DOE/WIPP 06-3177
Volume 1

# Waste Isolation Pilot Plant

# Geotechnical Analysis Report For July 2004 – June 2005

April 2006

This document has been submitted as required to:

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-8401

Additional information about this document may be obtained by calling (800) 336-9477. Copies may be obtained by contacting the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

This page intentionally left blank

## 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, 2004, to June 30, 2005.

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 B and C, Title 40 *Code of Federal Regulations* (CFR) Part 191, "Environmental Radiation Protection Standards 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 geotechnical 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), in Carlsbad, New Mexico. Work was supported by the DOE under Contract No. DE-AC29-01AL66444.

---

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

This page intentionally left blank

# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| bp | before present |
| bsc | below shaft collar |
| CAO | Carlsbad Area Office |
| CBFO | Carlsbad Field Office |
| 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 |
| HWFP | Hazardous Waste Facility Permit |
| in. | inch(es) |
| km | kilometer(s) |
| kPa | kilopascal(s) |
| kVA | kilovolt ampere(s) |
| LANL | Los Alamos National Laboratory |
| lb | pound(s) |
| m | meter(s) |
| Ma | million years |
| MB | marker bed |
| μin | $10^{-6}$ inch(es) |
| NMED | New Mexico Environment Department |
| OMB | orange marker bed |
| psi | pound(s) per square inch |
| RH | remote-handled |

| | |
|---|---|
| SDD | system design description |
| SNL | Sandia National Laboratories |
| SPDV | Site and Preliminary Design Validation |
| TRU | transuranic |
| WIPP | Waste Isolation Pilot Plant |
| WTS | Washington TRU Solutions LLC |
| yr(s) | year(s) |

# 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 quarterly to document the geomechanical performance during and immediately after early excavations 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, 2004, to June 30, 2005. It is divided into nine 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 in the shafts and shaft stations, present the data collected by that instrumentation, and provide interpretation of these data. Chapters 5 and 6 present the results of geomechanical monitoring in the two main portions of the WIPP underground (the access drifts and the waste disposal area). Chapter 7 discusses the results of the Geoscience Program, which include fracture mapping and borehole observations. Chapter 8 summarizes the results of the geomechanical monitoring and compares the current excavation performance to the design requirements. Chapter 9 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 terrain that is 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 underground configuration of WIPP as of June 30, 2005.

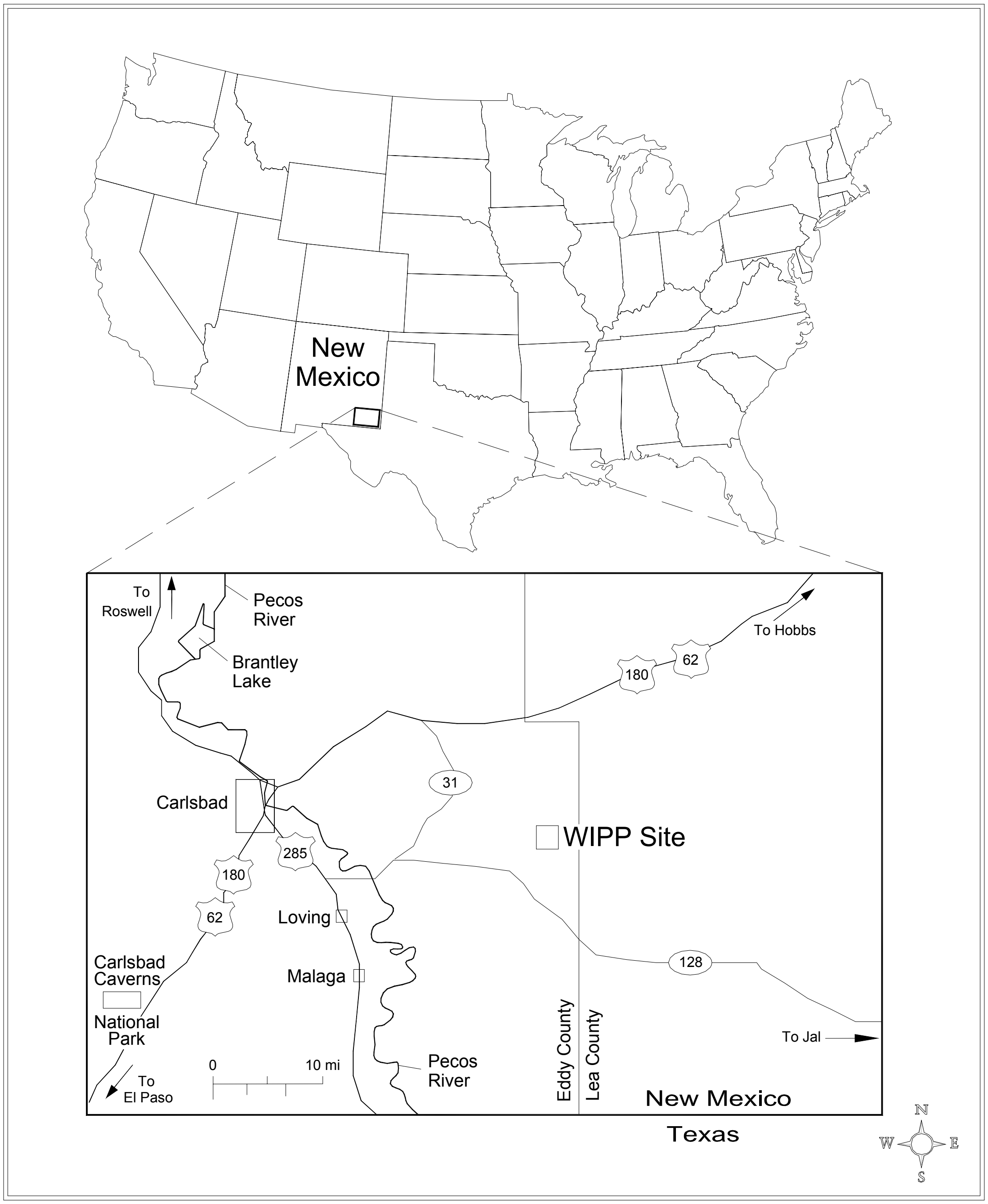


Figure 1-1 – WIPP Location

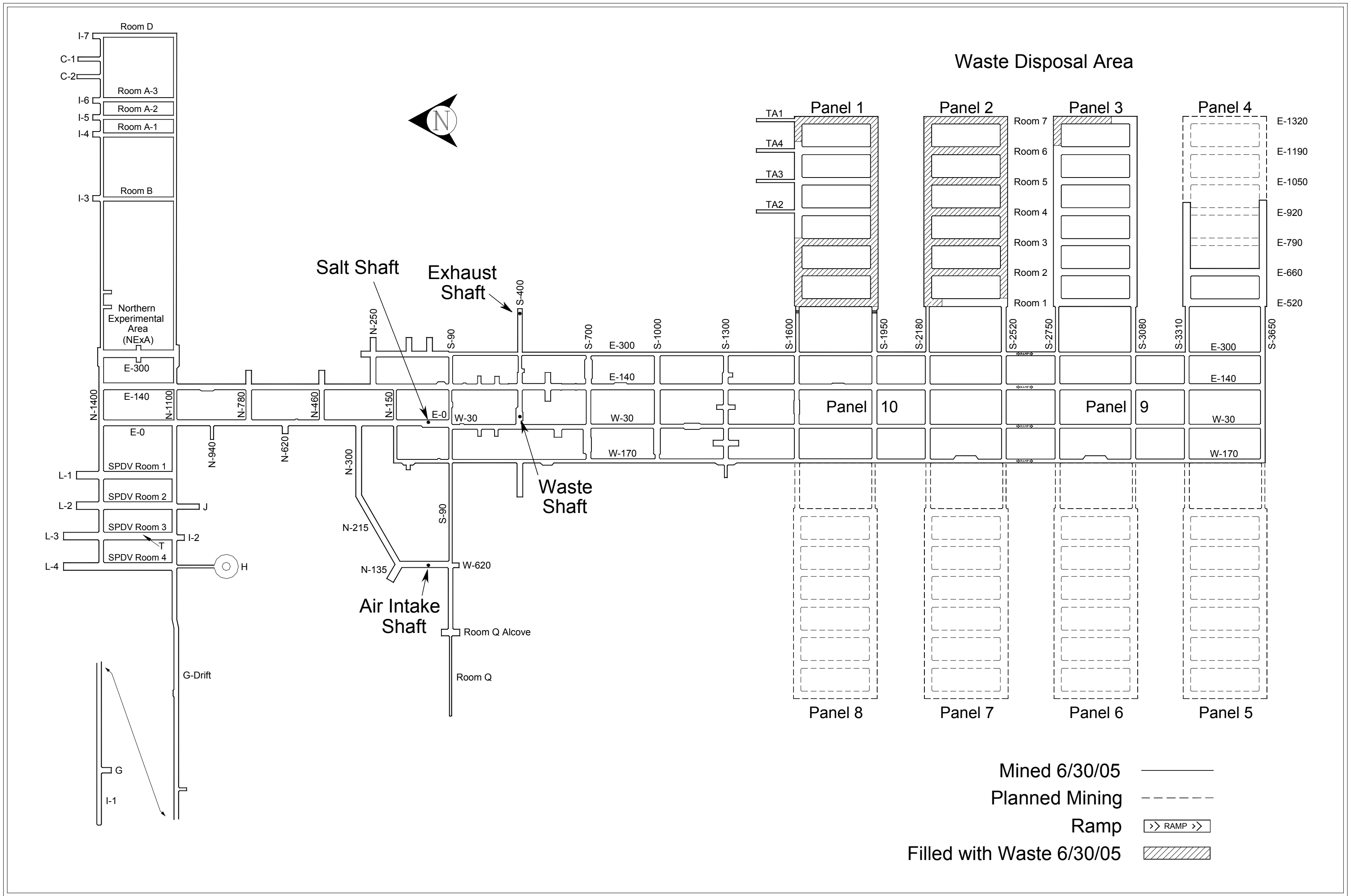


Figure 1-2 – Underground Mining and Waste Disposal Configuration as of 6/30/05

## 1.2 Mission

In 1979 Congress authorized WIPP (Public Law 96-164, National Security and Military Applications of Nuclear Energy Authorization Act of 1980) 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." 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 transuranic (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 first used for in situ studies and experiments without the use of radioactive waste. WIPP now receives, handles, and permanently disposes of TRU waste and TRU mixed 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 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. However, the demonstration and pilot plant phase was not conducted because waste disposal operations had to wait until permits were acquired.

In October 1996, the DOE submitted to the U.S. Environmental Protection Agency (EPA) a compliance certification application in accordance with 40 CFR Parts 191 and 194, which addressed the long-term (10,000-year) performance criteria for the disposal system. On May 18, 1998, the EPA published the final certification that allowed for the receipt of TRU waste at WIPP. Immediately before 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 March 26, 1999, the first shipment of TRU waste was received from Los Alamos National Laboratory (LANL). By the end of June 2005, additional generator sites, including Savannah River Site, Hanford Site, Rocky Flats Environmental Technology Site, Idaho National Engineering and Environmental Laboratory, and the Nevada Test Site, had shipped waste to WIPP.

Waste disposal operations in Panel 1 are complete, and closures were constructed in the panel entries. Mining of Panel 2 began in September 1999 and was completed in August 2000. Mining of Panel 3 began on January 2003 and was completed by the end of March 2004. As of June 30, 2005 Rooms 2 through 6 of Panel 2 were filled, and waste was being emplaced in Room 1, Panel 2, and Room 7, Panel 3. Mining of the south main drifts and the Panel 4 entry drifts was completed, and Room 1 was excavated to final dimensions.

### 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 compared to the established design criteria.

Data taken by or input into 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
- Displacement of deformation features.

Convergence measurements and borehole extensometers provide data on salt creep closure induced by rock excavation. Data on the extent of deformation are generated through borehole extensometers and borehole observations. Fracture mapping of the excavation surface, as well as borehole observations are used to provide data on the initiation of brittle deformation. Displacement of deformation features in the underground facility is 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.

**Instrumentation**

Instrumentation installed for measuring the geomechanical response of the shafts, drifts, and other underground openings includes 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.

## 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 underground data-loggers, 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 data sheets 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. Instruments are connected to polling devices that are installed in electrical enclosures near the instrument locations. Polling devices are connected by a data link 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].

[3] Instrumentation data and data plots are presented in "Geotechnical Analysis Report for July 2004-June 2005 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.

| 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 meter | Cumulative deformation | 0–3.5 ft | 0.001 in |
| Embedded strain gauge | Cumulative strain | 0–3000 μin/in | 1 μin/in |
| Spot-welded strain gauge | Cumulative strain | 0–2500 μin/in | 1 μin/in |
| Rock bolt load cell | Load | 0–50 tons | 40 lb |
| Earth pressure cell | Pressure | 0–1000 psi | 1 psi |
| Piezometers | Fluid pressure | 0–500 psi | 0.5 psi |
| Joint meter | 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.

## Data Evaluation

Rounding and significant digits are used in the data tables of this document. The reference document is ASTM E 29–04, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specification."[4]

Closure measurements are acquired manually from convergence point anchors and remotely from convergence meters. The data are presented in plots as closure versus time. Closure 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). Displacement rate data for the hole collar relative to the deepest anchor are presented in the data analysis.

[4] Copyright by ASTM
Reproduction authorized per License Agreement with Washington TRU Solutions LLC.

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.

Earth pressure cells and strain gauges are used to determine the stresses and deformation in and around the shaft liners. Data are depicted in time-based plots.

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

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

**Data Errors**

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, the reading frequency may be increased. This process to correct erroneous readings is documented and filed for future reference.

# 2.0 GEOLOGY

This chapter provides a summary of the stratigraphy of the WIPP region and the site 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 of Permian (295 to 250 million years ago [Ma]), Triassic (250 to 203 Ma), and Quaternary (1.75 Ma to present) ages. The descriptions of formations provided in this section are given in order of deposition (oldest to youngest), beginning with the Castile Formation (Figure 2-1).

### Permian

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 redbeds 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. The Permian rocks are overlain by fluvial deposits of the Triassic and Quaternary periods.

