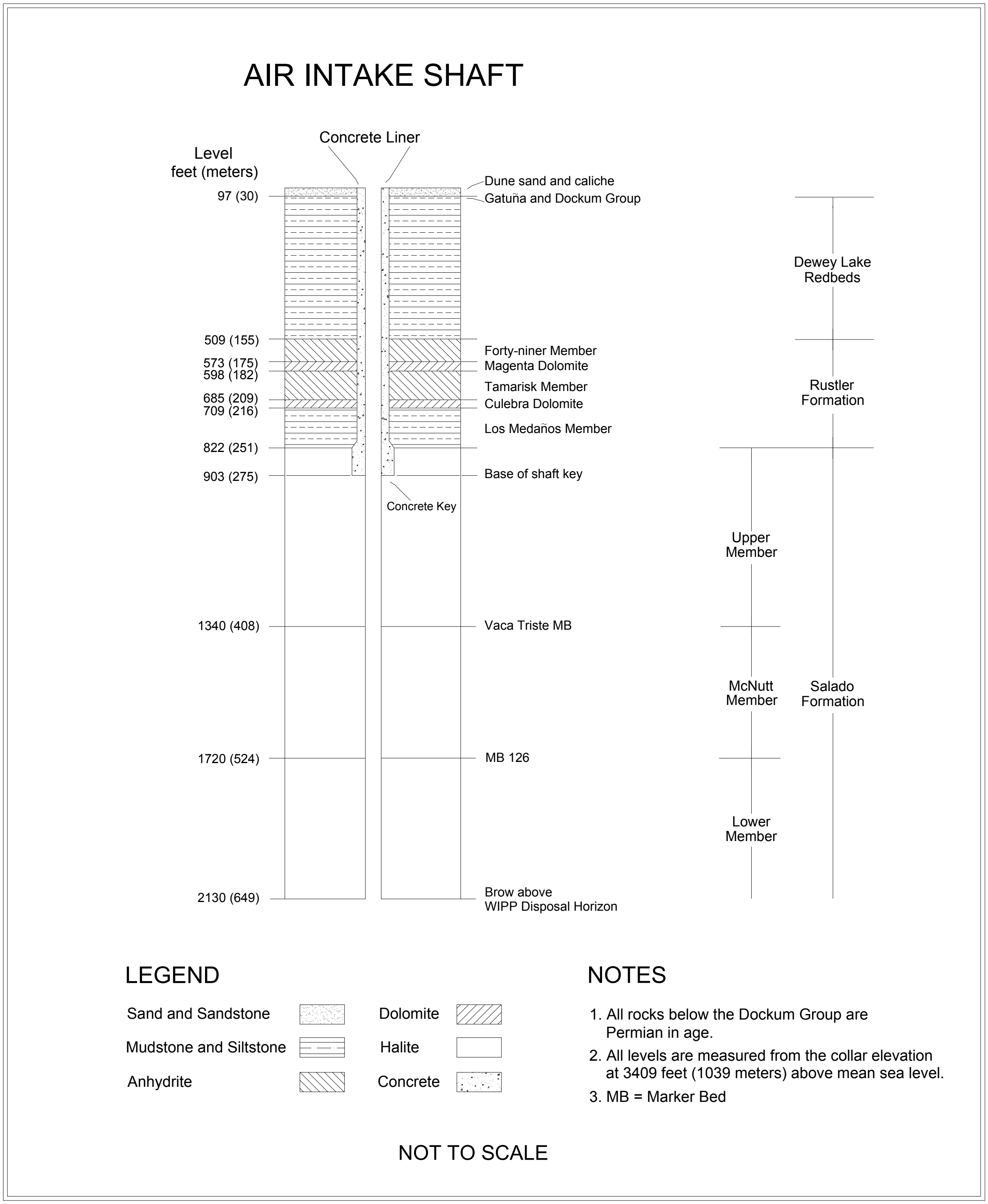

Figure 3-12
Air Intake Shaft Stratigraphy

3.4.2 Instrumentation

Sandia National Laboratories/New Mexico (SNL/NM) installed geomechanical instruments in the Air Intake Shaft in 1988. WTS maintains responsibility for the operation of all of the instruments located in the Air Intake Shaft as well as for data acquisition and instrument maintenance. WTS provides the data to SNL/NM for analysis. Data from these instruments are available from SNL/NM by request.

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4.0 Performance of Shaft Stations

This chapter describes the instrumentation and geomechanical performance of the shaft stations at the base of the Salt Handling Shaft, the Waste Shaft, and the Air Intake Shaft. The Exhaust Shaft does not have an enlarged shaft station and, therefore, is not included in this chapter.

4.1 Salt Handling Shaft Station

The Salt Handling Shaft Station was excavated between May 2 and June 3, 1982, by drilling and blasting. In 1987 the station was enlarged, removing the roof beam up to Anhydrite "b" between South 90 and North 20 using a mechanical scaler. In 1995 the remaining roof beam at the north end of the station was also removed up to Anhydrite "b." The station area south of the shaft is 90 ft (27.5 m) long and 32 to 38 ft (10 to 12 m) wide. The height of the station south of the shaft is 18 ft (5.5 m). The station dimensions north of the shaft are approximately 30 ft (9 m) long, 32 to 35 ft (10 to 11 m) wide, and 18 ft (5.5 m) high. The shaft extends approximately 140 ft (43 m) below the facility horizon to accommodate the skip loading equipment and to act as a sump. Figure 4-1 shows a generalized cross section of the station.

4.1.1 Modifications to Excavation and Ground Control Activities

No major modifications were performed in the Salt Handling Station during this reporting period. Removal of the roof beam immediately north of the station is addressed in Section 5, Performance of Access Drifts. Ground control was performed as routine maintenance.

4.1.2 Instrumentation

Geomechanical instrumentation was installed in the Salt Handling Shaft Station between June 1982 and February 1983, with subsequent reinstallation of extensometers and convergence points as necessary. Figure 4-2 shows the instrument locations after the roof beam was taken down.