#### 2.1.1.1 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.

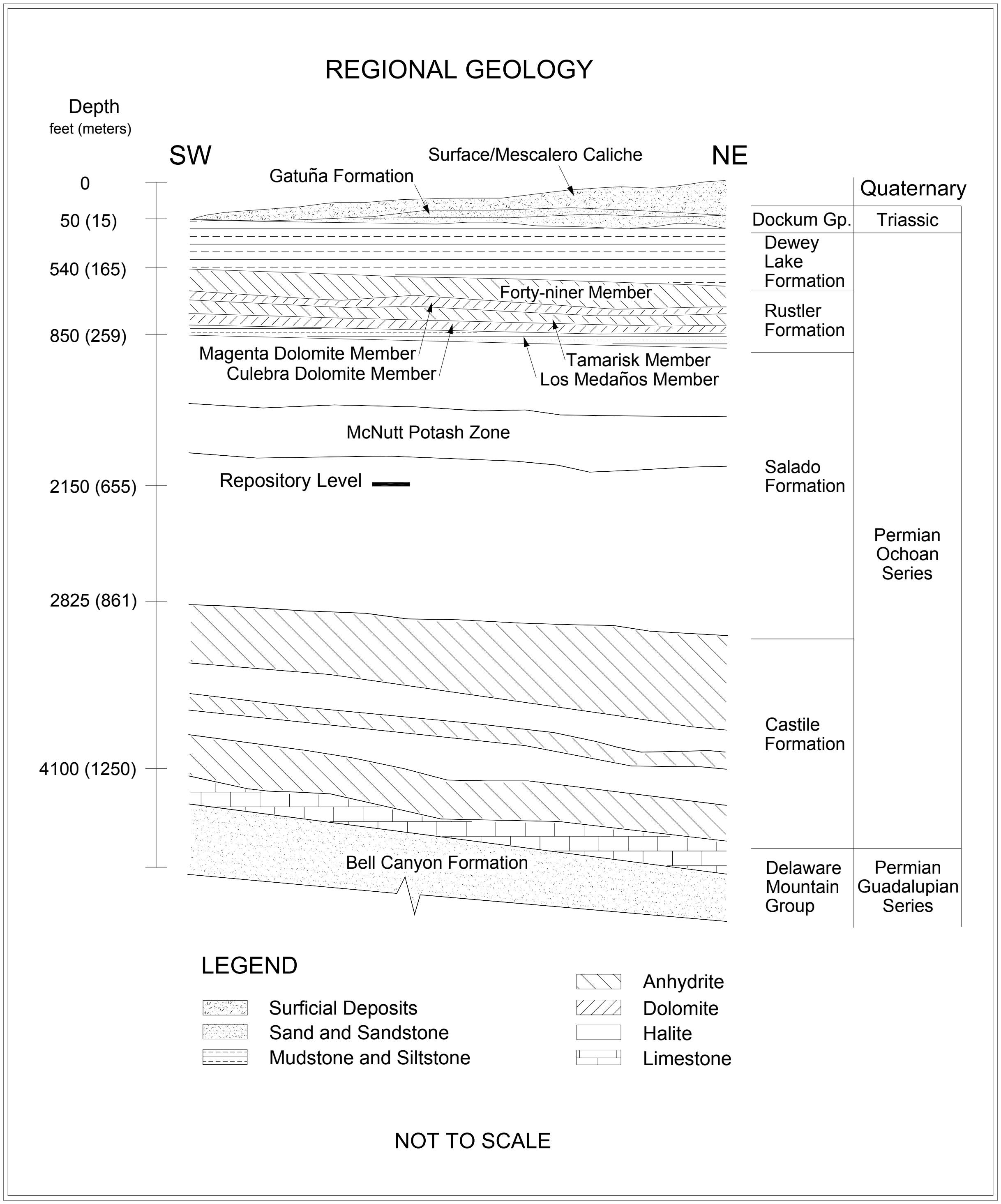


Figure 2-1 – Regional Geology

#### 2.1.1.2 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.

#### 2.1.1.3 Rustler Formation

The Rustler Formation is subdivided into five members, starting from its 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.

#### 2.1.1.4 Dewey Lake Redbeds

The Dewey Lake Redbeds are the uppermost of the Ochoan Series formations. Within the series, the Dewey Lake represents a transition from the lower marine 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.

**Triassic**

The only Triassic rocks present in the WIPP region belong to the Dockum Group.

#### 2.1.1.5 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.

**Quaternary**

Quaternary Period deposits include the Gatuña Formation, Mescalero Caliche, and surficial sediments.

#### 2.1.1.6 Gatuña Formation, Mescalero Caliche, and Surficial Sediments

The Gatuña Formation (ranging in age from approximately 1.3 Ma to 600,000 years before present [bp] [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 bp) 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 indicate 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 near the midpoint 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), counted from MB100 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.

In the vicinity of the WIPP facility, the stratigraphy is fairly continuous and uniform. Beds generally dip towards the south-southeast at a slope of approximately 3 percent.

### Disposal Horizon Stratigraphy of Panels 1, 2, 7, and 8

This disposal horizon contains Panels 1, 2, 7, and 8, all the shaft areas, the shop areas, the SPDV areas (which are now closed), and all the access drifts to S-2620 (the four main entries that extend south rise in a ramp that starts at S-2620 and ends at S-2740). Panels 7 and 8 have not yet been excavated.

Most underground excavations are located within this disposal horizon (see Figure 2-2). In this horizon, the Orange Marker Bed (OMB) lies near the middle of the rib, i.e., the excavation wall. The OMB is a laterally consistent unit of moderate to light reddish-orange halite about 6 in (15 centimeters [cm]) thick that is used as a point of reference during excavation.

MB139 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 sub-horizontal 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.

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 S-1000 and 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, approximately 6.5 ft (2 m) above the upper contact of Anhydrite "b."

### Disposal Horizon Stratigraphy of Panels 3, 4, 5, and 6

This disposal horizon contains Panels 3, 4, 5, and 6, and all the access drifts south of S-2740. As is the case with the other disposal horizon, some panels (5 and 6) have not yet been excavated. The rise in floor elevation from S-2620 to S-2740 is approximately 6 ft.

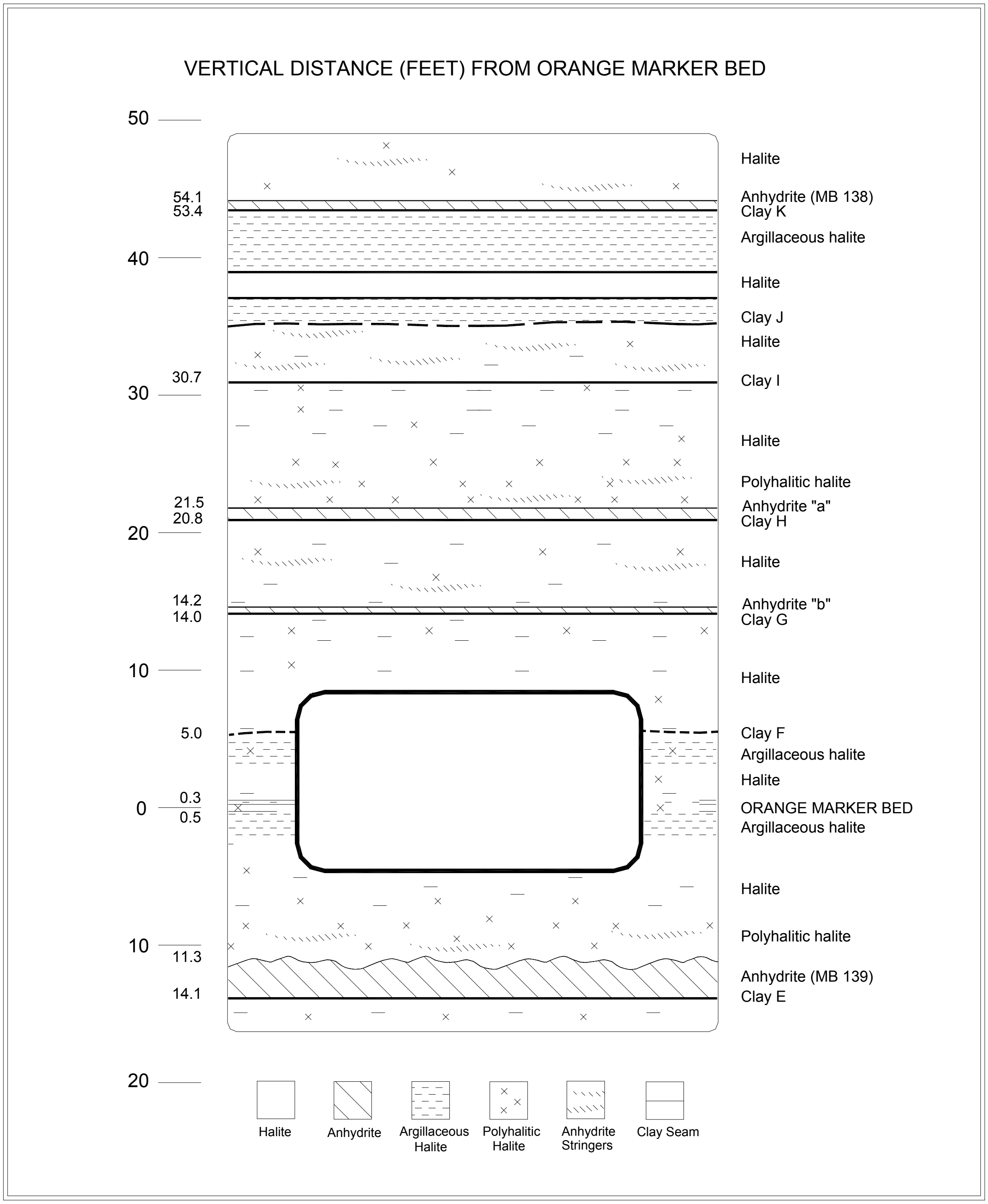


Figure 2-2 – Repository Level Stratigraphy of Panels 1, 2, 7, and 8

In this horizon (see Figure 2-3), the OMB lies at or below the floor. MB139 lies about 12 ft (3.7 m) below the 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 during excavation of this disposal horizon.

### Northeast Area Stratigraphy

All of the Northeast Area, a former experimental area, is now deactivated and closed to access. These excavations lie at a higher stratigraphic level than the disposal excavations. Floors are 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.

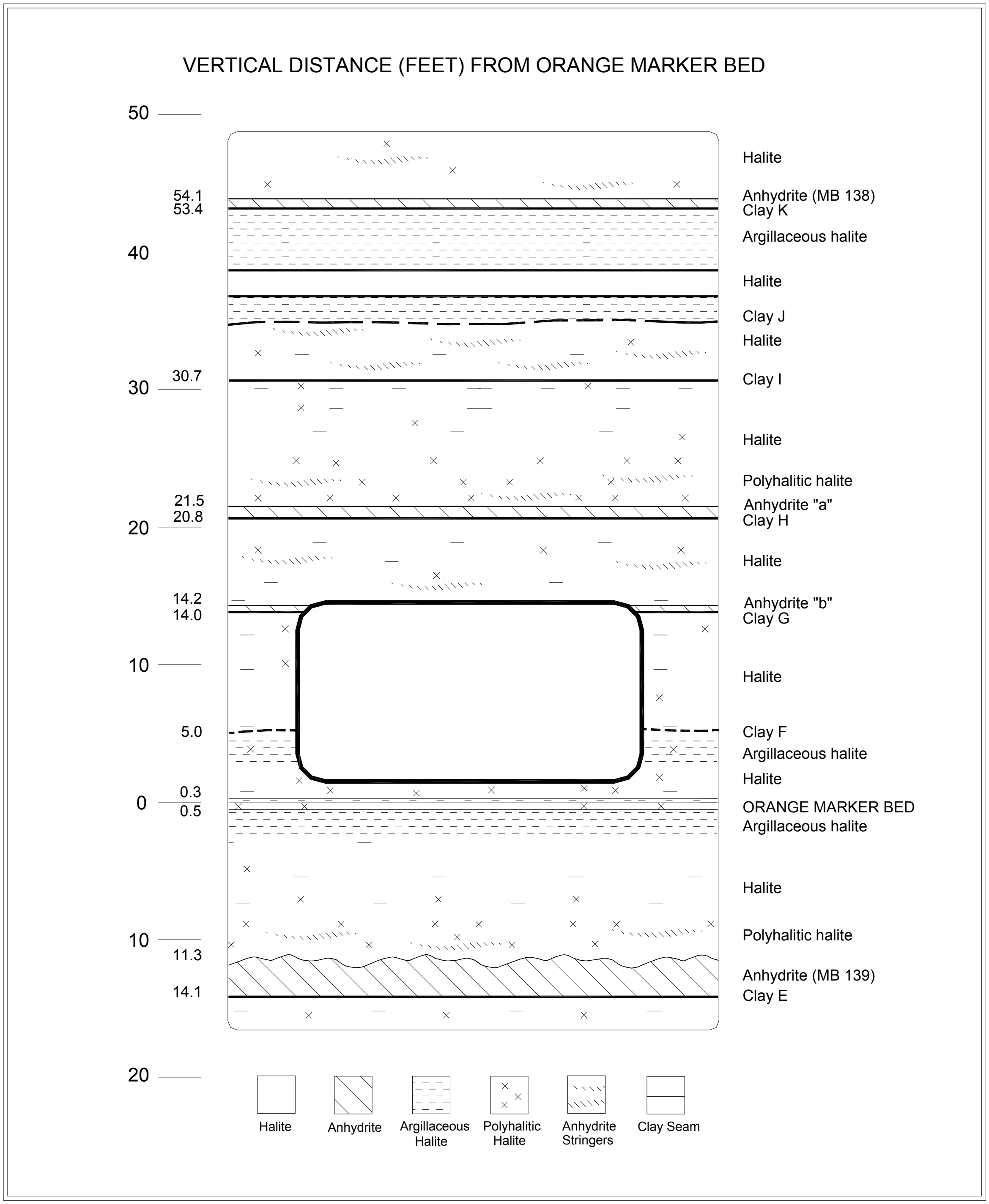


Figure 2-3 – Repository Level Stratigraphy of Panels 3, 4, 5, and 6

## PERFORMANCE OF SHAFTS AND KEYS

Four shafts connect the surface with the WIPP underground. These shafts are: the Salt Shaft, which is primarily used for removing excavated salt from the underground; the Waste Shaft, which is the primary shaft for transporting personnel 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 much 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.

### 2.3 Salt 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 Shaft and is currently designated the Salt 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 Shaft.

The Salt 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 (258 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 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).

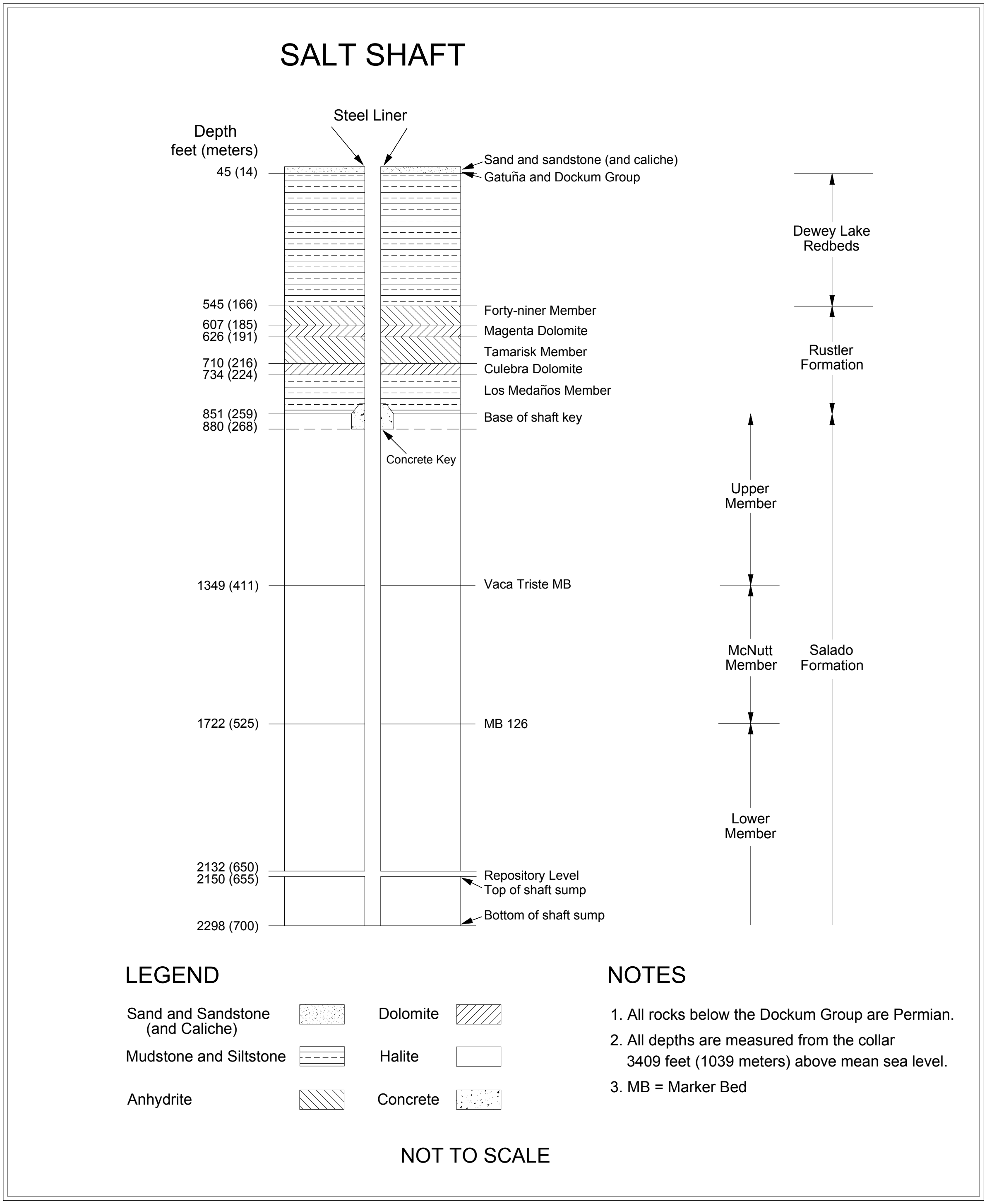


Figure 0-1 – Salt Shaft Stratigraphy

Wire mesh anchored by rock bolts is installed in sections of the lower shaft 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.