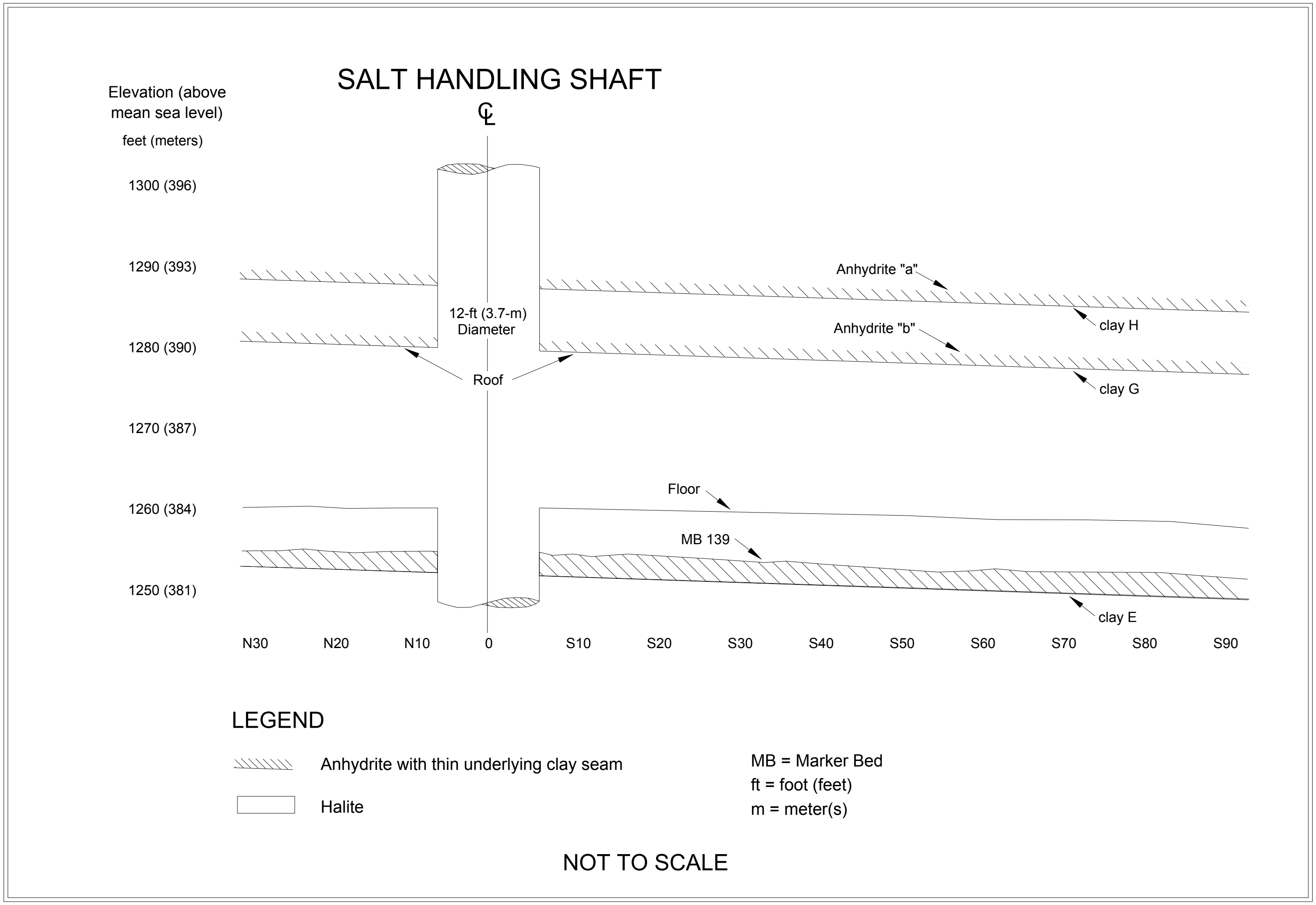

Figure 4-1
Salt Handling Shaft Station Stratigraphy

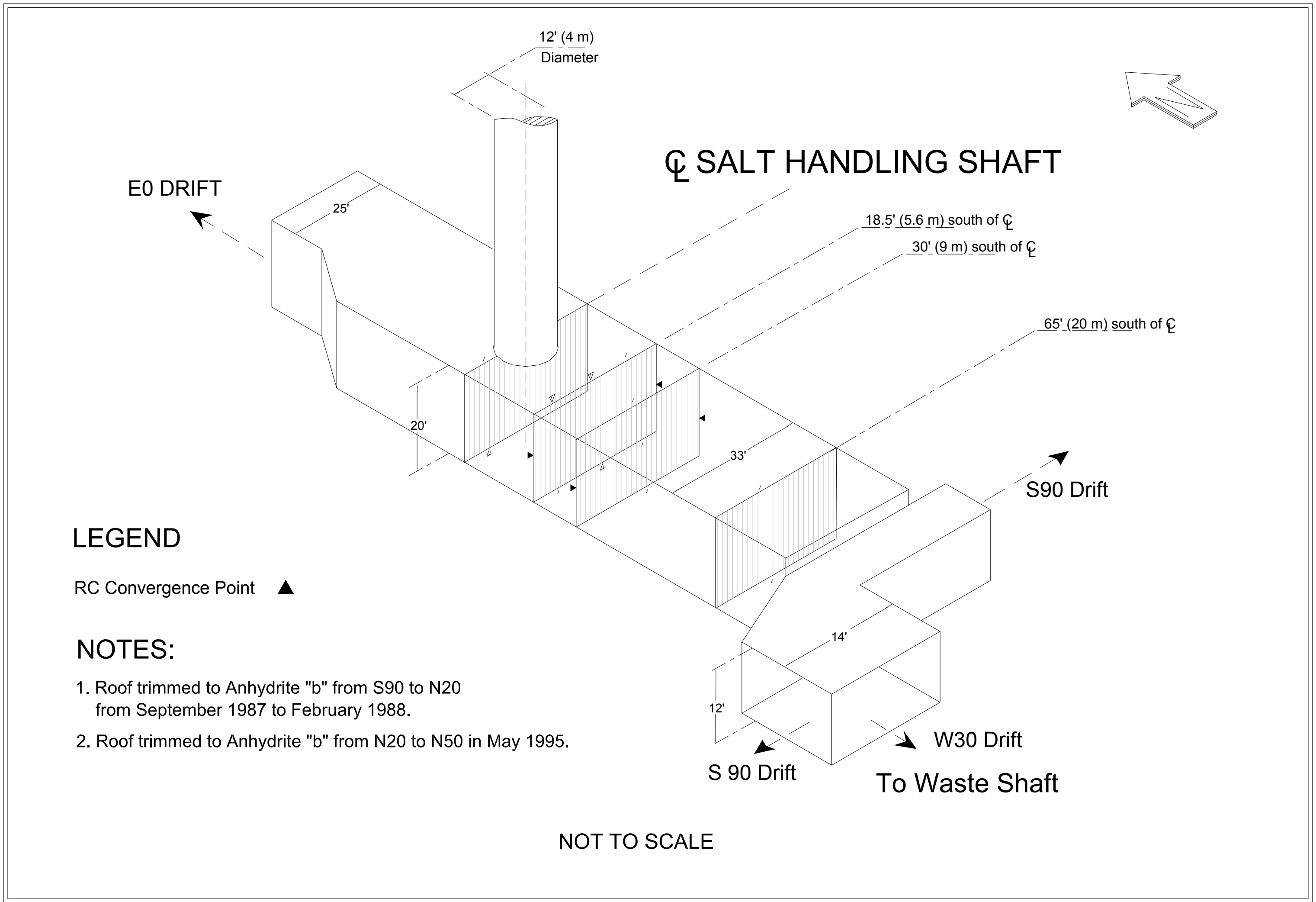

Figure 4-2
Salt Handling Shaft Station Instrumentation After Roof Beam Excavation

There were three extensometers located in the Salt Handling Shaft Station. Due to instrument malfunctions and the removal of one extensometer during roof removal, there are no extensometer data for the Salt Handling Shaft Station for this reporting period; however, historical data are maintained for comparative purposes. Four vertical convergence point arrays and one horizontal convergence chord are currently monitored. Table 4-1 summarizes the vertical closure rates in the Salt Handling Shaft Station from July 2002 through June 2003. Salt Handling Shaft Station vertical closure rates have remained relatively consistent compared to previous reporting periods.

Table 4-1
Vertical Closure Rates in the Salt Handling Shaft Station

Field Tag	Location	Last Reading Date	Cumulative Displacement (inches)	2002-2003 Closure Rate in./yr (cm/yr)	2001-2002 Closure Rate in./yr (cm/yr)	Percent Rate Change
E0-W12-5 A-C	Salt Shaft-W12	06/05/03	16.971	0.832 (2.113)	0.765 (1.943)	9%
E0-S18-6 A-E	E0 Drift-S18	06/05/03	24.632	1.573 (4.000)	1.579 (4.011)	0%
E0-S18-4 B-D	E0 Drift-S18	06/05/03	24.796	1.831 (4.651)	1.596 (4.054)	15%
E0-S18-4 F-H	E0 Drift-S18	06/05/03	15.709	1.103 (2.802)	1.016 (2.581)	9%
E0-S30-5 A-C	E0 Drift-S30	06/05/03	39.043	1.652 (4.201)	1.533 (3.894)	8%
E0-S65-3 A-C	E0 Drift-S65	06/05/03	35.902	1.235 (3.137)	1.201 (3.051)	3%

in./yr = inch(es) per year.
cm/yr = centimeter(s) per year.

4.2 Waste Shaft Station

The Waste Shaft Station was initially excavated with a continuous miner as a ventilation connection to a 6-ft (2-m) diameter exhaust shaft in November 1982. In 1984, the station was enlarged to a height of 15 to 20 ft (4.5 to 6 m) and a width of 20 to 30 ft (6 to 9 m). The station is approximately 150 ft (46 m) long. In 1988, the station walls were trimmed and concrete was placed on the floor. Since 1988, the Waste Shaft Station has undergone three major floor renovations. A 53-ft (16-m)-long section of the reinforced concrete was removed in February 1991, in 1995 an additional 30-ft (9-m) section was removed, and in 2000 the most recent floor maintenance included trimming of the floor and reinstallation of the rails supported by segmented concrete panels on a crushed rock backfill. Figure 4-3 shows a cross section of the Waste Shaft Station.

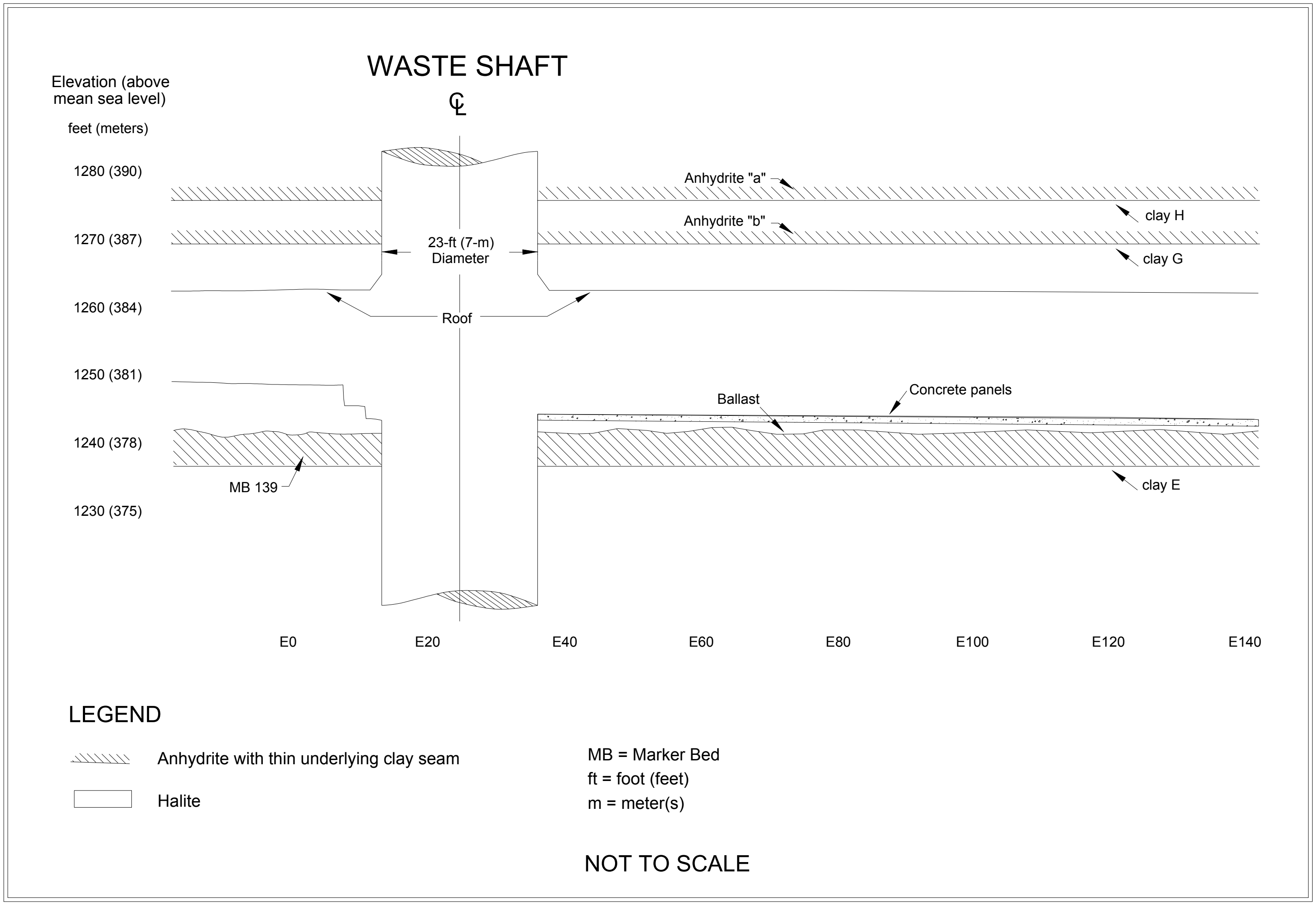

Figure 4-3
Waste Shaft Station Stratigraphy

4.2.1 Modifications to Excavation and Ground Control Activities

Ground control activities performed in the Waste Shaft Station during this reporting period consisted of routine rib maintenance and the routine replacement of failed rock bolts.

4.2.2 Instrumentation

Instruments were initially installed in the Waste Shaft Station between November 12 and December 2, 1982. Figure 4-4 illustrates the locations after enlargement. There are two extensometers in the roof of the Waste Shaft Station (located at West 30 and East 140) that are currently being monitored. In addition, horizontal convergence is being monitored at East 30 and East 90.

Table 4-2 summarizes the history of the roof extensometers in the Waste Shaft Station. The extensometers, 51X-GE-00268 (West 30) and 51X-GE-00279 (East 140), remain in good working condition and the data indicate a relatively steady displacement rate. Extensometers 51X-GE-00277 (East 35) and 51X-GE-00278 (East 90) are no longer functional due to damage. The annual displacement rate calculated for extensometer 51X-GE-00279, located in South 400 drift at East 140, is -19.0 percent lower than the rate calculated for the previous reporting period. The data trend at this installation is consistent with historic displacement rates for this instrument.

Table 4-3 summarizes the annual horizontal closure rates calculated from convergence point data for this reporting period. The data indicate a slight decrease in horizontal closure rates at East 30 and East 90 of -7.0 and -1.0 percent, respectively, relative to the previous annual closure rates.

Sixteen rock bolt load cells are installed in the roof and brow of the Waste Shaft Station. The loads on these rock bolts are monitored regularly.

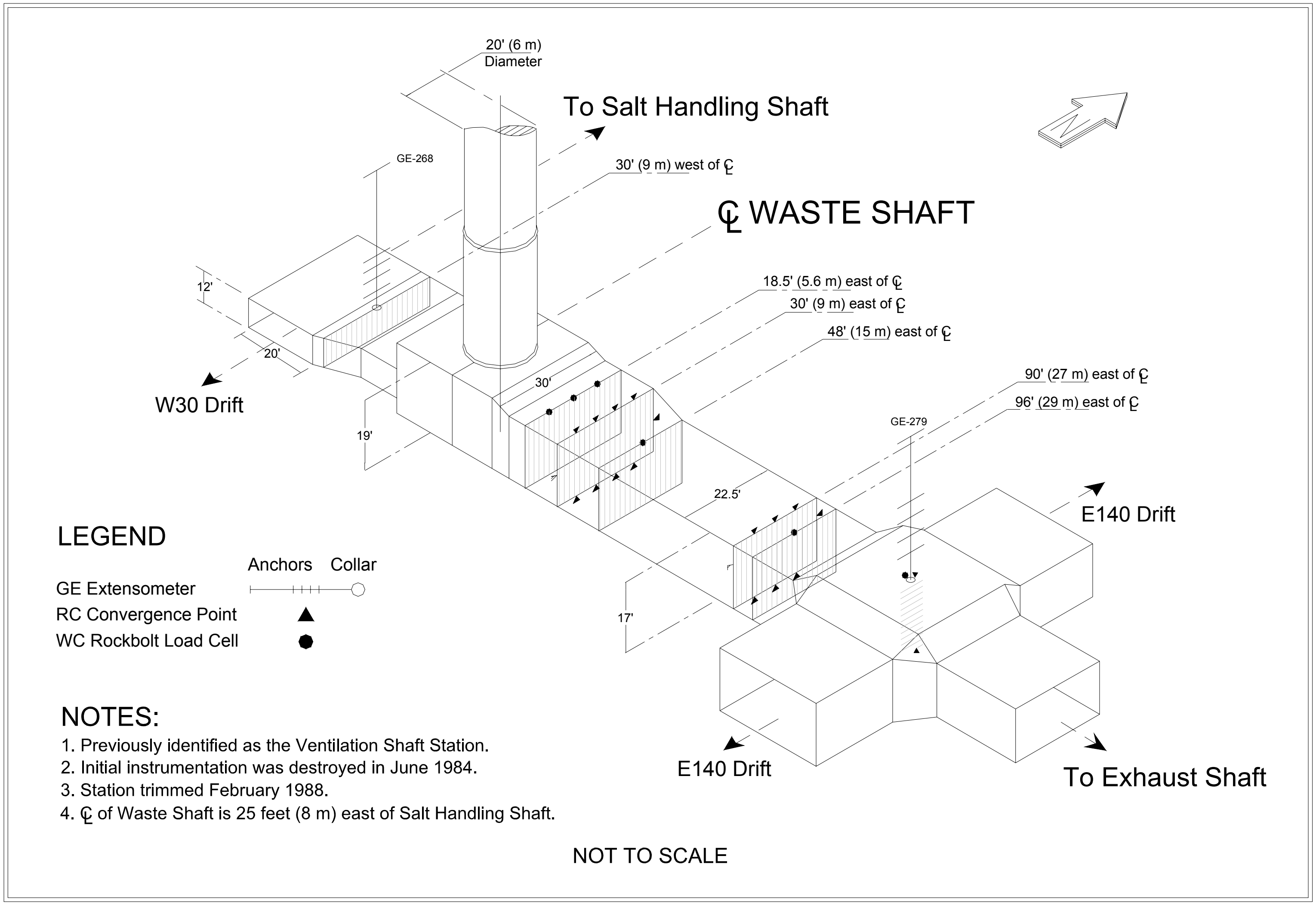

Figure 4-4
Waste Shaft Station Instrumentation After Wall Trimming

Table 4-2
Historical Summary of Roof Extensometers in Waste Shaft Station

Instrument	Location	Date Installed	Date of Last Reading	Collar Displacement Relative to Deepest Anchor in. (cm)	Displacement Rate 2002 to 2003 in./yr (cm/yr)	Displacement Rate 2001 to 2000 in./yr (cm/yr)	Rate Change Percent
51X-GE-00268	S400-W30	10/24/1984	6/02/2003	7.928 (20.137)	0.254 (0.645)	0.243 (0.617)	5%
51X-GE-00279	S400-E140	11/29/1988	5/12/2003	10.212 (25.939)	0.662 (1.682)	0.820 (2.083)	-19%

cm = centimeter(s)
in. = inch(es)

Table 4-3
Horizontal Closure Rates in the Waste Shaft Station

Location Date of Last	Date of Last Reading	Last Reading in. (cm)	Cumulative Displacement in. (cm)	2002 to 2003 Closure Rate in./yr (cm/yr)	2001 to 2002 Closure Rate in./yr (cm/yr)	Percent Rate Change
S400-E30	6/04/2003	15.753 (40.010)	15.826 (40.198)	0.856 (2.174)	0.920 (2.337)	-7%
S400-E90	6/04/2003	17.920 (45.517)	18.111 (46.002)	0.958 (2.433)	0.968 (2.459)	-1%

cm/yr = centimeter(s) per year.
in./yr = inch(es) per year.

4.3 Air Intake Shaft Station

The Air Intake Shaft Station was excavated in late 1987 and early 1988 using a continuous miner. The Air Intake Shaft typically is not used to transport personnel or materials between the surface and the underground, but does have a work platform that can be raised and lowered in the shaft to perform routine ground maintenance. There is minimal operational activity at the Air Intake Shaft Station.

4.3.1 Modifications to Excavation and Ground Control Activities

Bolts and mesh around the shaft brow were installed during this reporting period. Routine maintenance and inspections were also performed at the Air Intake Shaft Station during this reporting period.

4.3.2 Instrumentation

Convergence point and extensometer instrumentation located near the Air Intake Shaft Station is presented in Chapter 5.0 as part of the discussion on the performance of the access drifts. Twenty rock bolt load cells installed in the Air Intake Shaft Station area are monitored regularly.

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5.0 Performance of Access Drifts

This chapter describes the geomechanical performance of the central underground access drifts. The Northern Experimental Area and the Waste Disposal Area are discussed later in Chapters 6.0 and 7.0, respectively. There are four major north-south drifts in the WIPP underground, intersected by shorter east-west cross-drifts. These drift dimensions range from 8 ft (2.4 m) to 21 ft (6.4 m) in height and from 14 ft (4.3 m) to 33 ft (9.2 m) in width.

5.1 Modifications to Excavation and Ground Control Activities

The four major north-south access drifts were extended towards the south during this reporting period. Trimming, scaling, and floor milling activities were performed as necessary in many areas throughout the WIPP underground. Table 5-1 summarizes these activities. Table 5-1 also summarizes ground control activities (e.g., rock bolting and installing wire mesh) performed in various locations in the access drifts. The roof was removed to above Anhydrite "b" in the two major north-south access drifts, East 0 and East 140, north to North 1400 and in East 140, South 1900 to South 2600.

5.2 Instrumentation

This section discusses instrumentation details and locations for each instrumentation type.

5.2.1 Borehole Extensometers

Sixteen new extensometers were installed during this reporting period. All of these borehole extensometers were installed in the north and south mains with the exception of one installation in Panel 3, Room 1. All operating underground extensometers continue to be monitored. Twenty-four borehole extensometers were damaged or mined out during this reporting period. Fifty borehole extensometers continue to be monitored.

5.2.2 Convergence Points

Figure 5-1 shows typical convergence point array configurations. Instrumentation installed during this reporting period was limited to the installation and replacement of convergence point arrays and the installation of new monitoring arrays in the newly mined areas. Ninety-six new convergence points were reinstalled in various locations throughout the WIPP underground where rib, roof, or floor trimming activities had been performed during this and the previous reporting periods. Horizontal and vertical convergence point arrays were installed at various locations in the West 170, West 30, East 140, and East 300 drifts.

Convergence points within the access drifts are read manually at least every two months, with more frequent monitoring in some areas. Table 5-2 lists the new and replacement convergence points that were installed during this reporting period.

Table 5-1
Summary of Modifications and Ground Control Activities in the Access Drifts
July 1, 2002, through June 30, 2003

Location	Work Performed
E300/S2750 to S3310	Cut to final
E300/S3110 to S3380	Rough cut
E140/S2750 to S3310	Cut to final
E140/S3100 to S3496	Rough cut
W30/S2750 to S3310	Cut to final
W30/S3110 to S3366	Rough cut
W170/S2750 to S3310	Cut to final
W170/S3110 to S3347	Rough cut
S3080/W170 to E300	Cut to final
S3310/W170 to E300	Cut to final and rough cut
E300/S1600, S2180, S2750, and S3080	Cut overcasts
E140/S1920 to S2600	Roof removal cut final to clay G
Entire accessible underground	Annual ground survey
E140/S2520 to S3080	Installed mechanical bolts and chainlink mesh
W30/S2520 to S3080	Installed mechanical bolts and chainlink mesh
E140/S1500 to S1700, S1800 to S1900	Installed 12’ rock bolts and mats
N780/E0 to E140	Installed mechanical bolts and chainlink mesh
E300/S1600 Intersection	Installed mechanical bolts and chainlink mesh
E140/S1950 Intersection	Installed mechanical bolts and chainlink mesh
S2520/W30 to E140	Installed mechanical bolts and chainlink mesh
E300/S3080 Intersection brows	Installed mechanical bolts and chainlink mesh
Air Intake Shaft station	Installed 13’ rock bolts
N300 drift and Core Storage drift	Replaced broken mechanical rock bolts
E0/N910 to N1100	Roof removal rough cut
E140/N780 to N1100	Roof removal rough cut

Table 5-2
New and Replaced Convergence Points Installed in the Access Drifts
July 1, 2002, through June 30, 2003