**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 Shaft was in satisfactory condition. Only routine ground control activities were required during this reporting period.

**Instrumentation**

Geomechanical instruments (radial convergence points, extensometers, and piezometers) were installed at various levels in the Salt Shaft from April through July of 1982 (Figure 3-2). In the shaft key, instruments included strain gauges, pressure cells, and piezometers (Figure 3-3). The radial convergence points were installed prior to outfitting of the Salt Shaft. Upon completion of the outfitting, no more readings were taken. All of the extensometers in the Salt Shaft have ceased functioning.

All 12 piezometers continue to provide data. The fluid pressures recorded at the end of this reporting period range from approximately 72 pounds per square inch (psi) (496 kilopascals [kPa]) at the 580-ft (177-m) level in the Forty-niner Member to 155 psi (1,069 kPa) at the 691-ft (211-m) level in the Tamarisk Member. The recorded pressure of 145 psi (1,000 kPa) at the Magenta Dolomite Member represents an 18-psi decrease; however, the installations at this level have historically exhibited large fluctuations. The recorded pressures of 140 psi (965 kPa) at the Culebra Dolomite Member represent no significant change from the recorded pressure in the same location at the end of the previous reporting period. The fluid pressure on 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 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 loads up the key structure. Three of the four earth pressure cells continue to provide data. These instruments have indicated essentially no contact pressure since their installation (readings resemble instrument drift at a zero pressure). The contact pressures recorded by the instruments for this reporting period ranged from -26 to 3 psi (-179 to 21 kPa).

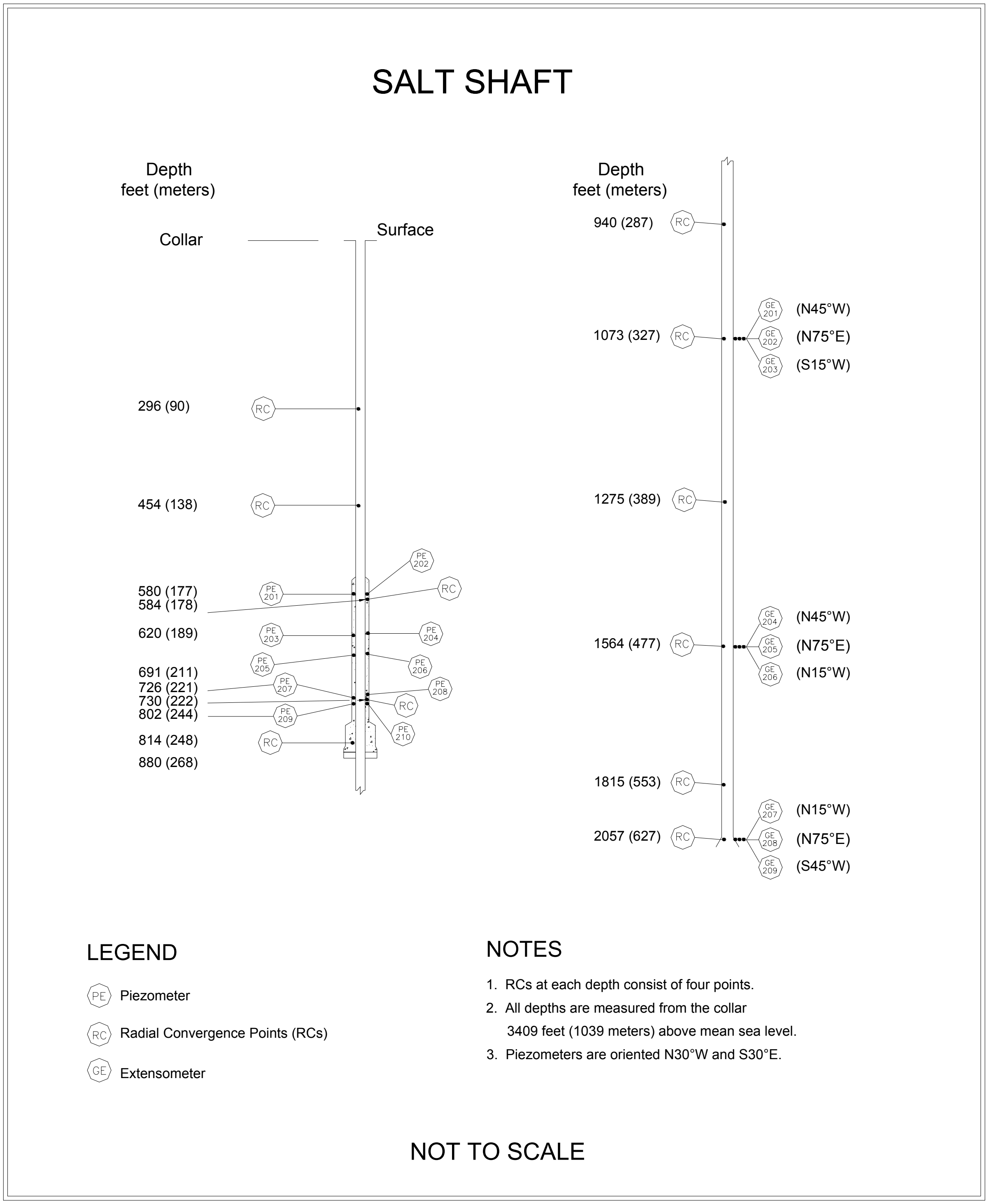


Figure 0-2 – Salt Shaft Instrumentation (Without Shaft Key)

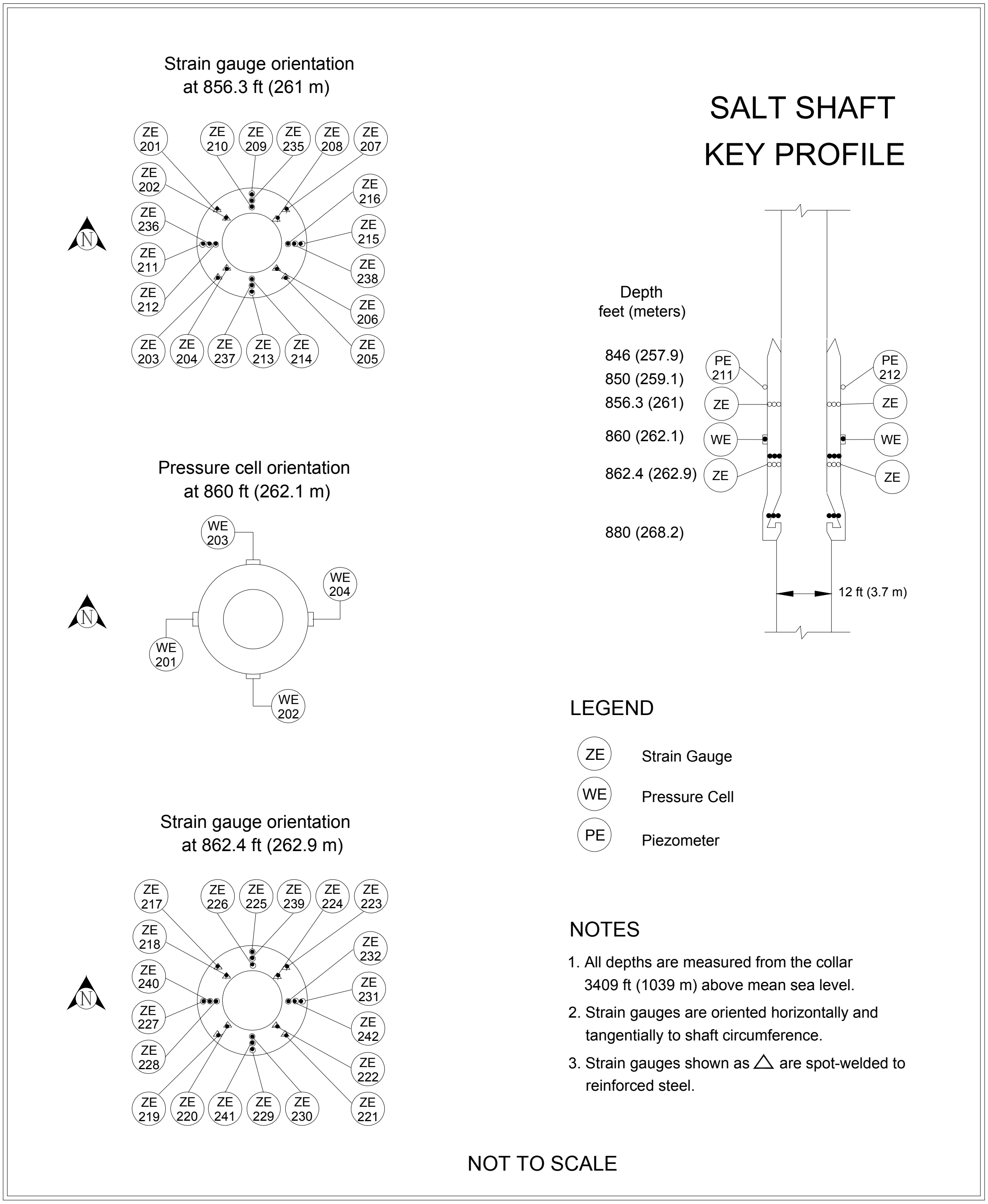


Figure 0-3 – Salt Shaft Key Instrumentation

Sixteen spot-welded and twenty-four embedment strain gauges were installed on and in the shaft key concrete at both the 856.3-ft (261-m) level and at the 862.4-ft (263-m) level. Four spot-welded strain gauges are still functioning at these levels. Maximum strains at the 856.3-ft (261-m) level were 677 and 727 microstrain. Strains at the 862.4-ft (262.9-m) level were 568 and 825 microstrain. The strains from the 12 embedment strain gauges at the 856.3-ft (261-m) level ranged from -804 to 989 microstrain. The strains from the two embedment strain gauges at the 862.4-ft (263-m) level were 200 to 340 microstrain. The strains recorded by the spot-welded strain gauges and the embedment strain gauges during this reporting period are very similar to the strains recorded by these instruments at the end of the previous reporting period.

## 2.4 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 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 non-reinforced concrete and has a 19 ft (6 m) inside diameter from the surface to the top of the 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 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 bottom of 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.

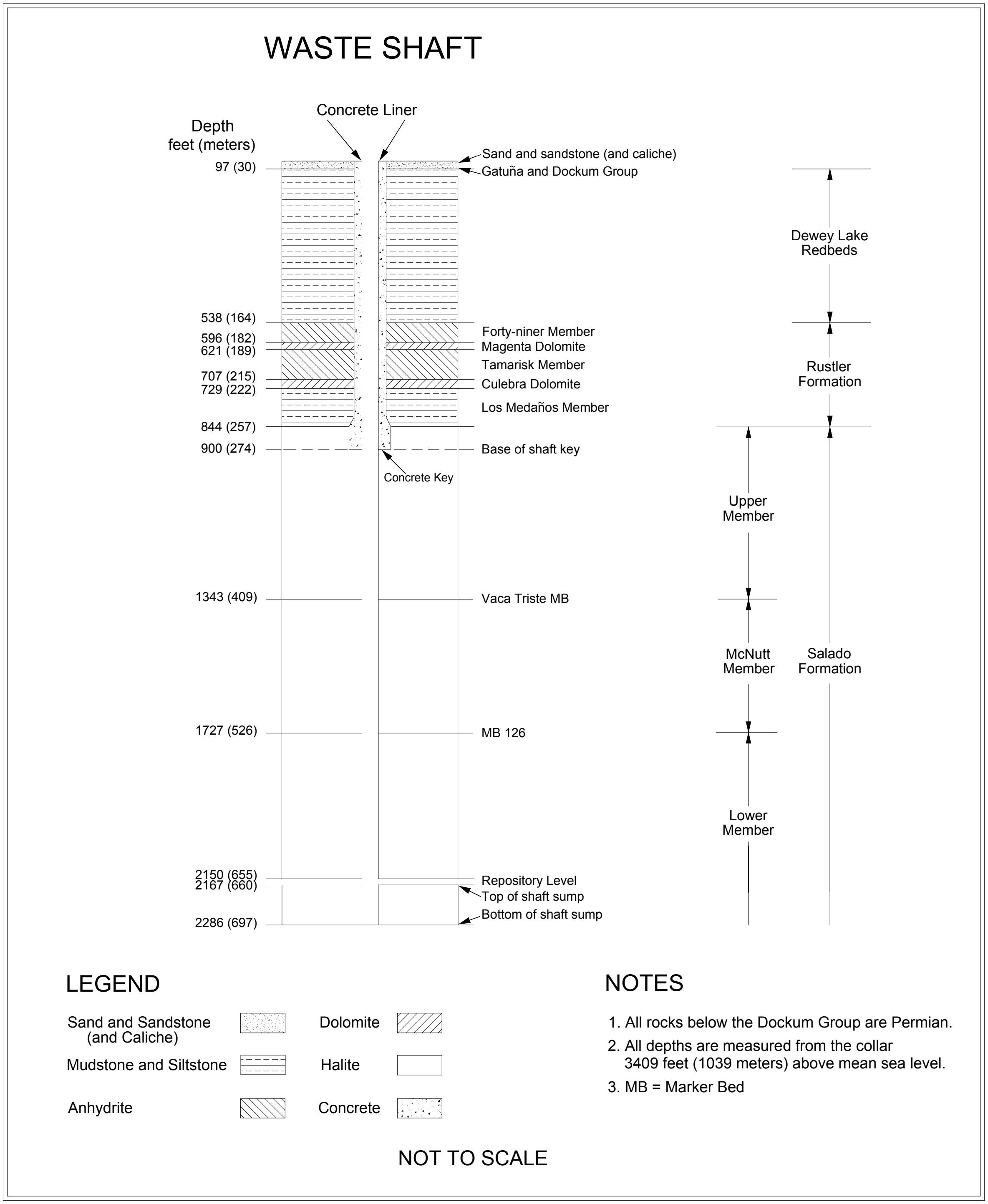


Figure 0-4 – Waste Shaft Stratigraphy

### Shaft Observations

Underground operations personnel conduct weekly visual shaft inspections, 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 found that the Waste Shaft was in satisfactory condition. No ground control activities other than routine maintenance were required.

### Instrumentation

Radial convergence points, extensometers, piezometers, and earth pressure cells 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. The radial convergence points were installed prior to the outfitting of the Waste Shaft. Upon completion of the outfitting, no more radial convergence readings were taken.

Nine multiposition borehole extensometers were installed in arrays 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; however, few data have been collected during this reporting period due to the malfunction of the data-logger.

Twelve piezometers were installed in the lined section of the Waste Shaft on September 7 and 8, 1984, to monitor fluid pressure behind the shaft liner and key section in the shaft. Data continue to be received from 10 piezometers.

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.

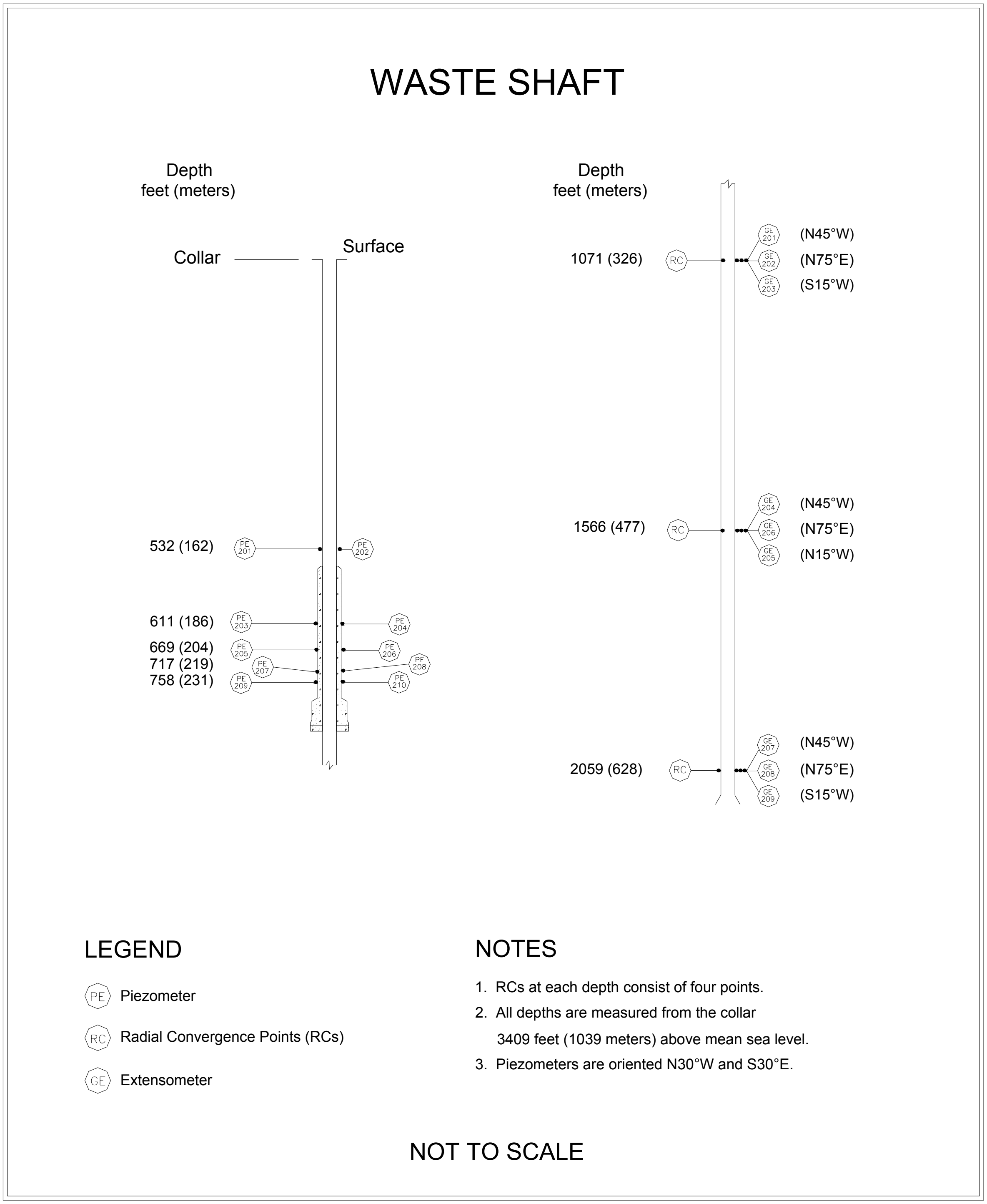


Figure 0-5 – Waste Shaft Instrumentation (Without Shaft Key)

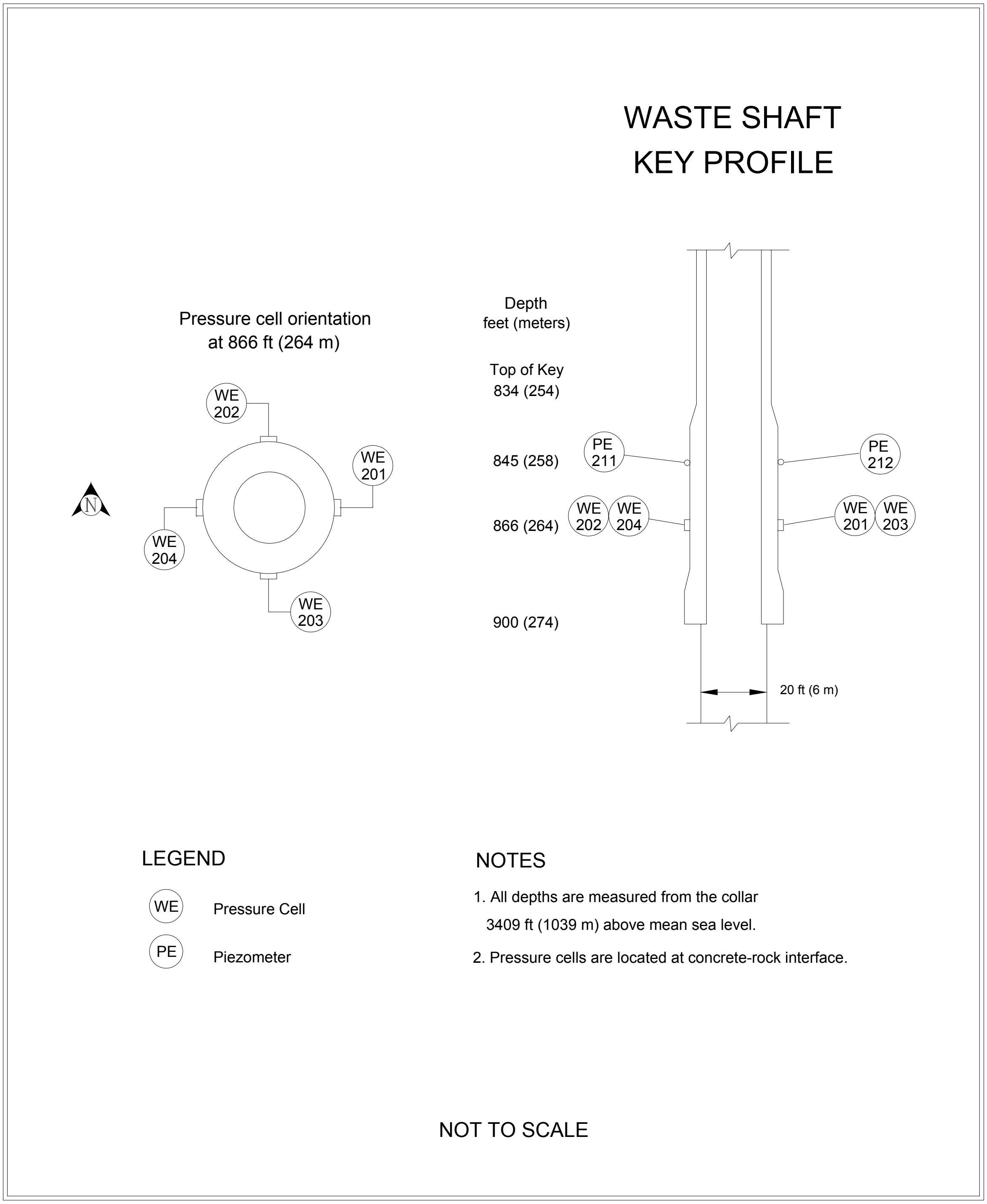


Figure 0-6 – Waste Shaft Key Instrumentation

## 2.5 Exhaust Shaft

The Exhaust Shaft was drilled from September 22, 1983, to November 29, 1984, to establish a route from the underground 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.

The Exhaust Shaft is lined with non-reinforced concrete from the surface to the top of the shaft key at 844 ft (257 m). The liner thickness increases from 10 to 16 in (25 to 41 cm) over that interval. The 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, approximately 2,150 ft (655 m) deep. This shaft has no sump.

**Exhaust Shaft Observations**

Quarterly Exhaust Shaft video inspections were conducted according to approved WIPP procedures. Inspections were performed to evaluate the condition and to verify the integrity of the shaft. The shaft was examined for cracks, corrosion, salt buildup, leaks, and debris. In addition, inspections examined the condition of anchors, brackets, and down-hole equipment. Between July 2004 and June 2005, four shaft inspections were conducted: August 31, 2004; November 10, 2004; February 21, 2005; and May 24, 2005.

#### 2.5.1.1 Video Camera

Video inspections use 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 multi-mode optical fibers. The cable is reeled out by a winch mounted in a control van. Video inspections are recorded.

#### 2.5.1.2 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 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 accumulate salt buildup of up to several inches.

The Exhaust Shaft liner is examined for cracks, seepage, and general shaft stability. Currently, there are three principal zones of seepage in the shaft. The first is about 50 to 55 ft below the shaft collar (bsc). The second is about 60 to 65 ft bsc. The third is about 75 to 80 ft bsc, as shown in Figure 3-9. Monitoring of seepage horizons started before 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 about 43 to 44 ft below the 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.

When fluid was detected seeping into the Exhaust Shaft in 1995, a catch basin was designed and installed at the base of the shaft to intercept and prevent water from draining into the Waste Shaft Sump. Fluid has been removed from the catch basin since March 1996 as needed. Table 3-1 presents the volume of fluid removal from the catch basin from July 1997 through June 2005. Between July 2004 and June 2005, the volumes of fluid removed from the catch basin ranged from 220 gallons to 1100 gallons (Table 3-1). 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 catch basin was damaged in 2004 by fallen debris, either from a salt slab or instrumentation cables or both. A new catch basin was fabricated and installed in December 2004.