Location	N/R	Field Tag*	Chord#	Date Installed
E0 DRIFT-N562	N	E0-N562	A-C (Vertical)	04/28/2003
E0 DRIFT-N562	N	E0-N562	B-D (Horizontal)	04/28/2003
E0 DRIFT-N626	R	E0-N626-4	A-C (Vertical)	04/28/2003
E0 DRIFT-N686	N	E0-N686	A-C (Vertical)	04/28/2003
E0 DRIFT-N686	N	E0-N686	B-D (Horizontal)	04/28/2003
E140 DRIFT-N562	R	E140-N562-2	A-C (Vertical)	03/25/2003
E140 DRIFT-N562	R	E140-N562-2	B-D (Horizontal)	03/25/2003
E140 DRIFT-N626	R	E140-N626-3	A-C (Vertical)	03/25/2003
E140 DRIFT-N626	R	E140-N626-4	B-D (Horizontal)	03/25/2003
E140 DRIFT-N686	R	E140-N686-2	A-C (Vertical)	03/26/2003
E140 DRIFT-N686	R	E140-N686-2	B-D (Horizontal)	03/26/2003
E140 DRIFT-N780	R	E140-N780-2	A-C (Vertical)	03/26/2003
E140 DRIFT-S1950	R	E140-S1950-5	A-C (Vertical)	03/12/2003
E140 DRIFT-S2007	R	E140-S2007-3	A-C (Vertical)	03/12/2003
E140 DRIFT-S2065	R	E140-S2065-2	B-D (Horizontal)	03/12/2003
E140 DRIFT-S2065	R	E140-S2065-3	A-C (Vertical)	03/12/2003
E140 DRIFT-S2122	R	E140-S2122-3	A-C (Vertical)	03/12/2003
E140 DRIFT-S2180	R	E140-S2180-4	A-C (Vertical)	03/12/2003
E140 DRIFT-S2275	R	E140-S2275-2	A-C (Vertical)	03/12/2003
E140 DRIFT-S2350	R	E140-S2350-3	A-C (Vertical)	03/12/2003
E140 DRIFT-S2425	R	E140-S2425-2	A-C (Vertical)	03/12/2003
E140 DRIFT-S2520	R	E140-S2520-2	A-C (Vertical)	03/12/2003
E140 DRIFT-S2634	N	E140-S2634	A-C (Vertical)	03/18/2003
E140 DRIFT-S2634	N	E140-S2634	B-D (Horizontal)	03/18/2003
E140 DRIFT-S2750	N	E140-S2750	A-C (Vertical)	12/30/2002
E140 DRIFT-S2833	N	E140-S2833	A-C (Vertical)	12/19/2002
E140 DRIFT-S2833	N	E140-S2833	B-D (Horizontal)	12/19/2002
E140 DRIFT-S2915	N	E140-S2915	A-C (Vertical)	12/23/2002
E140 DRIFT-S2915	N	E140-S2915	B-D (Horizontal)	12/23/2002
E140 DRIFT-S2998	N	E140-S2998	A-C (Vertical)	12/23/2002
E140 DRIFT-S2998	N	E140-S2998	B-D (Horizontal)	12/23/2002
E140 DRIFT-S3080	N	E140-S3080	A-C (Vertical)	02/20/2003
E140 DRIFT-S3195	N	E140-S3195	A-C (Vertical)	02/20/2003
E140 DRIFT-S3195	N	E140-S3195	B-D (Horizontal)	02/20/2003
E140 DRIFT-S3310	N	E140-S3310	A-C (Vertical)	02/20/2003
E300 DRIFT-S2634	N	E300-S2634	A-C (Vertical)	01/29/2003
E300 DRIFT-S2634	N	E300-S2634	B-D (Horizontal)	01/29/2003
E300 DRIFT-S2833	N	E300-S2833	A-C (Vertical)	01/29/2003
E300 DRIFT-S2833	N	E300-S2833	B-D (Horizontal)	01/29/2003
E300 DRIFT-S2916	N	E300-S2916	A-C (Vertical)	01/29/2003
E300 DRIFT-S2916	N	E300-S2916	B-D (Horizontal)	01/29/2003
E300 DRIFT-S2998	N	E300-S2998	A-C (Vertical)	02/24/2003
E300 DRIFT-S2998	N	E300-S2998	B-D (Horizontal)	02/24/2003
E300 DRIFT-S3195	N	E300-S3195	A-C (Vertical)	02/20/2003
E300 DRIFT-S3195	N	E300-S3195	B-D (Horizontal)	02/20/2003
E660 DRIFT-S2275	R	E660-S2275-3	A-C (Vertical)	07/03/2002

N = New installation.

R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).

*Field tag chords are defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data.

#Chord configuration is defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data."

Table 5-2 (continued)

Location	N/R	Field Tag*	Chord#	Date Installed
E660 DRIFT-S2350	R	E660-S2350-4	A-C (Vertical)	07/10/2002
E660 DRIFT-S2425	R	E660-S2425-3	A-C (Vertical)	07/03/2002
N780 DRIFT-E70	N	N780-E70	A-C (Vertical)	04/30/2003
N780 DRIFT-E70	N	N780-E70	B-D (Horizontal)	04/30/2003
S2520 DRIFT-E660	R	S2520-E660-2	A-C (Vertical)	07/03/2002
S2750 DRIFT-E220	N	S2750-E220	A-C (Vertical)	01/28/2003
S2750 DRIFT-E220	N	S2750-E220	B-D (Horizontal)	01/28/2003
S2750 DRIFT-E55	N	S2750-E55	A-C (Vertical)	12/19/2002
S2750 DRIFT-E55	N	S2750-E55	B-D (Horizontal)	12/19/2002
S2750 DRIFT-W93	N	S2750-W93	A-C (Vertical)	01/13/2003
S2750 DRIFT-W93	N	S2750-W93	B-D (Horizontal)	01/13/2003
S3080 DRIFT-E220	N	S3080-E220	A-C (Vertical)	02/24/2003
S3080 DRIFT-E220	N	S3080-E220	B-D (Horizontal)	02/24/2003
S3080 DRIFT-E55	N	S3080-E55	A-C (Vertical)	01/22/2003
S3080 DRIFT-E55	N	S3080-E55	B-D (Horizontal)	01/22/2003
S3080 DRIFT-W100	N	S3080-W100	A-C (Vertical)	01/21/2003
S3080 DRIFT-W100	N	S3080-W100	B-D (Horizontal)	01/21/2003
S3310 DRIFT-E220	N	S3310-E220	A-C (Vertical)	02/20/2003
S3310 DRIFT-E220	N	S3310-E220	B-D (Horizontal)	02/20/2003
S3310 DRIFT-E55	N	S3310-E55	A-C (Vertical)	03/07/2003
S3310 DRIFT-E55	N	S3310-E55	B-D (Horizontal)	03/07/2003
S3310 DRIFT-W100	N	S3310-W100	A-C (Vertical)	03/07/2003
S3310 DRIFT-W100	N	S3310-W100	B-D (Horizontal)	04/30/2003
W170 DRIFT-S2750	N	W170-S2750	A-C (Vertical)	11/20/2002
W170 DRIFT-S2833	N	W170-S2833	A-C (Vertical)	01/16/2003
W170 DRIFT-S2833	N	W170-S2833	B-D (Horizontal)	01/16/2003
W170 DRIFT-S2916	N	W170-S2916	A-C (Vertical)	01/16/2003
W170 DRIFT-S2916	N	W170-S2916	B-D (Horizontal)	04/30/2003
W170 DRIFT-S2998	N	W170-S2998	A-C (Vertical)	01/16/2003
W170 DRIFT-S2998	N	W170-S2998	B-D (Horizontal)	01/16/2003
W170 DRIFT-S3080	N	W170-S3080	A-C (Vertical)	01/16/2003
W170 DRIFT-S3195	N	W170-S3195	A-C (Vertical)	01/21/2003
W170 DRIFT-S3195	N	W170-S3195	B-D (Horizontal)	01/21/2003
W170 DRIFT-S3310	N	W170-S3310	A-C (Vertical)	03/07/2003
W170 DRIFT-S90	R	W170-S90-3	A-C (Vertical)	08/09/2002
W30 DRIFT-S2750	N	W30-S2750	A-C (Vertical)	12/30/2002
W30 DRIFT-S2833	N	W30-S2833	A-C (Vertical)	01/23/2003
W30 DRIFT-S2833	N	W30-S2833	B-D (Horizontal)	01/23/2003
W30 DRIFT-S2916	N	W30-S2916	A-C (Vertical)	02/24/2003
W30 DRIFT-S2916	N	W30-S2916	B-D (Horizontal)	02/24/2003
W30 DRIFT-S2998	N	W30-S2998	A-C (Vertical)	01/23/2003
W30 DRIFT-S2998	N	W30-S2998	B-D (Horizontal)	01/23/2003
W30 DRIFT-S3080	N	W30-S3080	A-C (Vertical)	01/22/2003
W30 DRIFT-S3195	N	W30-S3195	A-C (Vertical)	01/22/2003
W30 DRIFT-S3195	N	W30-S3195	B-D (Horizontal)	01/22/2003
W30 DRIFT-S3310	N	W30-S3310	A-C (Vertical)	03/07/2003

N = New installation.

R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).

*Field tag chords are defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data.

#Chord configuration is defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data."

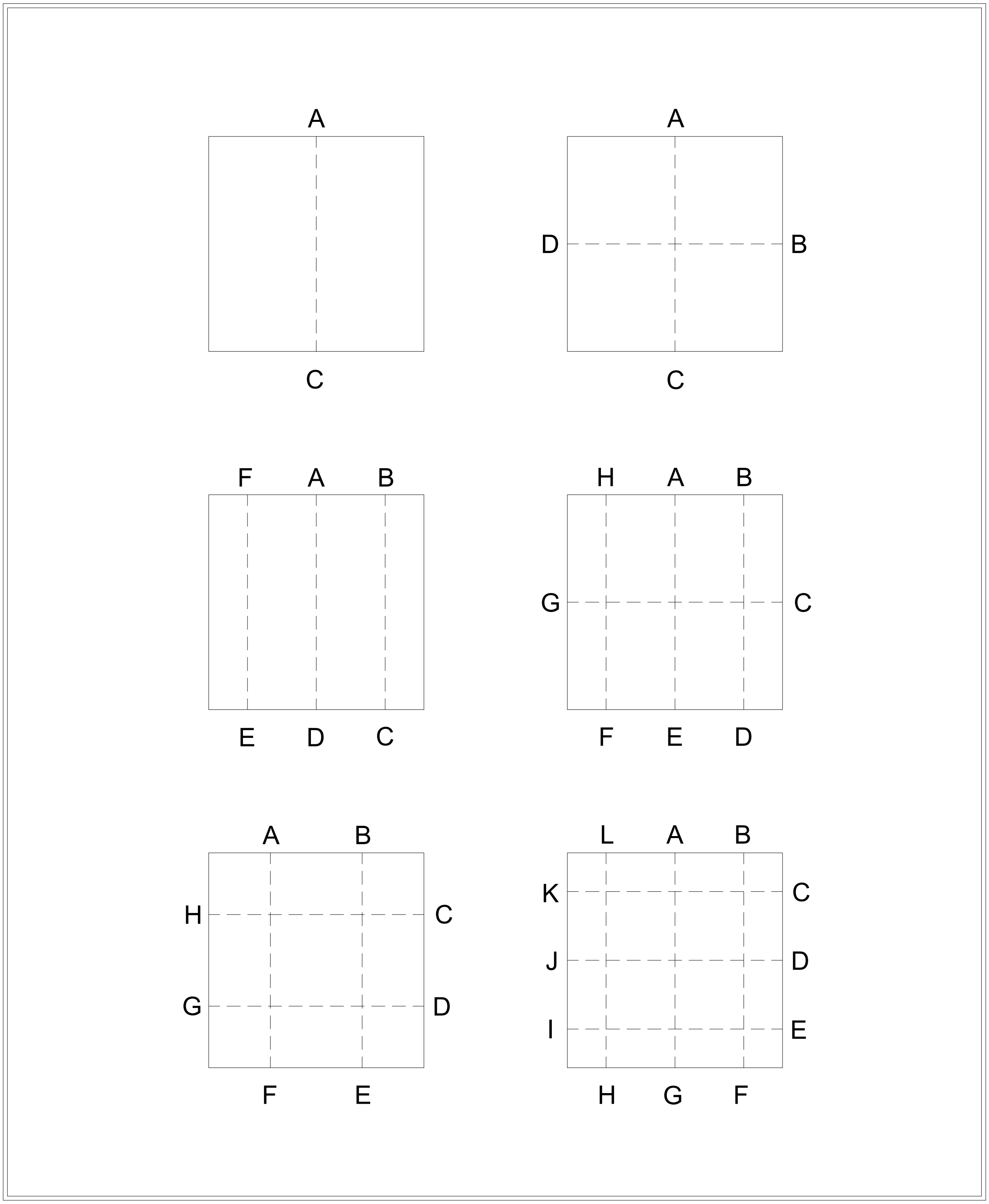

Figure 5-1
Typical Convergence Point Array Configurations

5.3 Analysis of Convergence Point and Extensometer Data

Convergence point data are obtained by measuring the change in distance between fixed points anchored into the rock across an opening, either from rib-to-rib or from roof-to-floor. Extensometer data are obtained by measuring the displacement from the reference head anchor (collar) to each fixed anchor of the extensometer. These measurements are made, at a minimum, every two months throughout the WIPP underground, with the exception of when convergence points are not accessible. Convergence rates and extensometer displacement rates and indicate how an excavation is performing; rates that decrease or are relatively constant typify stable excavations, whereas increasing rates may indicate some type of developing instability.

Where possible, annual closure rates were calculated from convergence point array data from the access drifts. A complete tabulation of these convergence point data and calculated closure rates are presented in the supporting data document for this report[5]. Locations with increases in annual vertical and horizontal closure rates of greater than 10 percent are listed in Table 5-3.

Routinely, extensometer displacement rates and convergence rates are plotted against time, and comparisons are made through time to identify any acceleration. Annual convergence rates are calculated by determining the difference between the first and last readings of the reporting period and dividing that difference by the time between the two readings (in years). Instruments that indicate acceleration are analyzed to determine the significance of the acceleration. Factors that are considered during the analysis include the magnitude of the respective rates, percentage increase, convergence history, and any recent excavation in the vicinity.

There are 50 active borehole extensometers being monitored at various locations in the access drifts. Of the 50 extensometers, 25 are in the southern East 140 drift to monitor the waste transport route. Where data are available, annual displacement rates were calculated for each of the active extensometers and compared to the annual displacement rates from the previous reporting period. Many of the extensometers in this area show increased rates; in some cases, this is attributed to lateral displacement. The increased movement in the

[5] Instrumentation data and data plots are presented in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data." The document is available upon request from the National Technical Information Service. See the back side of this documents cover sheet for details and addresses.

East 140 roof rates may also be attributed to localized fracturing and a clay stringer separation approximately 12 to 18 in. above the roof.

Table 5-3
Increases in Annual Vertical Convergence Rates Greater than 10 Percent in the Access Drifts

Location	Chord*	Last Reading 2002 to 2003 Date	Closure Rate 2002 to 2003 in./yr	Closure Rate 2001 to 2002 in./yr	Rate Change Percent [a]	Comments
E140-S2275-2	A-C	06/03/2003	11.037	3.768	193%	Mining Excavation and instrument re-installation.
E140-S2180-4	A-C	06/03/2003	3.739	2.072	80%	Mining Excavation and instrument re-installation.
E140-S2350-3	A-C	06/03/2003	4.489	2.994	50%	Mining Excavation and instrument re-installation.
E140-S2425-2	A-C	06/03/2003	4.449	2.791	59%	Mining Excavation and instrument re-installation.
E140-S2065-3	A-C	06/03/2003	3.599	2.480	45%	Mining Excavation and instrument re-installation.
E140-S2520-2	A-C	06/03/2003	3.805	2.674	42%	Mining Excavation and instrument re-installation.
S1000-E120-2	A-C	06/03/2003	1.108	0.788	41%	Clay stringer separation.
E140-S1950-5	A-C	06/03/2003	3.092	2.338	32%	Mining Excavation and instrument re-installation.
E140-N780-2	A-C	06/05/2003	3.613	2.905	24%	Instrument re-installation.
E300-S1300	A-C	06/10/2003	0.700	0.574	22%	
E140-S2007-3	A-C	06/03/2003	3.115	2.567	21%	Mining Excavation and instrument re-installation.
E140-S2122-3	A-C	06/03/2003	3.626	3.032	20%	Mining Excavation and instrument re-installation.
E140-S1862-2	A-E	06/03/2003	2.944	2.493	18%	Clay stringer separation.
E140-N686-2	A-C	06/05/2003	2.478	2.131	16%	Instrument re-installation.
E140-S1534-2	H-F	06/03/2003	2.986	2.573	16%	Clay stringer separation.
E140-N626-3	A-C	06/05/2003	2.844	2.478	15%	Instrument re-installation.
E300-N45	H-F	06/04/2003	1.533	1.349	14%	Instrument re-installation.
S90-W400	A-C	06/02/2003	0.765	0.671	14%	
S90-W920-2	A-C	06/02/2003	1.226	1.073	14%	
E140-S1534-2	A-E	06/03/2003	5.592	4.936	13%	Clay stringer separation.
S1950-E113-4	A-C	06/03/2003	0.712	0.642	11%	
E140-N562-2	A-C	06/05/2003	2.211	2.012	10%	Instrument re-installation.

[a] Increase in convergence rate is calculated from the difference between the 2001–2002 rate and the 2002–2003 rate.
*Chord is defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data."
in./yr = inch(es) per year.

Further analysis of these accelerations has shown many of them to be relatively insignificant. Others, such as the southern areas of the access drifts, had closure rate increases that can be directly attributed to the effects of mining Panel 3 and the associated access drifts. In the south half of Panel 2 and Panel 3 and the Panel 3 access drifts, increased closure rates will continue due to the continued mining of Panel 3 and the Panel 4 access drifts and redistribution of stress effects in those areas.

The rates in East 0 and East 140, north of North 460 and from South 1900 to South 2600, where the roof has been mined to Clay "G," show an increase in the closure rates. These rates are expected to decrease over time as the roof beam removal effect subsides. Convergence measurements in East 140 between South 1534 and South 1862 show an increasing trend over the long-term median convergence rate. This is due to a separation caused by a clay stringer approximately 12 in. to 18 in. above the roof and localized fracturing. A supplemental ground control system was installed in this area to address the separation.

5.4 Excavation Performance

Over 490 readings are collected and assessed on a regular basis from convergence point pairs located throughout the WIPP underground. Convergence rates continue to seasonally vary, typically increasing during the warmer summer months and decreasing during the cooler winter months.

The performance of the access drift excavations during this reporting period was within acceptable criteria. "Acceptable criteria" is when the drift remains accessible and the ground can be controlled by routine maintenance. Standard remedial ground control maintenance in some areas was required to maintain the performance of the excavations. The drifts remain stable and controlled. The majority of the annualized rates remain steady indicating stability. In some locations where the rates are high, nearby mining activities are most likely the cause. In other locations where necessary, additional ground control measures have been or will be installed.

6.0 Northern Experimental Area

This area includes all excavations north of the North 1100. Access to this area was blocked in August and September 1996 by the construction of barriers in the East 0 and East 140 drifts at North 800 and the area was deactivated. In October and November 1999, members of the Geotechnical Engineering Section and Underground Operations made a reentry and the area was reopened. Since that time, some areas have been renovated.

6.1 Modifications to Excavation and Ground Control Activities

Roof removal in East 0, East 140, and East 300 from the North 1100 to North 1400 was performed during this reporting period. Table 6-1 summarizes these activities. The Experimental Area was spot-bolted, replacing failed bolts and addressing drummy areas after roof removal. Muck disposal/backfilling operations have filled all areas west of the East 0 drift. All remote and manually read instruments of this area are no longer being read. As access to these areas is reestablished, it is anticipated that some instrumentation will be reinstalled, including both remote and manually read instruments.

Table 6-1
Summary of Modifications and Ground Control Activities
in the Northern Experimental Area
July 1, 2002, through June 30, 2003

Location	Work Performed
E0/N1100 to N1400	Roof removal rough cut
E140/N1100 to N1400	Roof removal rough cut
N1100/W70 to E343	Roof removal rough cut
N1400/W50 to E325	Roof removal rough cut
E300/N1100 to N1400	Roof removal rough cut
N1100/W570 to W70	Backfilled
N1400/W515 to W50	Backfilled

6.2 Deactivated Areas in the Northern Experimental Area

The Northern Experimental Area, including the SPDV rooms and associated access drifts, is no longer accessible and readings were temporarily discontinued in June 2002 to facilitate removal of the roof beam. Remote monitoring of instrumentation east of the East 300 shop was discontinued due to mining activities in North 1100 drift that required removal of the data logger. There are no instrument data results from this area during this reporting period.

6.3 Northern Experimental Area Condition

A reentry into previously closed sections of North 1100 and North 1400 drifts was performed on March 13, 2003. The purpose of the reentry was to evaluate this area for future operational use. This reentry documented the condition of installed ground support, opening geometry, and observed geotechnical conditions.

North 1100

Entry in North 1100 drift started at the barricade located just east of the East 300 intersection and progressed towards the east. Conditions in North 1100 drift varied with location along the drift. Minor and discontinuous low-angle fracturing was observed between the East 300 intersection to the ramp, which starts at approximately East 675 and ends at East 835. There were minor areas of drummy ground, generally near the rib line. The installed ground control was mostly intact with isolated roof bolt failures. The floor through this area was competent and in generally good condition.

The ramp area exhibited increasing deterioration as the roof beam thickness was reduced. The occurrence of low-angle fracturing increased along both ribs, ending at the brows. The brows were bolted and meshed; however, there was noticeable bulging of the mesh and localized bolt failures. The magnitude of floor heave increases as the ramp approaches the brow locations. Significant lateral rib movement was observed along the clay seam underlying the anhydrite layers. Small blocks of anhydrite formed by this rib movement were easily addressed by hand scaling.

This section between the ramp and Room D displayed generally good conditions. The roof was generally sounded with minor drummy areas observed. The ground control system was mostly intact and did not indicate excessive loading or stress. This section of North 1100 exhibited significant floor heave in localized areas. Significant lateral rib movement was observed along the clay seam underlying the anhydrite layers. Small blocks of anhydrite formed by this rib movement were easily addressed by hand scaling. The wooden cribs installed at the experimental room brow locations were intact and did not show excessive deformation.

Room D

Entry into Room D started from the North 1100 drift intersection and progressed north to approximately 125 feet into the room. Visual observations indicated a significant change in found conditions near the room center. A 25 to 30 ft section south of the room center exhibited significant roof deformation and rock bolt failures. The Tensar mesh continues to provide some containment, however, the rock bolt pattern supporting this area has mostly failed. Approximately one dozen bolts had failed and fallen to the ground. Visual observations indicated that these bolts had failed at approximately 4.5 to 5 ft into the roof and exhibited tensile failure characteristics. The ground support installed in Room D consists of resin-grouted threaded bar bolts with a plate and slip nut. A full load nut was installed on the bottom of the bolt to limit the amount of yield.

With the exception of the area near the room center, the remaining ground conditions were good. Excessive deformations of ground support failures were not observed.

North 1400

Entry in the North 1400 drift started at the barricade located just east of the East 300 intersection and progressed eastward. Conditions in North 1400 drift varied with location along the drift. Minor and discontinuous low angle fracturing was observed between the East 300 intersection to the ramp. There were minor areas of drummy ground, generally near the rib line. The installed ground control was mostly intact, with isolated roof bolt failures. The floor though this area was competent and in generally good condition. The alcoves are bolted and meshed and are in generally good condition, with the installed ground support mostly intact.

The ramp area exhibited increasing deterioration as the roof beam thickness was reduced. The occurrence of low angle fracturing increased along both ribs ending at the brows. The brows were bolted and meshed; however, there was noticeable bulging of the mesh and localized bolt failures. The magnitude of floor heave increases as the ramp approaches the brow locations. Significant lateral rib movement was observed along the clay seam underlying the anhydrite layers. Small blocks of anhydrite formed by this rib movement were easily addressed by hand scaling.