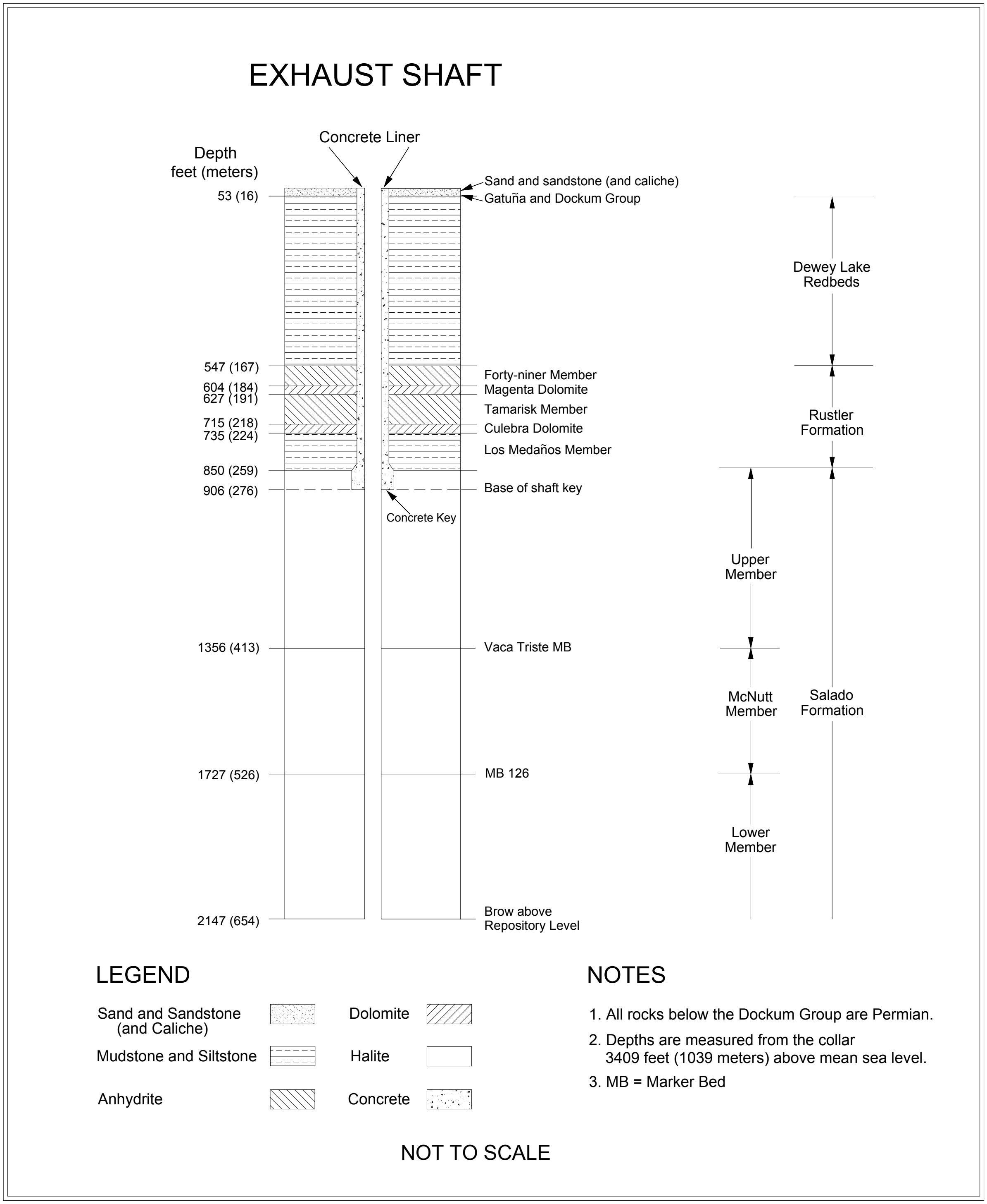


Figure 0-7 – Exhaust Shaft Stratigraphy

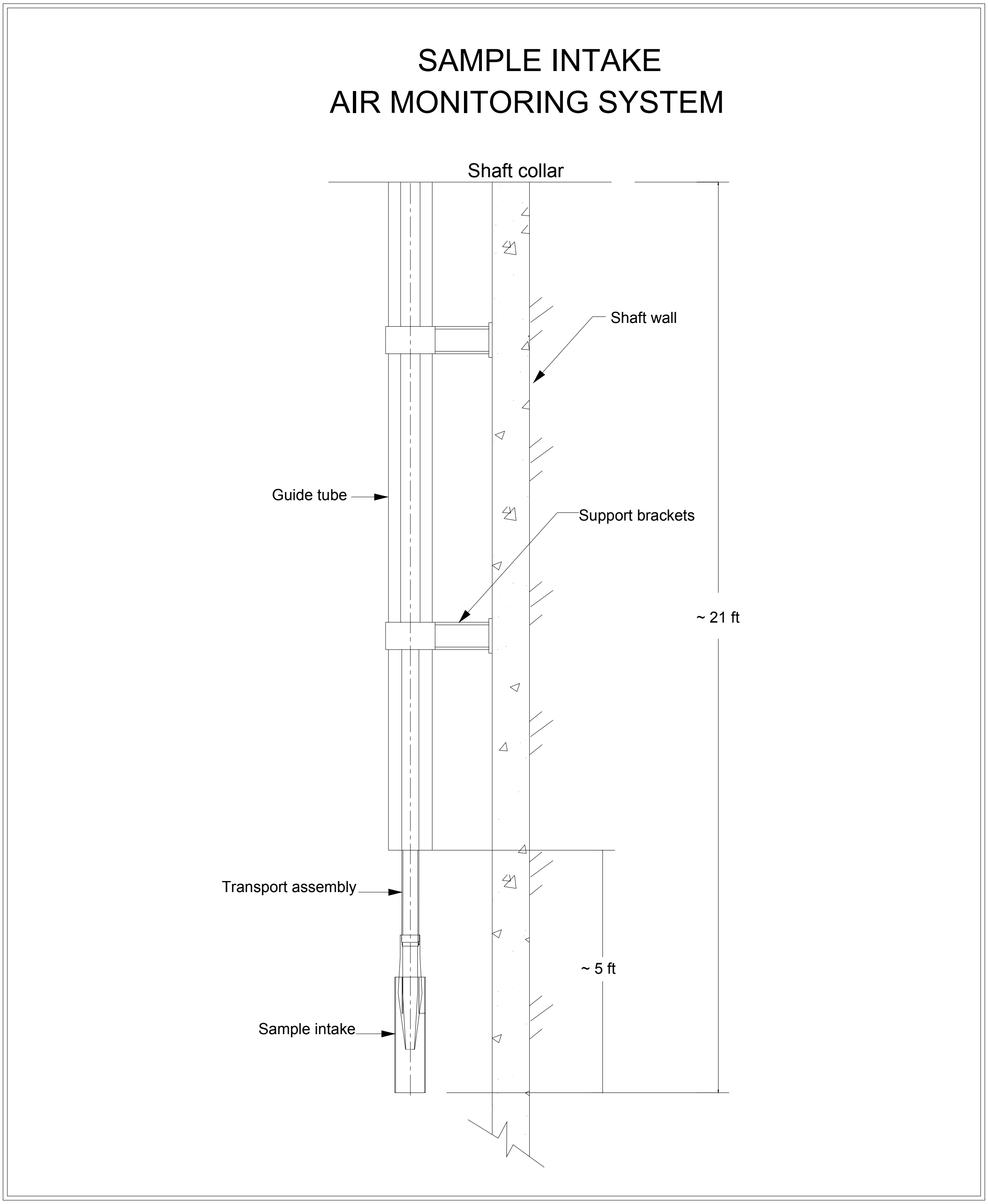


Figure 0-8 – Sample Intake of Exhaust Shaft Air Monitoring System

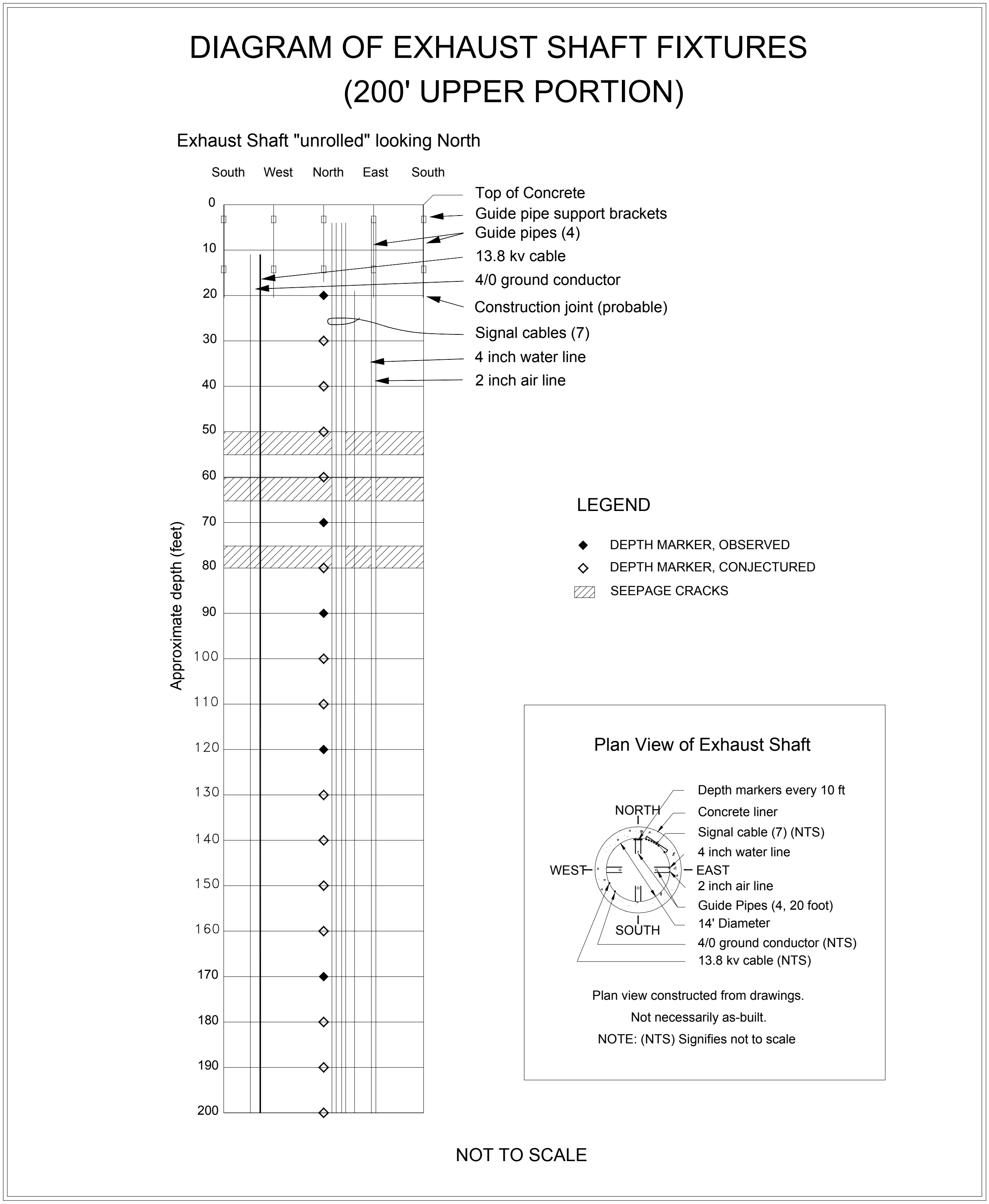


Figure 0-9 – Diagram of Exhaust Shaft Fixtures (Upper 200 ft)

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. 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 Panel 4 and the south access drifts. The principal areas in the shaft with significant salt buildup were the three water rings at the Magenta, the Culebra, and the key, and along upper portions of the east wall of the shaft generally associated with the support brackets, instrument cables and the air- and water-lines.

Though the Magenta and Culebra water rings are encrusted with salt buildup, no water appears to emanate 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 water-lines 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, but the presence of brine increases the probability of corrosion and deterioration of utility hangers and brackets. There are no visible signs of dissolution of the salt below the key.

The video inspection also focused on the installed utilities and support brackets. These include the 13.8 kilovolt amp (kVA) power cable and the grounding cable on the west wall of the shaft, the instrumentation cables on the northeast wall of the shaft, and the 4-in. air-line and the 2-in. water-line on the east wall of the shaft. Video inspection of the 13.8 kVA cable and the grounding cable showed no visible signs of damage. There was sporadic salt buildup on the cables. The long-term implication of salt buildup is increased loading on cables and cable hangers. The 4-in. compressed air-line and the 2-in. water-line extend from the surface to the bottom of the shaft. At present, neither line is being used. The integrity of the brackets holding the air-line and water-line was difficult to assess because of salt buildup; however, there was no indication that the brackets were broken. Instrumentation cable breaks were observed in the shaft; however, most of these breaks affected abandoned cables, with negligible impact on shaft monitoring and operations.

## Table 0-1 – 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 | Sludge 330 |
| 8/18/97 | 330 | 7/28/98 | 330 | 6/22/00 | 330 | 4/17/01 | 220 | 6/22/02 | 330 | 03/25/2003 | Sludge 220 |
| 8/22/97 | 330 | 8/3/98 | 495 | 6/30/00 | 165 | 4/24/01 | 110 | **Total** | **4235** | 05/27/2003 | 55 |
| 8/25/97 | 1045 | 8/10/98 | 1265 | **Total** | **2475** | 5/22/01 | 110 | | | 06/03/2003 | 220 |
| 8/25/97 | Sludge 110 | 8/21/98 | 330 | | | 5/22/01 | Sludge 440 | | | 06/25/2003 | 330 |
| 9/2/97 | 220 | 8/24/98 | 990 | | | 6/12/01 | 1100 | | | **Total** | **3300** |
| 9/15/97 | 605 | 8/27/98 | 1155 | | | 6/13/01 | 110 | | | | |
| 9/22/97 | 550 | 9/1/98 | 330 | | | Sludge | 110 | | | | |
| 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 | 6/10/99 | 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** | | | | | | | | | | |

## Table 3-1 – Water Removed from the Exhaust Shaft Catch Basin (Continued)

| July 2003 – June 2004 | | July 2004 – June 2005 | | July2005 – June 2006 | | July 2006 – June 2007 | | July 2007 – June 2008 | | July 2008 – June 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Gallons** | **Date** | **Gallons** | | | | | | | | |
| 3/25/03 | Sludge 220 | 11/29/04 | Sludge 660 | | | | | | | | |
| 5/27/03 | 55 | 12/06/04 | Sludge 275 | | | | | | | | |
| 6/3/03 | 220 | 01/03/05 | 660 | | | | | | | | |
| 6/25/03 | 330 | 01/10/05 | 385 | | | | | | | | |
| 7/8/03 | 605 | 05/16/05 | 660 | | | | | | | | |
| 7/9/03 | 550 | 06/01/05 | 660 | | | | | | | | |
| 7/17/03 | 165 | 06/06/05 | 220 | | | | | | | | |
| 8/12/03 | 275 | 06/20/05 | 440 | | | | | | | | |
| 10/14/03 | 165 | 06/27/05 | 220 | | | | | | | | |
| 10/20/03 | 440 | Total | 4180 | | | | | | | | |
| 10/21/03 | 330 | | | | | | | | | | |
| 11/21/03 | 220 | | | | | | | | | | |
| 11/21/03 | Sludge 660 | | | | | | | | | | |
| **Total** | **4235** | | | | | | | | | | |

**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.

No extensometers were read during this reporting period.

Ten of the 21 piezometers remain in working condition. The fluid pressure readings from the working piezometers at the end of the reporting period range from -2.7 psi (-18.6 kPa) at 544-ft (166-m) to 140 psi (966 kPa) at 721-ft (220-m). 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.

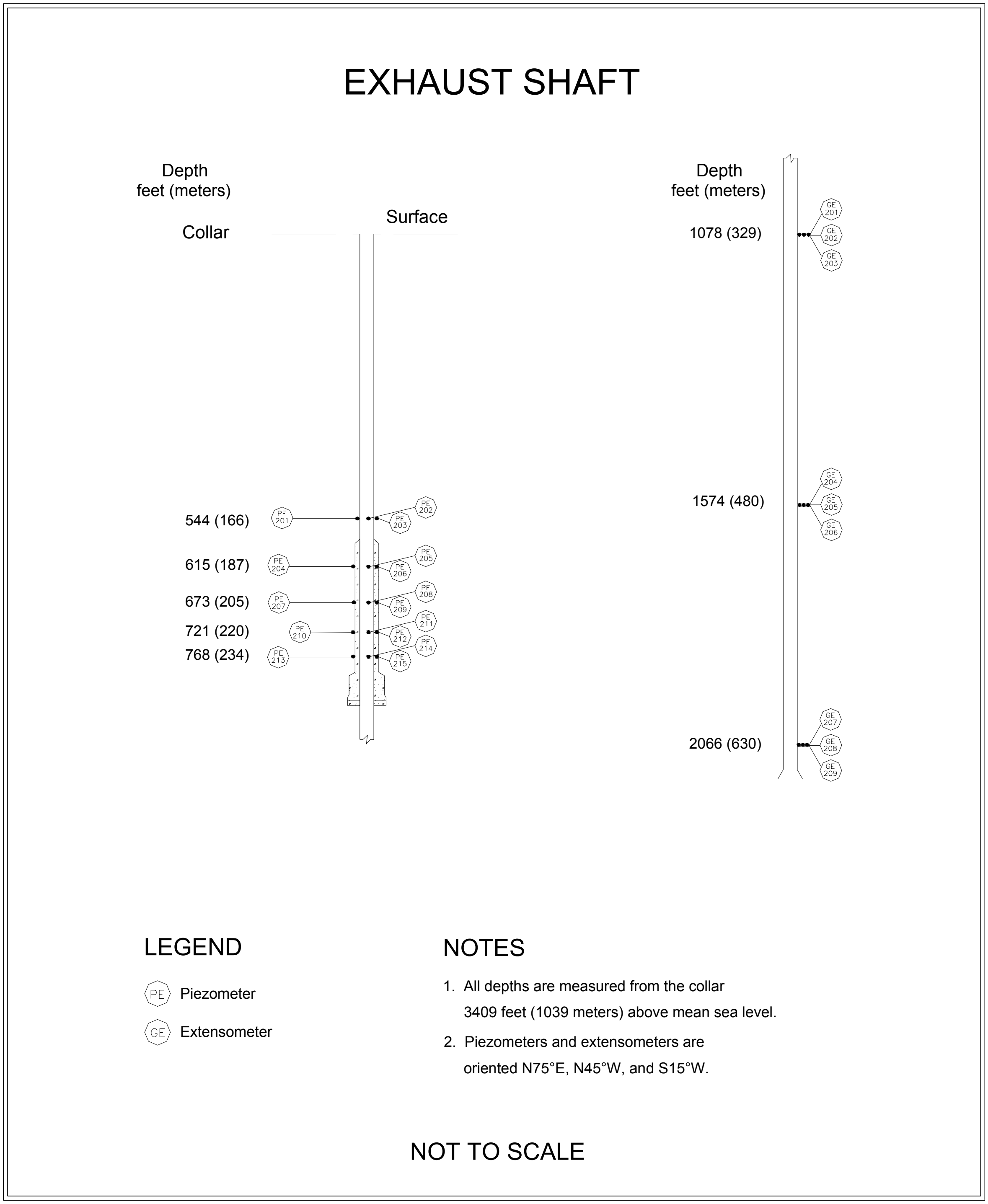


Figure 0-10 – Exhaust Shaft Instrumentation (Without Shaft Key)

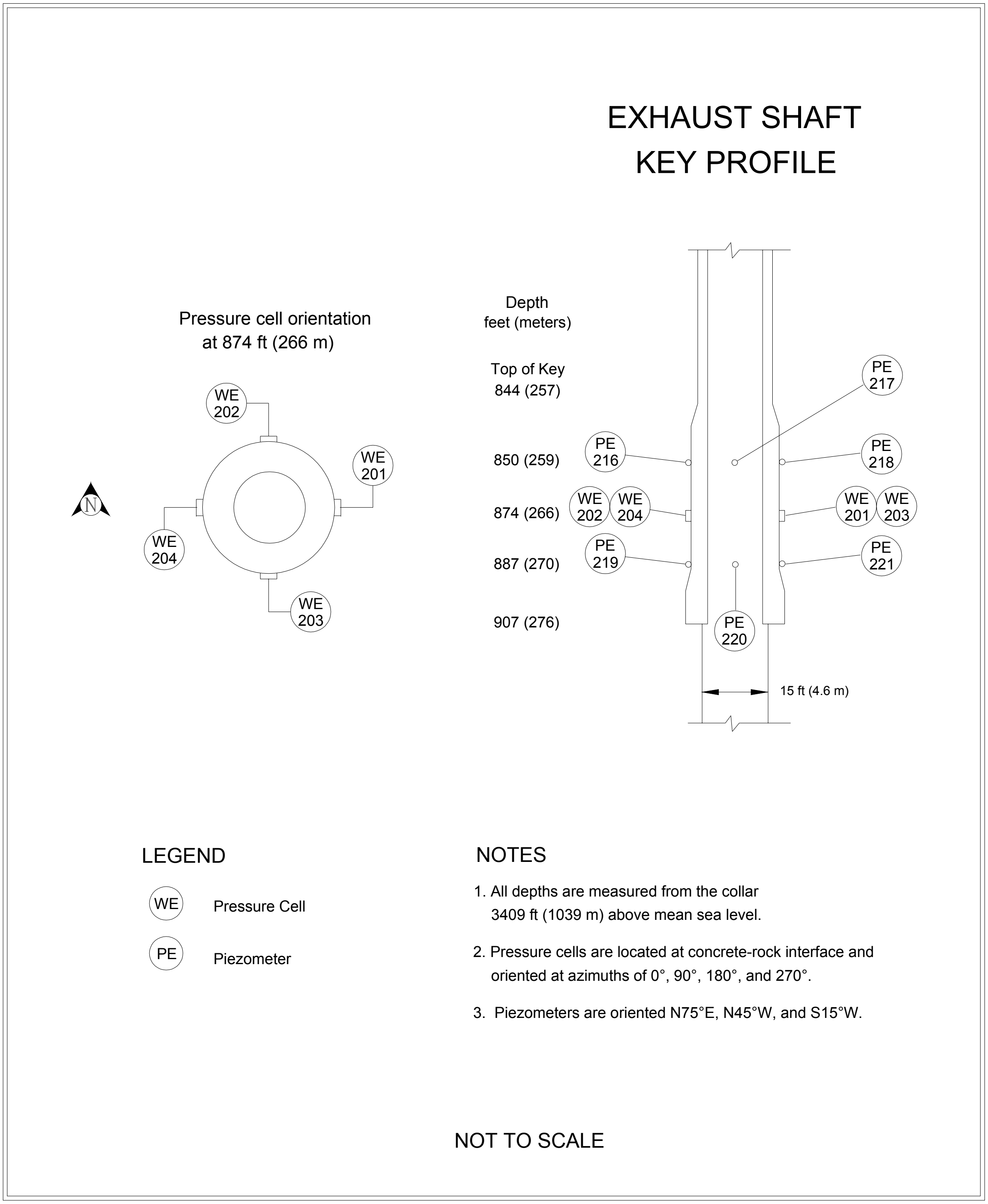


Figure 0-11 – Exhaust Shaft Key Instrumentation

Four earth pressure cells were installed in the key section of the Exhaust Shaft during concrete emplacement. Only two of these earth pressure cells are still functional. During this reporting period, the pressure cell readings indicated less than one psi since the last reporting period. The peak recorded pressures during this period were 56 and 44.3 psi (386 and 305 kPa).

## 2.6 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). The stratigraphy was mapped from September 14, 1988, to November 14, 1989 (Holt and Powers, 1990). Figure 3-12 summarizes the Air Intake Shaft stratigraphy.

The Air Intake Shaft is lined with non-reinforced concrete from the surface to the bottom of the shaft key at 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 shaft diameter below the key is 20 ft (6 m), and the shaft is unlined below the key to the facility horizon at 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.

### 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.

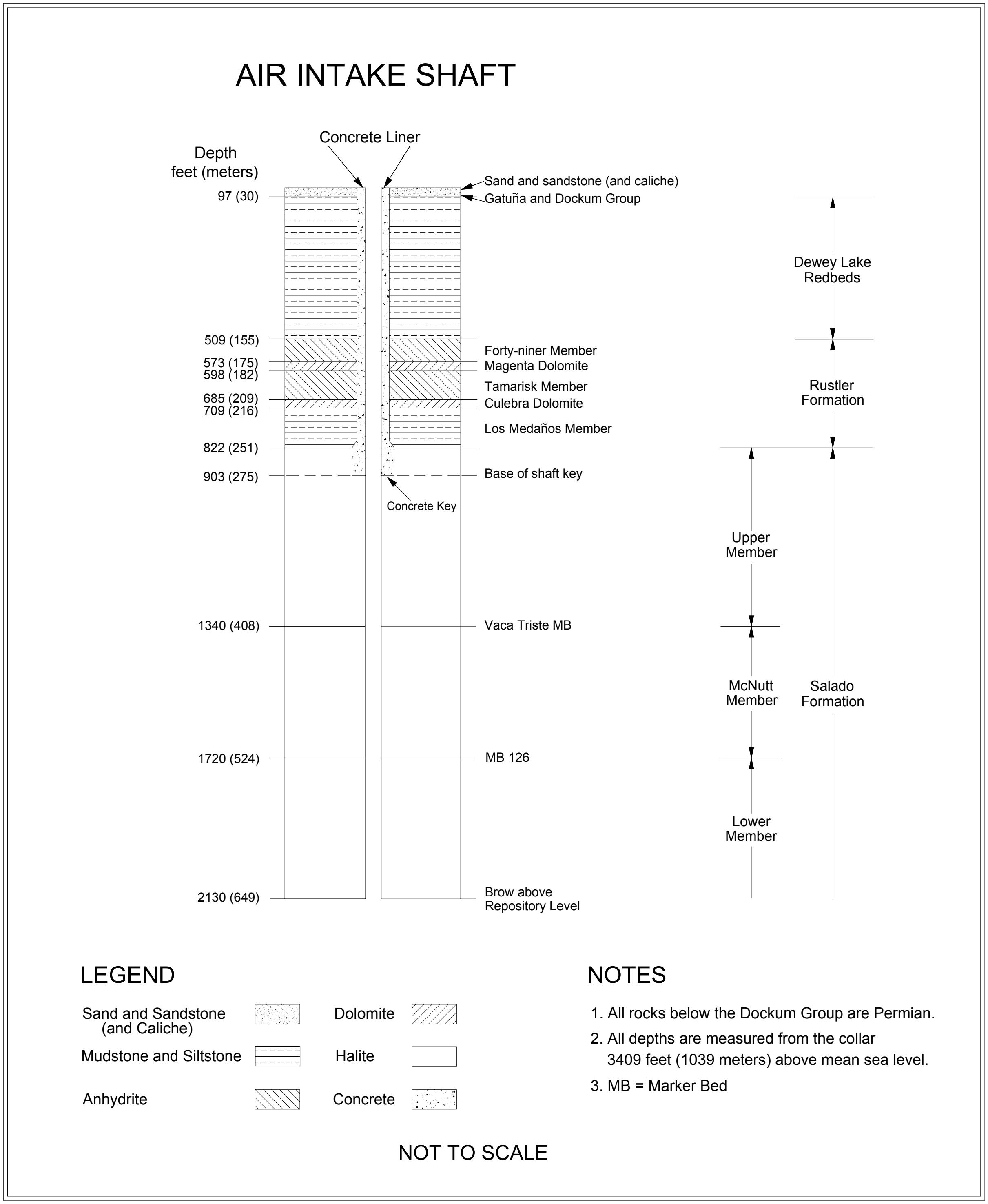


Figure 0-12 – Air Intake Shaft Stratigraphy

This page intentionally left blank.

# 3.0 PERFORMANCE OF SHAFT STATIONS

This chapter describes the instrumentation and geomechanical performance of the shaft stations at the base of the Salt 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.

## 3.1 Salt Shaft Station

The Salt Shaft Station was excavated between May 2 and June 3, 1982, by drilling and blasting. In 1987 the station was enlarged by removing the roof beam up to Anhydrite "b" between S-90 and N-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.

### Modifications to Excavation and Ground Control Activities

No major modifications were performed in the Salt Shaft Station during this reporting period. Ground control was performed as routine maintenance.

### Instrumentation

Geomechanical instrumentation was installed in the Salt 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.

Two extensometers were installed during this reporting period, one 30 ft and the other 60 ft south of the shaft. Four vertical convergence point arrays are currently monitored. Table 4-1 summarizes the vertical closure rates in the Salt Shaft Station from July 2004 through June 2005. Salt Shaft Station vertical closure rates indicate that the rates are decreasing compared to previous reporting periods.

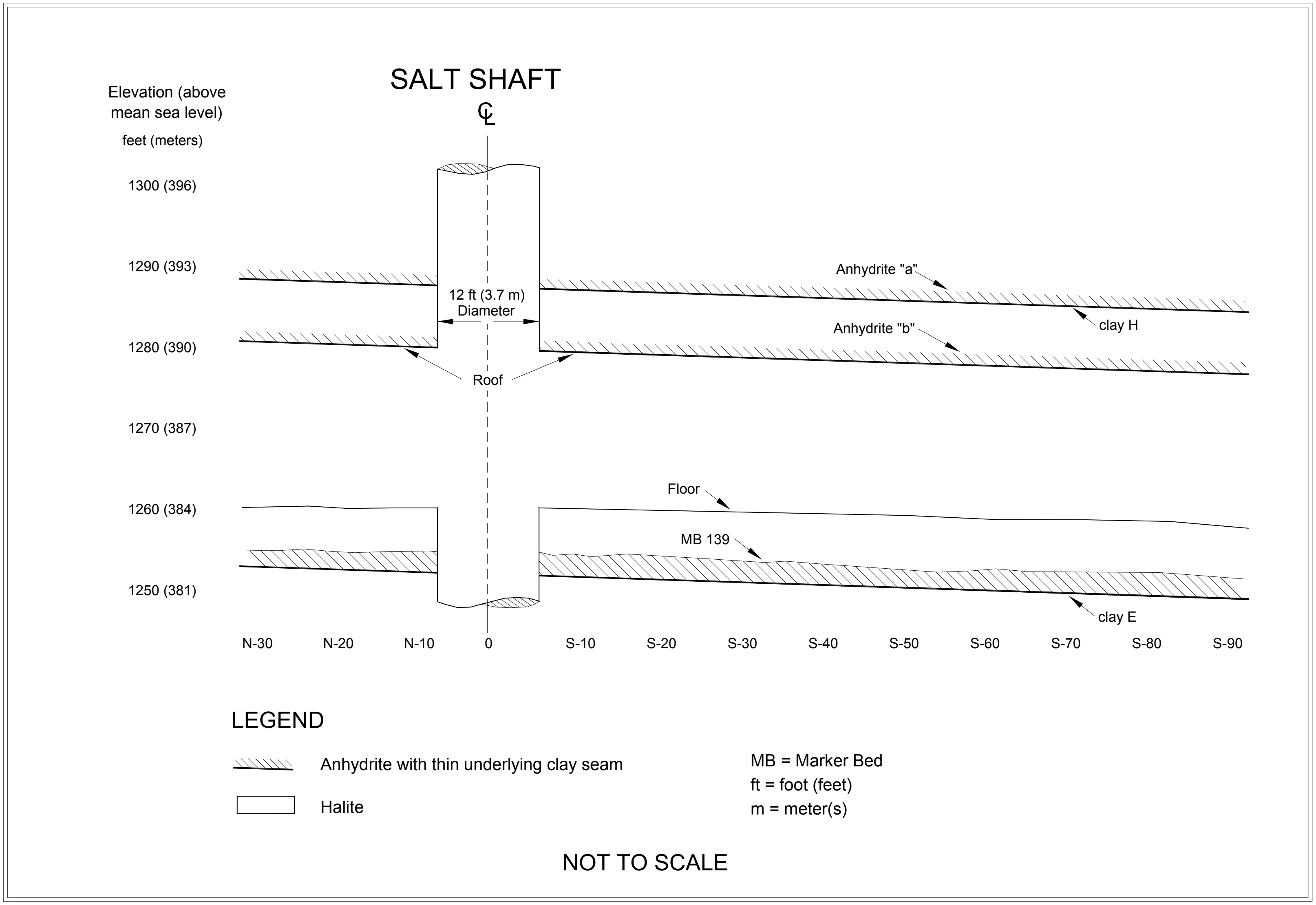


Figure 3-1 – Salt Shaft Station Stratigraphy

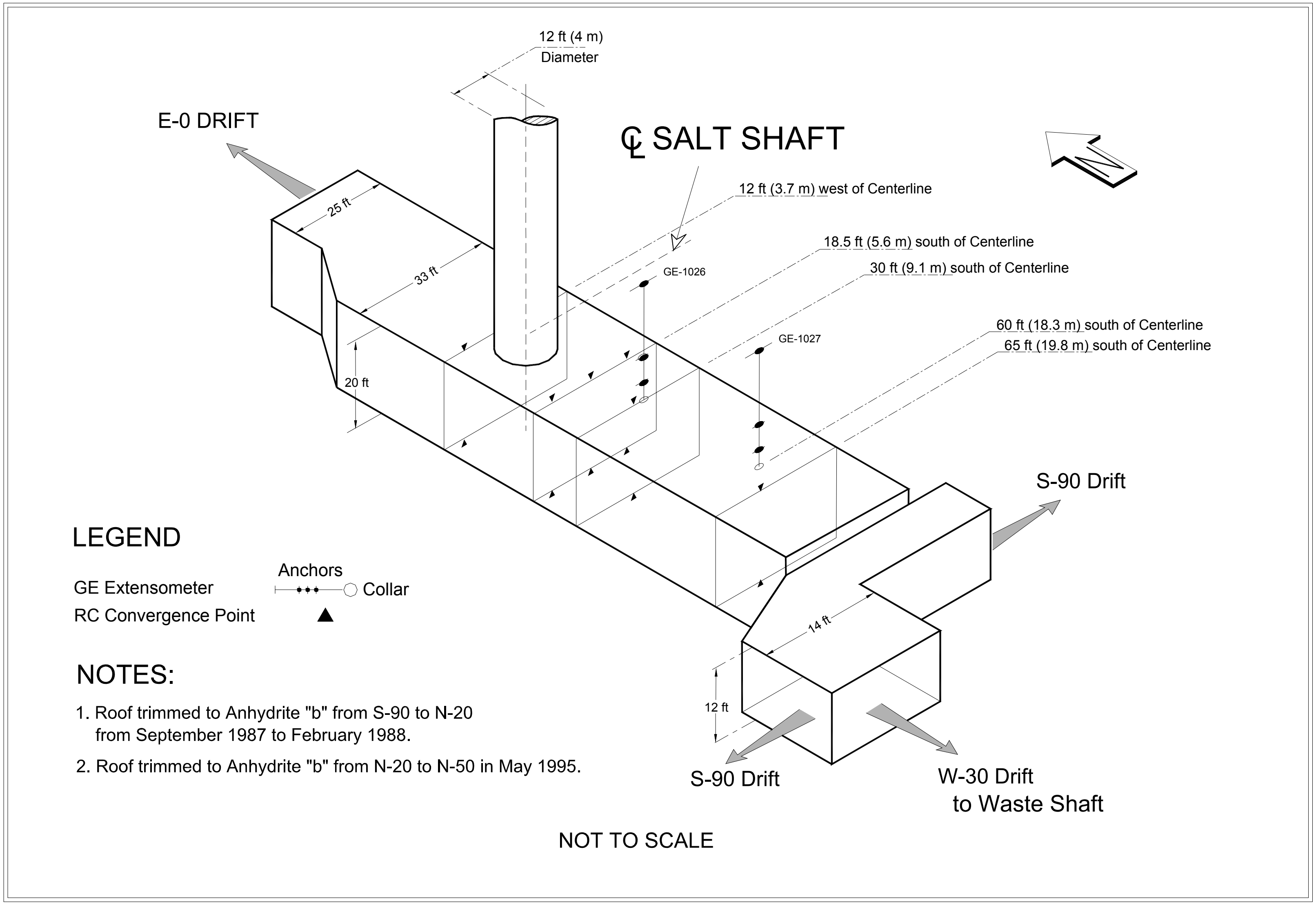


Figure 3-2 – Salt Shaft Station Instrumentation after Roof Beam Excavation

**Table 3-1 – Vertical Closure Rates in the Salt Shaft Station**

| Location | Chord* | Last Reading | Total Cumulative Displacement Inches/(cm.) | Closure Rate 2004 to 2005 in/yr (cm/yr) | Closure Rate 2003 to 2004 in/yr (cm/yr) | Rate Change Percent[a] | Comments |
|---|---|---|---|---|---|---|---|
| E0, W12 | A-C | 6/14/05 | 18.644 (47.356) | 0.70 (1.78) | 0.73 (1.85) | -3% | |
| E0, S18 | A-E | 6/14/05 | 27.842 (70.719) | 1.38 (3.51) | 1.39 (3.53) | -1% | |
| E0, S18 | B-D | 6/14/05 | 28.164 (71.537) | 1.50 (3.81) | 1.50 (3.81) | 0% | |
| E0, S18 | F-H | 6/14/05 | 17.885 (45.428) | 0.93 (2.36) | 0.96 (2.44) | -3% | |
| E0, S30 | A-C | 6/14/05 | 42.359 107.592) | 1.45 (3.68) | 1.47 (3.73) | -2% | |
| E0, S65 | A-C | 6/14/05 | 38.318 (97.328) | 1.07 (2.72) | 1.08 (2.74) | -1% | |

*Chord is defined in "Geotechnical Analysis Report for July 2004–June 2005 Supporting Data."
[a] Increase in convergence rate is calculated from the difference between the 2004–2005 rate and the 2003–2004 rate.