Entry east of the ramp progressed to approximately 100 feet from the intersection with Room B. Ground condition deterioration increased towards the east. Low angle fracturing in the roof increased in magnitude and continuity along both rib lines. Vertical fracturing along the centerline was observed running parallel to the axis of the drift. The ground support in this area has been greatly reduced due to significant roof bolt failures.

7.0 Performance of Waste Disposal Area

The Waste Disposal Area as of June 30, 2003, consist of Panels 1, 2 and 3. Panel 1 is closed. Panel 2 is currently being used for waste disposal, with Room 7 filled. Panel 3 is currently being mined as shown in Figure 1-2.

Excavation of the Panel 1 waste disposal area began in May 1986 with the mining of access entries to Panel 1. Initially, the disposal rooms and drifts were developed as pilot drifts that were later excavated to nominal operational dimensions of 13 ft (4 m) high, 33 ft (10 m) wide, and 300 ft (91 m) long. Room 1 was completed to these dimensions in August 1986, and pilot drifts for Rooms 2 and 3 were excavated in January and February 1987. Rooms 2 and 3 were completed in February and March 1988 and Rooms 4 through 7 were completed in May 1988. Short access drifts designed to lead to smaller test alcoves were excavated north off of the S1600 drift in June 1989. Only the access drifts to the alcoves were completed; the alcoves were not excavated. During this reporting period, waste emplacement in Panel 1 was completed and the panel is closed to all access.

Excavation of the Panel 2 waste disposal area began in September 1999 with the mining of access entries to Panel 2. Initially, the disposal rooms and drifts were developed as pilot drifts that were trimmed to finished dimensions. Room 1 was completed in January 2000, and pilot drifts for Rooms 2 and 3 were excavated in February 2000. Pilot drifts were completed for Rooms 4 through 6 in April 2000. The pilot drift for Room 7 was excavated in May 2000. All the rooms were excavated to final dimensions by August 2000.

Excavation of the Panel 3 waste disposal area began in January 2003 with the mining of access entries to Panel 3. As of June 30, 2003, South 2750 and South 3080 (the Panel 3 ventilation drifts) are rough cut from the east rib of Room 1 to the east of Room 5. The Panel 3 entries and Room 1 are mined to final dimensions. Room 2 is rough cut only (see Figure 1.2). Rooms 3 through 7 have not yet been mined.

7.1 Modifications to Excavations and Ground Control Activities

In Panel 1, excavations were made at East 460 in South 1600 and South 1950 drifts as part of the panel closure construction. No new excavations were mined in Panel 2 during the reporting period of July 2002 through June 2003. Panel 3 mining began in January 2003, with South 2750 and South 3080 being mined just east of Room 5. Panel 3, Room 1 was mined to final dimensions and Room 2 was rough cut. Routine maintenance and ground control activities in the form of trimming, scaling, rock bolt replacement, and installing wire mesh were performed on ribs, floor, and roof throughout accessible areas in Panels 1 and 2. During this reporting period, Panel 2, Rooms 2, 3, 4, 5, and parts of South 2520 were fully wire meshed and bolted. Table 7-1 summarizes the ground control activities performed in Panels 1, 2, and 3 during this reporting period.

7.2 Instrumentation

No extensometers or convergence points were installed or replaced in Panel 1 during this reporting period. Because of floor trimming, there were three convergence points replaced in Room 2 and one convergence point replaced in South 2520 at the intersection of Room 2, Panel 2 during this reporting period. Table 7-2 lists the convergence points replaced in Panel 2. Figure 7-1 shows the location of the various types of geotechnical instruments in Panel 1 of the Waste Disposal Area. During this reporting period, waste emplacement operations were completed and Panel 1 was closed. Remote monitoring of the extensometers was discontinued and the convergence points are no longer accessible in these rooms. Figure 7-2 shows the location of the various types of geotechnical instruments in Panel 2 of the Waste Disposal Area.

Table 7-1
Summary of Modifications and Ground Control Activities in the Waste Disposal Area July 1, 2002, through June 30, 2003

Location	Work Performed
Panel 3, Room 1	Cut to final
Panel 3, Rooms 1 and 2	Rough cut
Panel 3, S2750/E330 to E1046	Rough cut
Panel 3, S2750/E330 to E520	Cut to final
Panel 3, S3080/E330 to E1092	Rough cut
Panel 3, S3080/E300 to E520	Cut to final
E460/S1600 and S1950	Excavation for Panel Closure Wall.
Panel 1, Rooms 1 and 2	Replaced broken channel bolts
S2520/Panel 2, rooms 5 to 7	Installed bolts and mesh
Panel 1, Rooms 1 and 2/Ribs	Installed bolts and mesh
Panel 3, Room 1	Installed bolts
Panel 2, Rooms 2, 3, 4, 5 and 6	Installed bolts and mesh

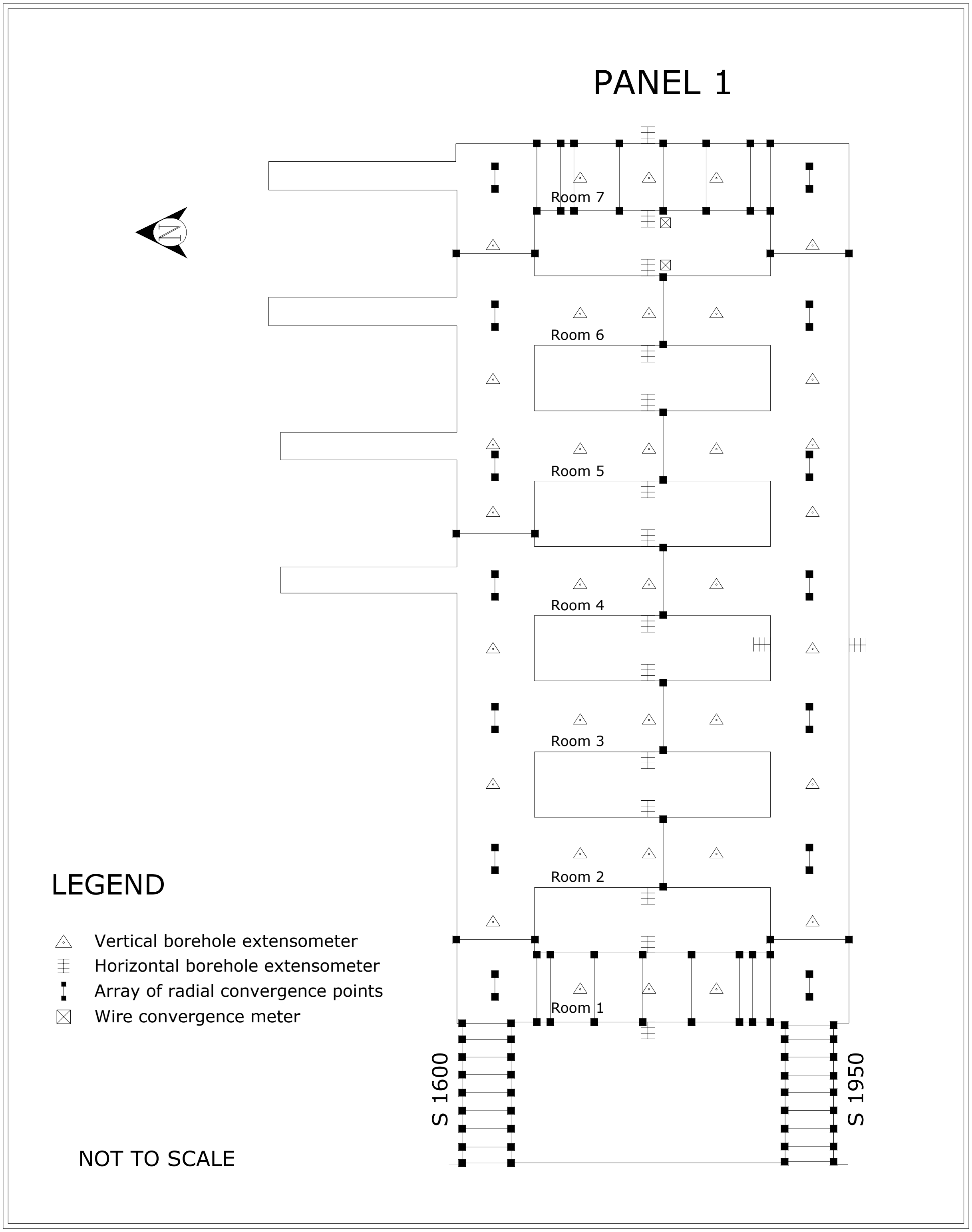

Figure 7-1
Location of Panel 1 Geotechnical Instruments

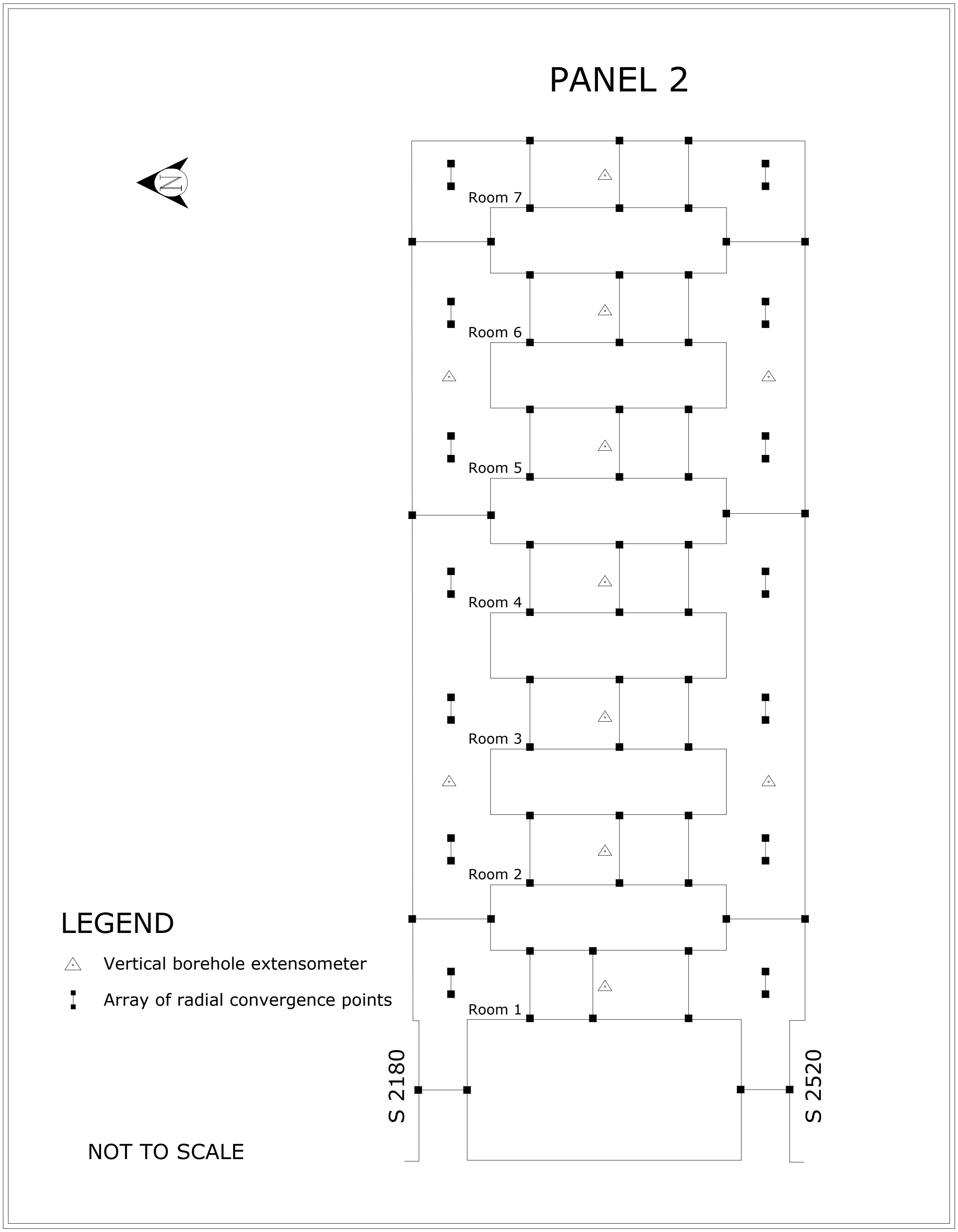

Figure 7-2
Location of Panel 2 Geotechnical Instruments

Table 7-2
New and Replaced Instruments in the Waste Disposal Area
July 1, 2002, through June 30, 2003