## 3.2 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.

### Modifications to Excavation and Ground Control Activities

No ground control activities were performed in the Waste Shaft Station other than routine roof and rib maintenance and replacement of failed roof bolts.

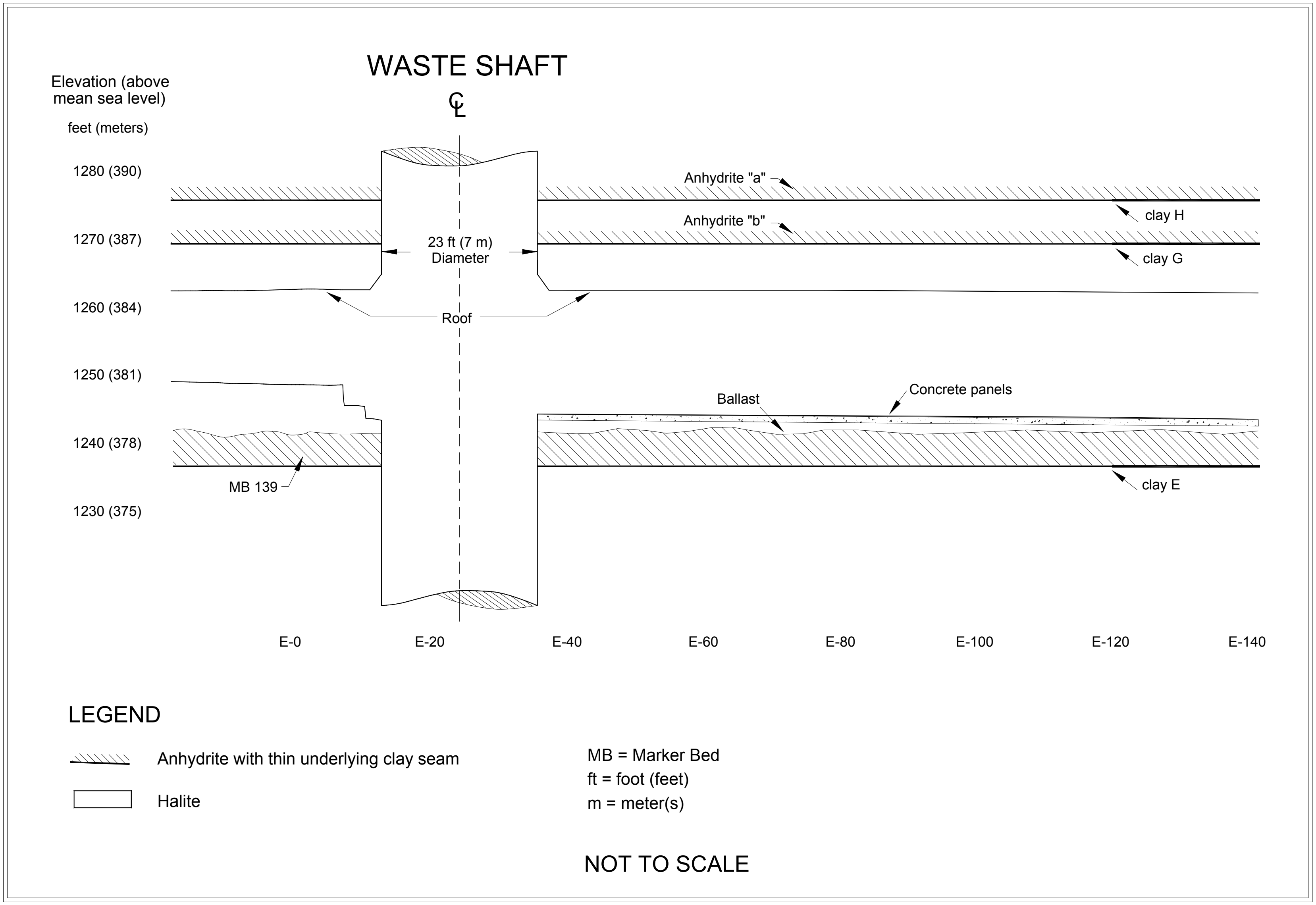


Figure 3-3 – Waste Shaft Station Stratigraphy

### 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. Four extensometers in the Waste Shaft Station are currently being monitored. In addition, horizontal convergence is being monitored at E-30 and E-90.

Table 4-2 summarizes the recent history of the roof extensometers in the Waste Shaft Station. Extensometers 51X-GE-00268 (W-30) and 51X-GE-01025 (E-87) are installed in boreholes drilled into the roof of the station. Extensometers 51X-GE-00356 and 51X-GE-00357 monitor fracture dilation along the shaft wall above the east brow.

**Table 3-2 – Summary of Roof Extensometers in Waste Shaft Station**

| Instrument | Location | Last Reading | Collar Displacement Relative to Deepest Anchor in (cm) | Displacement Rate 2004 to 2005 in/yr (cm/yr) | Displacement Rate 2003 to 2004 in/yr (cm/yr) | Rate Change Percent [a] | Comments |
|---|---|---|---|---|---|---|---|
| 51X-GE-00268 | S400, W30 | 6/28/05 | 8.789 (22.324) | 0.25 (0.64) | 0.65 (1.65) | -62% | |
| 51X-GE-00356 | Waste Shaft Brow | 6/27/05 | 0.092 (0.234) | 0.06 (0.15) | 0.05 (0.13) | 36% | |
| 51X-GE-00357 | Waste Shaft Brow | 6/27/05 | 0.134 (0.340) | 0.13 (0.33) | N/A | N/A | Re-installation |
| 51X-GE-01025 | S400, E87 | 6/30/05 | 0.760 (1.930) | 0.52 (1.32) | 0.53 (1.35) | -2% | |

[a] Change is calculated from the difference between the 2004–2005 rate and the 2003–2004 rate.

Table 4-3 summarizes the annual horizontal closure rates calculated from convergence point data for this reporting period. The data indicate a decrease in the horizontal closure rate at E-30 of -4.0 percent and a decrease at E-90 of -8.0 percent, respectively, relative to the previous annual closure rates.

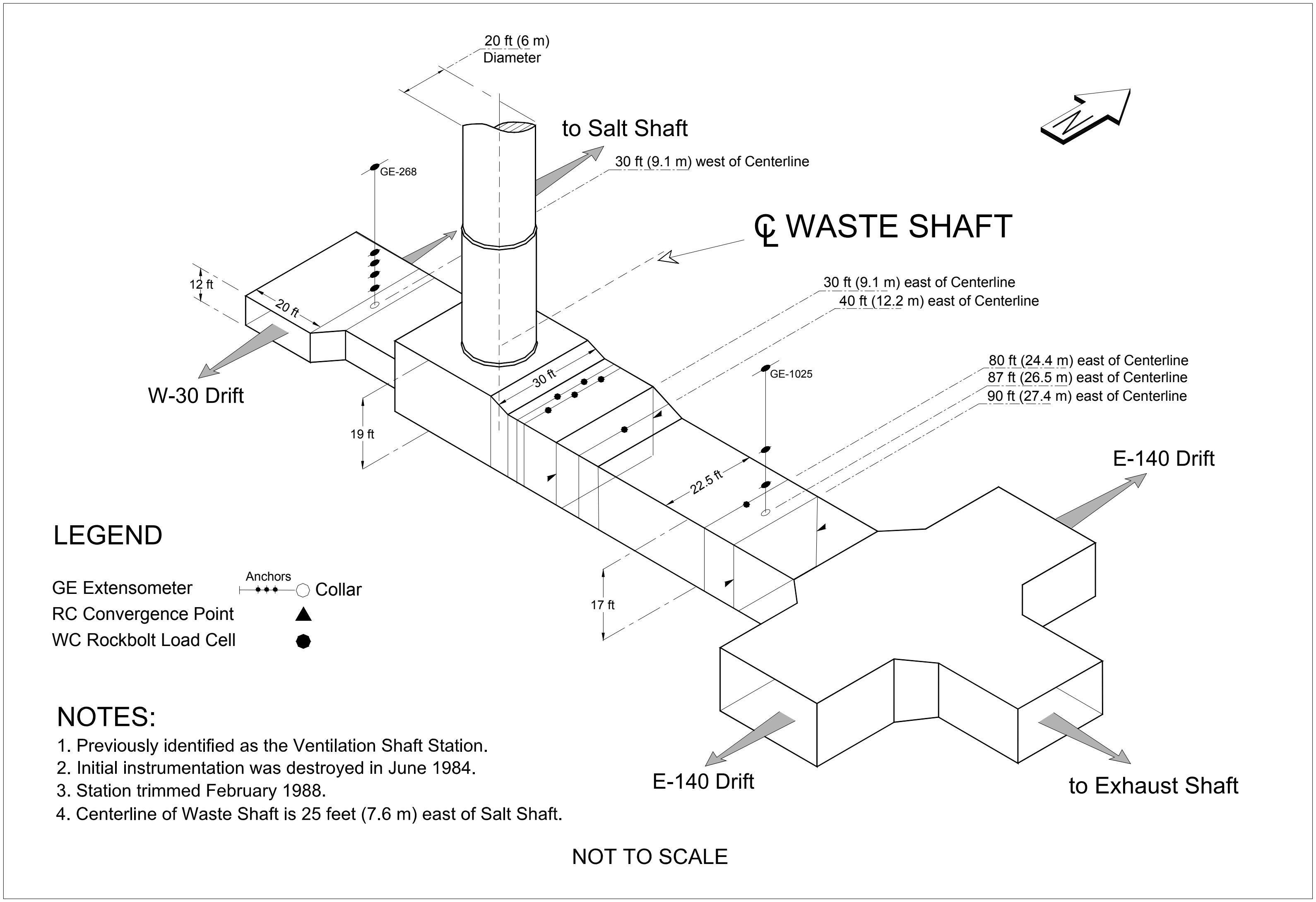


Figure 3-4 – Waste Shaft Station Instrumentation after Wall Trimming

Eighteen rock bolt load cells are installed in the roof and brow of the Waste Shaft Station. The loads on 12 of these rock bolt load cells are monitored regularly. Ten load cells are used to monitor loading on the brow cable support anchor shoes. Load cells at E-40 and E-80 are used to monitor the performance of the threaded bar anchorage.

**Table 3-3 – Horizontal Closure Rates in the Waste Shaft Station**

| Location | Chord* | Last Reading | Total Cumulative Displacement Inches (cm.) | Closure Rate 2004to 2005 in/yr (cm/yr) | Closure Rate 2003 to 2004 in/yr (cm/yr) | Rate change Percent [a] | Comments |
|---|---|---|---|---|---|---|---|
| S400, E30 | C-H | 6/30/05 | 17.554 (44.587) | 0.81 (2.06) | 0.84 (2.13) | -4% | |
| S400, E90 | C-G | 6/30/05 | 20.071 (50.980) | 0.89 (2.26) | 0.97 (2.46) | -8% | |

*Chord is defined in "Geotechnical Analysis Report for July 2004–June 2005 Supporting Data."
[a] Increase in convergence rate is calculated from the difference between the 2004–2005 rate and the 2003–2004 rate.

## 3.3 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 is not normally used to transport personnel or materials, but it does have a work platform and a small cage that can be raised and lowered to perform routine ground maintenance. There is minimal operational activity at the Air Intake Shaft Station.

### Modifications to Excavation and Ground Control Activities

No ground control activities were performed in the Air Intake Shaft Station other than routine roof and rib maintenance and replacement of failed roof bolts.

### Instrumentation

Radial convergence point and extensometer instrumentation data near the Air Intake Shaft Station are 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.

# 4.0 PERFORMANCE OF ACCESS DRIFTS

This chapter describes the geomechanical performance of the central underground access drifts. The Waste Disposal Area is discussed in Chapter 6.0. Four major north-south drifts in the WIPP underground are intersected by shorter east-west cross-drifts. Drift dimensions range from 8 ft (2.4 m) to 21 ft (6.4 m) high and from 14 ft (4.3 m) to 33 ft (9.2 m) wide.

## 4.1 Modifications to Excavation and Ground Control Activities

Access drifts into Panel 4 were completed during this reporting period. Trimming, scaling, and floor milling activities were performed as necessary in many areas. Table 5-1 summarizes these activities. It also summarizes ground control activities (e.g., rock bolting and installing wire mesh) in various locations in the access drifts.

## 4.2 Instrumentation

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

### Borehole Extensometers

Four new extensometers were installed during this reporting period in E-140 and the E-300 Northern Experimental Area. All operating underground extensometers continue to be monitored. Forty-five borehole extensometers continue to be monitored.

### Convergence Points

Figure 5-1 shows typical convergence point array configurations. Instrumentation installed during this reporting period was limited to the replacement of convergence point arrays in previously mined areas and the installation of new monitoring arrays in the newly mined areas. New and replacement convergence points were installed in 58 locations throughout the WIPP underground access drifts because of mining and trimming activities. Horizontal and vertical convergence point arrays were installed at various locations. Most of these installations were located in the southern access 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 4-1 – Summary of Modifications and Ground Control Activities in the Access Drifts July 1, 2004, through June 30, 2005**

| Location | Work Activity |
|---|---|
| E0 Drift | Trimmed floor between N940 Alcove and N1100.<br><br>Trimmed floor between N780 and N1100. |
| | |
| E300 Experimental Area (N-1100 – N1400) | Drilled instrumentation and observation boreholes.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh.<br><br>Trimmed ribs.<br><br>Trimmed floor, backfilled with salt and leveled. |
| | |
| E300 Drift | Installed 4-ft mechanically anchored bolts and chain-link mesh from S3310 to S3650.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from S2750 to S3080.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from S3080 to S3310. |
| | |
| E140 Drift | Installed 4-ft mechanically anchored bolts and chain-link mesh from N780 to N1100.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh on ribs between N1100 and N1400.<br><br>Installed 12-ft resin-anchored bolts and roof mats north and south of the S1775 truck pass.<br><br>Installed 10-ft mechanically anchored bolts from S400 to S90.<br><br>Installed 12-ft resin-anchored bolts and roof mats from S2750 to S3080.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from S3310 to S3650.<br><br>Drilled 20-ft deep observation holes between S1000 and S3080.<br><br>Localized trimming at the N-150 Overcast airlock.<br><br>Installed 12-ft resin-anchored bolts, chain-link, and roof mats between S90 and Substation #2.<br><br>Mined the roof beam between S3310 and S3650.<br><br>Trimmed ribs between S3310 and S3650.<br><br>Trimmed floor between S400 and S90.<br><br>Trimmed floor between S700 and S1000. |

**Table 4-1 – Summary of Modifications and Ground Control Activities in the Access Drifts July 1, 2004, through June 30, 2005**

| | |
|---|---|
| | Trimmed floor between S1950 and S2520.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh between S90 and N250. |
| | |
| W30 Drift | Completed initial mining between S3310 and S3650.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from S3310 to S3650. |
| | |
| W170 | Completed initial mining between S3310 and S3650.<br><br>Installed 12-ft resin-anchored bolts and roof mats in the S2900 truck pass.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from S3310 to S3650.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from S2520 to S2750. |
| | |
| N1400 | Installed 4-ft mechanically anchored bolts and chain-link mesh. |
| | |
| N940 | Installed 4-ft mechanically anchored bolts and chain-link mesh in N940 Alcove. |
| | |
| N780 | Installed 12-ft resin-anchored bolts in N780 Alcove. |
| | |
| N460 | Installed 12-ft resin-anchored bolts in N460 Alcove. |
| | |
| S400 | Installed 4-ft mechanically anchored bolts and chain-link mesh along the rib line west of W-170. |
| | |
| S700 | Installed 12-ft resin-anchored bolts from W30 to W170.<br><br>Trimmed the roof-rib juncture between E140 and E300.<br><br>Drilled 28-ft deep, 30 in-diameter borehole for RH emplacement demonstration activities.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh on ribs from E140 to E300. |
| | |
| S1000 | Installed 12-ft resin-anchored bolts from W30 to W170.<br><br>Installed 12-ft resin-anchored bolts from E140 to W30. |
| | |
| S2180 | Installed 4-ft mechanically anchored bolts and chain-link mesh in the E300 – S2180 intersection. |
| | |
| S2750 | Installed 4-ft mechanically anchored bolts and chain-link mesh from E300 to W170. |