Instrument Type	N/R	Field Tag*	Chord#	Location	Date Installed
Convergence Point	R	E660-S2275-3	A-C (Vertical)	E660 DRIFT-S2275	07/03/2002
Convergence Point	R	E660-S2425-3	A-C (Vertical)	E660 DRIFT-S2425	07/03/2002
Convergence Point	R	S2520-E660-2	A-C (Vertical)	S2520 DRIFT-E660	07/03/2002
Convergence Point	R	E660-S2350-4	A-C (Vertical)	E660 DRIFT-S2350	07/10/2002

N = New installation.
R = Replacement installation (i.e., instrument replaces older instrument that has failed or has been mined out).
*Field tag chords is defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data.
#Chord configuration is defined in "Geotechnical Analysis Report for July 2002–June 2003 Supporting Data."

7.3 Excavation Performance

Horizontal and vertical convergence rates have been calculated at the center of each of the rooms in Panel 1 for this and the previous reporting period. Tables 7-3 and 7-4 present these convergence rates. The vertical and horizontal convergence rates in Room 2, Panel 1, increased, while Room 1 rates decreased during the current reporting period relative to the previous reporting period. The increases in Room 2 are probably caused in response to floor trimming in Room 2.

Horizontal and vertical convergence rates have been calculated at the center of each of the rooms in Panel 2 for this and the previous reporting period. Tables 7-5 and 7-6 present these convergence rates. The vertical and horizontal convergence rates at the center of each room in Panel 2 have all decreased.

Panel 3, Rooms 1 and 2, were mined as of June 30, 2003. There were no extensometer or convergence point data for Panel 3 during this reporting period. Based on visual observations, these two rooms are performing very similar to the same rooms at the same age in Panels 1 and 2.

Table 7-3
Annual Vertical Convergence Rates at the Center of Panel 1 Disposal Rooms*

Location		Fieldtag	Total Cumulative Displacement in. (cm)	Convergence Rate 2002-2003 in./yr (cm/yr)	Convergence Rate 2001-2002 in./yr (cm/yr)	Rate Change Percent	Comments
Room 1	Centerline	E520-S1802-7 A-E	55.015 (139.738)	2.608 (6.624)	3.047 (7.739)	-14%	Room filled in March 2003
Room 2	Centerline	E660-S1775-6 A-C	40.158 (102.000)	2.574 (6.538)	2.214 (5.624)	16%	Room filled in November 2002

*Room 3-7 closed – unable to obtain readings.
cm/yr = centimeter(s) per year
in./yr = inch(es) per year

Table 7-4
Annual Horizontal Convergence Rates at the Center of Panel 1 Disposal Rooms*

Location		Fieldtag	Total Cumulative Displacement in. (cm)	Convergence Rate 2002-2003 in./yr (cm/yr)	Convergence Rate 2001-2002 in./yr (cm/yr)	Rate Change Percent	Comments
Room 1	Rib center	E520-S1802-3 C-G	23.999 (60.976)	1.485 (3.772)	1.650 (4.191)	-10%	Room filled in March 2003
Room 2	Rib center	E660-S1775-5 B-D	25.993 (66.022)	2.105 (5.347)	1.790 (4.547)	18%	Room filled in November 2002

*Room 3-7 closed – unable to obtain readings.
cm/yr = centimeter(s) per year
in./yr = inch(es) per year

Table 7-5
Annual Vertical Convergence Rates at the Center of Panel 2 Disposal Rooms

Location		Fieldtag	Total Cumulative Displacement in. (cm)	Convergence Rate 2002-2003 in./yr (cm/yr)	Convergence Rate 2001-2002 in./yr (cm/yr)	Rate Change Percent
Room 1	Centerline	E520-S2350-2 A-C	13.343 (33.891)	3.384 (8.595)	3.579 (9.091)	-5%
Room 2	Centerline	E660-S2350-3 A-C	13.454 (34.173)	3.309 (8.405)	3.656 (9.286)	-9%
Room 3	Centerline	E790-S2350-2 A-C	12.759 (32.408)	2.920 (7.417)	3.167 (8.044)	-8%
Room 4	Centerline	E920-S2350-2 A-C	15.566 (39.538)	3.195 (8.115)	3.591 (9.121)	-11%
Room 5	Centerline	E1050-S2350-2 A-C	15.008 (31.120)	2.923 (7.424)	3.279 (8.329)	-11%
Room 6	Centerline	E1190-S2350-3 A-C	13.469 (34.211)	2.872 (7.295)	3.322 (8.438)	-14%
Room 7	Centerline	E1320-S2350-3 A-C	11.837 (30.066)	3.050 (7.747)	3.550 (9.017)	-14%

cm/yr = centimeter(s) per year
in./yr = inch(es) per year

Table 7-6
Annual Horizontal Convergence Rates at the Center of Panel 2 Disposal Rooms

Location		Fieldtag	Total Cumulative Displacement in. (cm)	Convergence Rate 2002-2003 in./yr (cm/yr)	Convergence Rate 2001-2002 in./yr (cm/yr)	Rate Change Percent
Room 1	Rib center	E520-S2350 B-D	8.668 (22.017)	2.287 (5.809)	2.377 (6.038)	-4%
Room 2	Rib center	E660-S2350 B-D	8.775 (22.289)	2.100 (5.334)	2.268 (5.761)	-7%
Room 3	Rib center	E790-S2350 B-D	7.891 (20.043)	1.985 (5.042)	2.176 (5.527)	-9%
Room 4	Rib center	E920-S2350 B-D	8.619 (21.892)	2.083 (5.291)	2.360 (5.994)	-12%
Room 5	Rib center	E1050-S2350 B-D	7.380 (18.750)	1.785 (4.534)	2.031 (5.159)	-12%
Room 6	Rib center	E1190-S2350 B-D	7.186 (18.252)	1.654 (4.201)	1.960 (4.978)	-16%
Room 7	Rib center	E1320-S2425 B-D	6.691 (16.995)	1.584 (4.023)	1.748 (4.440)	-9%

cm/yr = centimeter(s) per year
in./yr = inch(es) per year

7.4 Analysis of Extensometer and Convergence Point Data

There were 36 monitored extensometers installed in the roofs and ribs of Panel 1, with most being located in the disposal rooms. Twenty-one of the 36 extensometers showed a displacement rate decrease. The extensometers with the greatest rate decreases are generally located in the northern half of the panel which is furthest from Panel 2. The other 15 extensometers showed an increase. These extensometers are generally located on the southern half of the panel, which is closest to Panel 2. The instrument data indicate that the rates have become steady since the increase in response to the mining of Panel 2.

During this reporting period, vertical convergence rates were read in Rooms 1 and 2 of Panel 1. All the readings from these rooms were decreasing, with the exception of one point located at South 1775 in Room 2, which showed a 16 percent increase. This increase was probably caused by floor milling for waste emplacement.

The closure rates in Panel 2 are generally decreasing with exception of the South 2520 drift, which are responding to the initial mining of Panel 3. At South 2520/East 586 the closure rate increase was the highest at 9 percent. The convergence rates in South 2520 and the southernmost points in the rooms of Panel 2 are expected to be affected due to Panel 3 mining, which will continue with an scheduled completion date in 2004.

There were no extensometer or convergence point data for Panel 3 during this reporting period.

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8.0 Geoscience Program

The Geoscience Program confirms the suitability of the site through the collection of various geologic data and excavation characteristics from the underground facility. These include the inspection of open boreholes for fractures (separations) and offsets (lateral displacements) in roof beams, the mapping of fracture development on roof (back) surfaces, and the documentation of stratigraphic features on wall (rib) surfaces.

Data collected through these activities support the design and evaluation of ground support systems (Westinghouse WID, 1999).

During this reporting period, the following activities were performed:

- Borehole Inspections
- Fracture Mapping
- Stratigraphic Mapping

8.1 Borehole Inspections

Geotechnical observation boreholes are drilled at various locations throughout the underground facility. A location may contain one or several boreholes arranged in an array. These holes are drilled to depths that allow the monitoring of fracture development and offsetting and are inspected for the development of those features. Roof observation holes usually intersect clays “G” and “H” (Figure 8-1).

The clay seams nearest the excavation surfaces define the immediate roof beam. Clay “G” defines the roof beam in most of the access drifts and Panels 1 and 2. Some areas, such as the Salt Handling Shaft Station, portions of the East 0 and East 140 drifts, the south mains south of South 2620 and Panel 3 are excavated to clay “G” and so have roof beams bounded by clay “H.”

The offset in a borehole is determined by visually estimating the degree of borehole occlusion. The direction of offset along clay seams is observed as the movement of the strata nearer to the observer relative to the strata farther away. Typically, the nearer strata moves toward the center of the excavation (Figure 8-2). Based on previous observations in the underground, the magnitude of offset is usually greater in boreholes located near ribs than in those located along excavation centerlines. Offsetting along the clay layers is

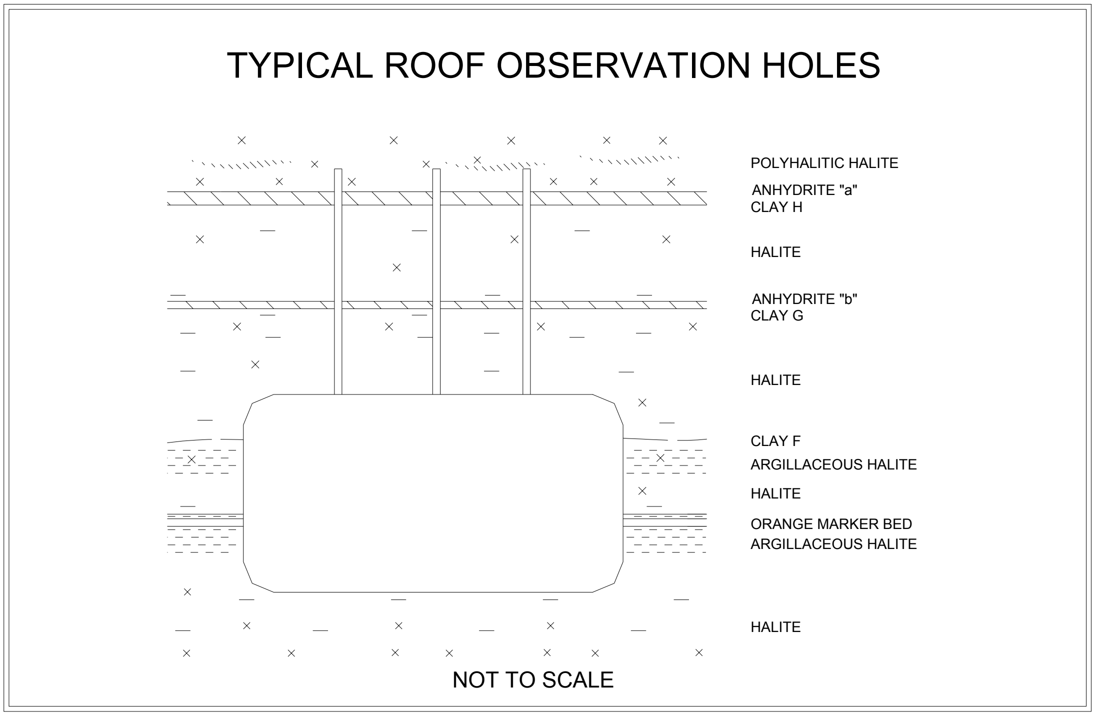

Figure 8-1
Examples of Observation Borehole Layouts

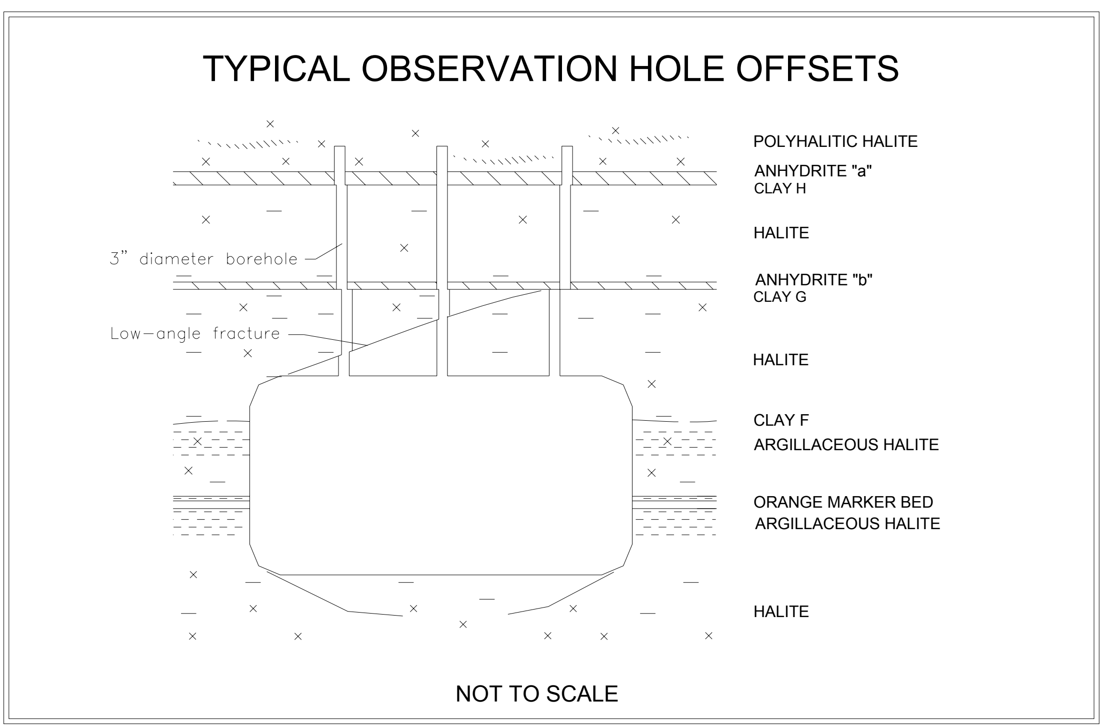

Figure 8-2
Generalized Fracture Pattern at Lower Horizon

observable until the total borehole offset is reached or visibility is obstructed by intervening offsets at other clay seams or fractures. Boreholes are inspected for fractures using an aluminum rod with a flattened steel wire probe attached to one end perpendicular to the rod (referred to as a "scratcher rod"). Fractures and clay seams are located by moving the probe along the sides of the borehole until it is snagged in one of these features. Depth to each feature is recorded, as is the magnitude of separations encountered.

The separation and offset data observed at clay "G" and clay "H" in accessible boreholes during this reporting period are presented in Table 7-1 of the supporting data document for this report.[6] Nineteen of the 28 observation holes in Panel 2 show some offset (compared to 17 holes the previous year). Most offsets are minor, with the exception of two holes in South 2180 which are 75 percent closed at clay "G" (compared to about 50 percent closure during the last reporting period).

8.2 Fracture Mapping

Routine mapping documents the progression of fractures in the roof exposed on the excavation surfaces of the drifts and rooms in the underground repository. The fracture surveys are generally performed on an annual basis, and the fracture maps are recorded on Mylar sheets or updated as AutoCAD files. The fracture maps facilitate the analysis of strain in the immediate roof-beam as they document the propagation of fractures through time. Figures 7-1 through 7-16 of the supporting data document contain fracture maps for Panels 1 and 2. For this reporting period only, Rooms 1 and 2 and a limited portion of South 1950 have been accessible in Panel 1. Some low angle fracturing along the southern end of the east ribs in the two rooms and along the south rib of South 1950 is all that has developed in Panel 1. As indicated on the map legends for Panel 2, the features documented are mainly surficial "onionskin" features. No notable fracturing has developed in Panel 2.

[6] Instrumentation data and data plots are available in "Geotechnical Analysis Report for July 2002-June 2003 Supporting Data." This document is available upon request from Washington TRU Solutions. Refer to Foreword and Acknowledgments for details and address.

8.3 Stratigraphic Mapping

The four south mains were ramped up between South 2520 and South 2750 to establish a new mining horizon for Panel 3 and future Panels 4, 5, 6, and 9. Figures 7-17 and 7-18 of the supporting data document are the stratigraphic maps of the east wall along East 140 where the excavation level ramps up to the new horizon. These maps are representative of the other three south mains. The geology at the upper horizon is as expected—a layer of halite capped by clay "G."

9.0 Summary

At the inception of the WIPP Project, criteria were developed that address the requirements for the design of WIPP (DOE, 1984). These criteria, in the form of design requirements, pertain to all aspects of the mined facility and its operation as a pilot plant for the demonstration of technical and operational methods for permanent disposal of contact-handled (CH) and remote-handled (RH) TRU waste. In 1994, as WIPP developed and the focus moved toward the permanent disposal of TRU waste, these design requirements were reassessed and replaced by a new set of requirements called system design descriptions (SDDs). Table 9-1 shows the comparison of these design requirements with conditions actually observed in the underground from July 2002 through June 2003.

Fracture development in the roof is primarily caused by the concentration of compressive stresses in the roof beam and is influenced by the size and shape of the excavation and the stratigraphy in the immediate vicinity of the opening. Pillar deformations induce lateral compressive stresses into the immediate roof and floor. With time, the buildup of stress causes differential movement along stratigraphic boundaries. This differential movement is identified as offsets in observation boreholes and is indicated by the bends in failed rock bolts. Large strains associated with lateral movements can induce fracturing in the roof, which is frequently seen near the ribs. This scenario of roof deterioration, combining compressive stresses, horizontal offsetting, and large strains associated with lateral movements, is substantiated by field observations.

Normal drift and room maintenance continued during this reporting period with rib, roof, and floor scaling and trimming in various locations, and rock bolting and wire mesh installation as needed. Supplemental ground control systems consisting of resin anchored bolts and roof mats were installed in sections of E140 drift and Panel 1.

New geomechanical instrumentations were installed in the access drifts to Panel 3 and in various locations throughout the repository to replace mined-out instruments. Remote convergence monitoring no longer continues in non-accessible areas north of the North 1100 drift. All accessible areas of the underground are connected to data loggers or are monitored manually.

Table 9-1
Comparison of Excavation Performance to System Design Requirements

Requirement	Comments
"The lining shall be designed for a hydrostatic pressure. . . ."	Water pressure observed on piezometers located behind the shaft liners remains below design levels.
"The key shall be designed to resist the lateral pressure generated by salt creep."	Geomechanical data from the Waste Shaft indicate that the shaft key is minimally loaded and is structurally stable. Visual inspections of all shaft keys do not indicate any deterioration due to creep loading.
"The key shall be designed to retain the rock formation and will be provided with chemical seal rings and a water collection ring with drains to prevent water from flowing down the unlined shaft from the lining above."	Shaft inspection observations and instrumentation show no indication of instability due to salt dissolution.
"The underground waste disposal facilities shall be designed to provide space and adequate access for the underground equipment and temporary storage space to support underground operations."	Geomechanical instrument data and visual observations indicate that the current design provides adequate access and storage space. Ground control maintenance is performed as necessary to maintain access.
"The underground waste disposal facilities shall be designed to provide the capability of retrieving the emplaced CH and RH TRU waste."	(Retrievability is not presently a requirement in the waste disposal program.)
"Entries and sub-entries to the underground disposal area and the experimental areas shall be provided and sized for personnel safety, adequate air flow, and space for equipment."	Deformation of excavation remains within the required limits. Normal periodic maintenance consisting of rock bolting, wire meshing, trimming, and scaling continue throughout the repository.
"Geomechanical instrumentation shall be provided to measure the cumulative deformation of the rock mass surrounding mined drifts. . . ."	Geotechnical instrumentation is operated and maintained to meet this requirement. This annual report acts to provide a summary and analysis of the geomechanical data.

The *in situ* performance of the excavations generally continues to satisfy the appropriate design criteria, although specific areas are being identified where deterioration resulting from aging must be addressed through routine maintenance and implementation of engineered systems. This deterioration has been identified through the analysis of data acquired from geomechanical instrumentation and the Geoscience Program. If the planned life of some of the openings needs to be extended, redesigning the geometry of the access drifts (e.g., changing the horizontal and vertical dimensions) or additional ground control (e.g., roof removal, installing bolts, mesh, or straps) may be necessary. The ground conditions in the Waste Disposal Area and associated waste transport routes continue to slowly deteriorate; however, routine ground control installations and maintenance continue to allow safe access in the underground facility.

In addition to underground instrumentation, qualitative assessments of fracture development are documented through mapping the underground repository and inspecting the observation boreholes. The information acquired from these programs provides early detection of ground deterioration, contributes to the understanding of the dynamic geomechanical processes in the WIPP underground, and aids in the design of effective ground control and support systems.

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10.0 References and Bibliography

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