**Table 4-1 – Summary of Modifications and Ground Control Activities in the Access Drifts July 1, 2004, through June 30, 2005**

| | |
|---|---|
| S3080 | Installed 4-ft mechanically anchored bolts and chain-link mesh along the miters at the S3080-E140 intersection. |
| | |
| S3310 | Trimmed floor between W30 and W170. |
| | |
| S3650 | Mined initial excavation between E140 and E300.<br><br>Installed 4-ft mechanically anchored bolts and chain-link mesh from E300 to W170. |

**Table 4-2 – New and Replaced Convergence Points Installed in the Access Drifts July 1, 2004, through June 30, 2005**

| Location | N/R | Field Tag[#] | Chord[*] | Date Installed |
|---|---|---|---|---|
| E140, S2998 | R | E140-S2998-2 | A-C (Vertical) | 7/1/2004 |
| E140, S2915 | R | E140-S2915-2 | A-C (Vertical) | 7/1/2004 |
| E140, S2833 | R | E140-S2833-2 | A-C (Vertical) | 7/1/2004 |
| E140, S2750 | R | E140-S2750-2 | A-C (Vertical) | 7/1/2004 |
| S3080, E220 | R | S3080-E220 | A-C (Vertical) | 7/1/2004 |
| N215, W620 | R | N215-W620-2 | A-C (Vertical) | 7/15/2004 |
| W30, S250 | R | W30-S250-4 | A-C (Vertical) | 8/12/2004 |
| N1420, E140 | R | N1420-E140-2 | A-C (Vertical) | 10/7/2004 |
| E140, N1266 | R | E140-N1266-3 | A-C (Vertical) | 10/7/2004 |
| E140, N1266 | R | E140-N1266-4 | A-C (Vertical) | 10/7/2004 |
| N1100, E140 | R | N1100-E140-2 | A-C (Vertical) | 10/7/2004 |
| E140, N940 | R | E140-N940-2 | A-C (Vertical) | 10/7/2004 |
| E140, N940 | R | E140-N940-2 | B-D (Horizontal) | 10/7/2004 |
| E0, N940 | R | E0-N940-5 | A-C (Vertical) | 1/5/2005 |
| E0, N1110 | R | E0-N1110-5 | A-C (Vertical) | 1/5/2005 |
| E140, S2425 | R | E140-S2425-3 | A-C (Vertical) | 1/13/2005 |
| E140, S2350 | R | E140-S2350-4 | A-C (Vertical) | 1/13/2005 |
| E140, S2275 | R | E140-S2275-3 | A-C (Vertical) | 1/13/2005 |
| E140, S2180 | R | E140-S2180-5 | A-C (Vertical) | 1/13/2005 |
| E140, S2007 | R | E140-S2007-5 | A-C (Vertical) | 1/13/2005 |
| E140, S700 | R | E140-S700-5 | E-F (Vertical) | 1/19/2005 |
| E140, S700 | R | E140-S700-5 | B-C (Vertical) | 1/19/2005 |
| E140, S700 | R | E140-S700-6 | A-D (Vertical) | 1/19/2005 |
| E140, S850 | R | E140-S850-8 | A-C (Vertical) | 1/19/2005 |
| S1000, E160 | R | S1000-E160-2 | A-C (Vertical) | 1/19/2005 |
| E140, S1000 | R | E140-S1000-2 | A-C (Vertical) | 1/19/2005 |
| S1000, E120 | R | S1000-E120-3 | A-C (Vertical) | 1/19/2005 |
| E140, S1025 | R | E140-S1025-3 | A-C (Vertical) | 1/19/2005 |
| E140, S1075 | R | E140-S1075-3 | F-H (Vertical) | 1/19/2005 |
| E140, S1075 | R | E140-S1075-3 | A-E (Vertical) | 1/19/2005 |
| E140, S1075 | R | E140-S1075-3 | B-D (Horizontal) | 1/19/2005 |
| E140, S1150 | R | E140-S1150-4 | L-H (Vertical) | 1/19/2005 |
| E140, S1150 | R | E140-S1150-3 | A-G (Vertical) | 1/19/2005 |
| E140, S1150 | R | E140-S1150-3 | B-F (Vertical) | 1/19/2005 |
| E140, S1225 | R | E140-S1225-3 | A-E (Vertical) | 1/19/2005 |

| Table 4-2 – New and Replaced Convergence Points Installed in the Access Drifts July 1, 2004, through June 30, 2005 | | | | |
|---|---|---|---|---|
| E140, S2065 | R | E140-S2065-4 | A-C (Vertical) | 1/18/2005 |
| N1420, E0 | R | N1420-E0-2 | A-C (Vertical) | 1/31/2005 |
| E140, S262 | R | E140-S262-4 | A-C (Vertical) | 2/16/2005 |
| E300, N1341 | R | E300-N1341-2 | A-C (Vertical) | 2/18/2005 |
| E300, N1186 | R | E300-N1186-2 | A-C (Vertical) | 2/24/2005 |
| E300, N1262 | R | E300-N1262-2 | A-C (Vertical) | 2/23/2005 |
| S90, W400 | R | S90-W400-2 | A-C (Vertical) | 3/4/2005 |
| S90, W590 | R | S90-W590-2 | A-C (Vertical) | 3/4/2005 |
| S1000, E58 | R | S1000-E58-4 | A-C (Vertical) | 3/4/2005 |
| E140, S3480 | N | E140-S3480 | A-C (Vertical) | 4/19/2005 |
| S700, W98 | R | S700-W98-2 | A-C (Vertical) | 4/28/2005 |
| E140, S3395 | N | E140-S3395 | A-C (Vertical) | 4/21/2005 |
| E140, S3395 | N | E140-S3395 | B-D (Horizontal) | 4/21/2005 |
| E140, S3480 | N | E140-S3480 | B-D (Horizontal) | 4/21/2005 |
| E140, S3565 | N | E140-S3565 | A-C (Vertical) | 4/21/2005 |
| S700, W98 | R | S700-W98-2 | A-C (vertical) | 4/28/2005 |
| E140, N5-5 | R | E140-N5-5 | A-C (Vertical) | 5/9/2005 |
| W30, S3395 | N | W30-S3395 | A-C (Vertical) | 5/13/2005 |
| W30, S3395 | N | W30-S3395 | B-D (Horizontal) | 5/13/2005 |
| W30,S3480 | N | W30-S3480 | A-C (Vertical) | 5/13/2005 |
| W30, S3480 | N | W30-S3480 | B-D (Horizontal) | 5/13/2005 |
| W30, S3565 | N | W30-S3565 | A-C (Vertical) | 5/13/2005 |
| W30, S3565 | N | W30-S3565 | B-D (Horizontal) | 5/13/2005 |
| E140, S3565 | N | E140-S3565 | B-D (Horizontal) | 6/10/2005 |

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 2004–June 2005 Supporting Data"
*Chord configuration is defined in "Geotechnical Analysis Report for July 2004–June 2005 Supporting Data" and Figure 5-1.

## 4.3 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, except when convergence points are not accessible. Convergence rates and extensometer displacement rates 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 or may be the response to nearby mining.

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

[5] Instrumentation data and data plots are presented in "Geotechnical Analysis Report for July 2004–June 2005 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.

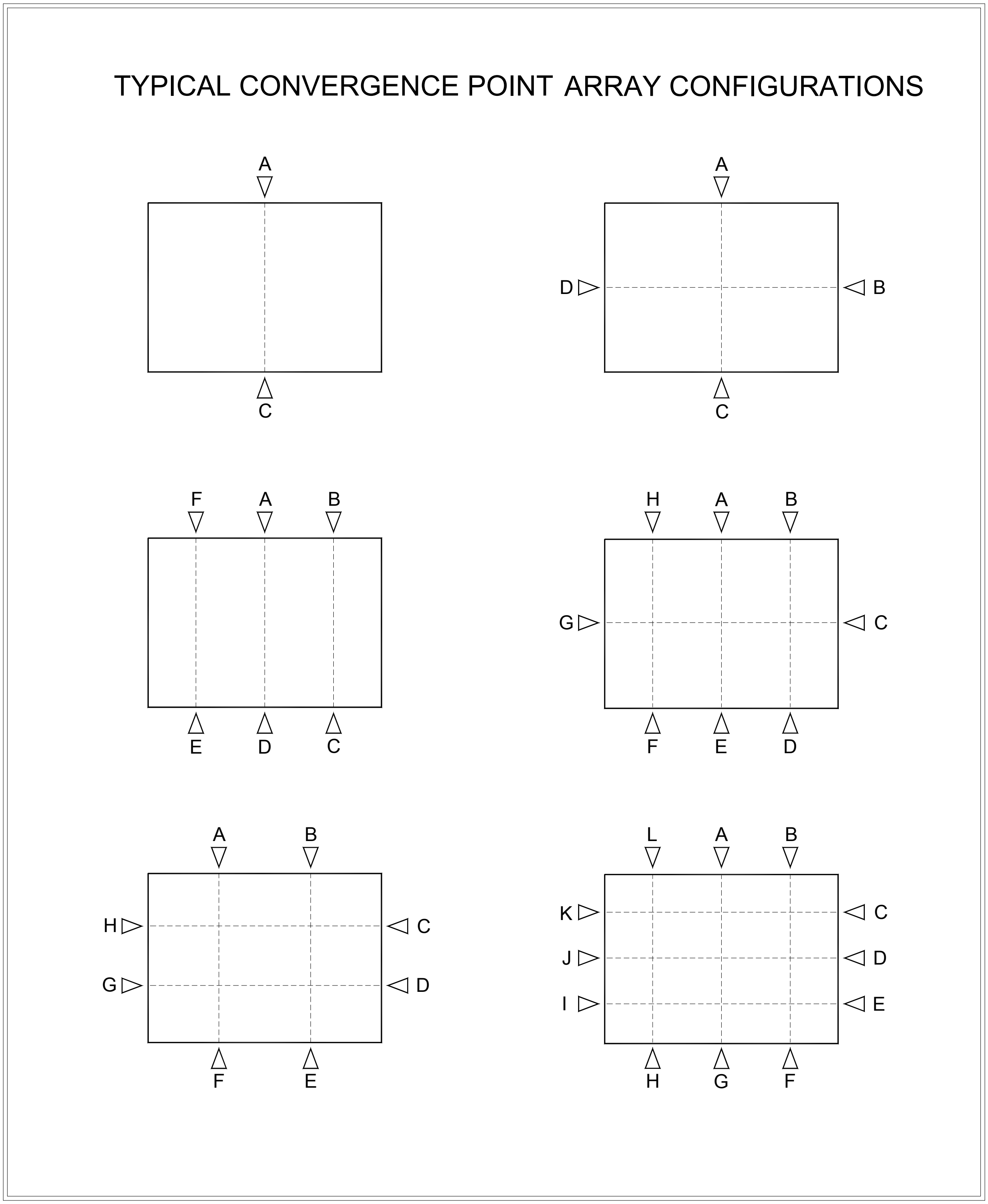


Figure 4-1 – Typical Convergence Point Array Configurations Showing Anchor Designations

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 the difference by the time between the two readings (in years). Instruments that indicate acceleration are analyzed to determine the significance of the acceleration. Factors considered during the analysis include magnitude of the respective rates, percentage increase, convergence history, and any recent excavation in the vicinity.

More than fifty active borehole extensometers were being monitored at various locations in the access drifts. Where displacement data were available, annual displacement rates were calculated for each active installation and compared to the annual displacement rates from the previous reporting period. Approximately fifty percent of the instruments are installed in the E-140 drift to monitor the waste transport route. Most of these extensometers exhibit an increase in deformation rates. The increased movement in the E-140 roof rates may also be attributed to local fracturing and the effects of anhydrite stringer separations in the roof. Although the borehole extensometer data indicate continued deformation and breakup of the lower beam, the roof beam above Clay H remains competent.

Further analysis of the convergence rate accelerations has shown many of them to be relatively insignificant. Other areas, such as the southern portions of the access drifts, had closure rate increases that can be directly attributed to the mining of Panel 3 and the associated access drifts.

Closure rates have increased in various locations by more than ten percent since the last reporting period. Most of these locations are in the E-140 drift. Increased closure rates were observed in E-140 from S-700 to S-1000 and from S-1687 to S-2065. The increased rates from S-700 to S-1000 are probably caused by a combination of the effects of floor trimming and continued ageing and deterioration of the roof beam.

The closure rates observed in E-140 from S-1687 to S-2065 are in an area where the roof beam has been mined to Clay G. The rate of increase in this area may be attributed to roof beam separations formed along shallow anhydrite stringers in the roof. These separations result in the formation of thin roof beams that can easily be deformed toward the opening. Tensile fractures generally develop on the roof surface in areas of maximum deformation.

The rate increases observed in other areas may be attributable to various reasons. The effect of nearby mining and trimming appears to have caused the rate increases at W170/S-3310 and S-3310/W-100. Field observations in these areas do not indicate any significant deterioration that may have caused these increases.

**Table 4-3 – Greater than 10 Percent Increases in Annual Vertical Convergence Rates in the Access Drifts**

| Location | Chord* | Last Reading | Total Cumulative Displacement Inches/(cm.) | Closure Rate 2004 to 2005 in/yr (cm/yr) | Closure Rate 2003 to 2004 in/yr (cm/yr) | Rate Change Percent [a] | Comments |
|---|---|---|---|---|---|---|---|
| E300, S2998 | A-C | 06/1/2005 | 12.379 (31.443) | 5.71 (14.5) | 4.94 (12.55) | 16 | |
| E140, S700 | A-D | 5/31/2005 | 22.143 (56.243) | 1.78 (4.52) | 1.09 (2.77) | 63 | |
| E140, S700 | E-F | 5/31/2005 | 15.753 (40.013) | 1.25 (3.18) | 0.8 (2.03) | 56 | |
| E140, S850 | A-C | 5/31/2005 | 40.032 (101.681) | 2.46 (6.25) | 1.75 (4.45) | 41 | |
| E140, S1000 | A-C | 5/31/2005 | 27.511 (69.878) | 1.65 (4.19) | 1.06 (2.69) | 56 | |
| E140, S1687 | A-E | 6/23/2005 | 20.979 (53.287) | 3.26 (8.28) | 2.79 (7.09) | 17 | |
| E140, S1862 | A-E | 6/23/2005 | 22.665 (57.569) | 4.42 (11.23) | 3.86 (9.8) | 15 | |
| E140, S1862 | B-D | 6/23/2005 | 20.948 (53.208) | 3.61 (9.17) | 3.05 (7.75) | 18 | |
| E140, S2065 | A-C | 6/23/2005 | 19.526 (49.596) | 3.6 (9.14) | 2.87 (7.29) | 25 | |
| E0, N1266 | A-C | 6/14/2005 | 40.945 (104) | 2.28 (5.79) | 2.02 (5.13) | 13 | |
| E0, N940 | A-C | 6/14/2005 | 41.826 (106.238) | 2.51 (6.38) | 2.19 (5.56) | 15 | |
| E0, N290 | A-C | 6/14/2005 | 41.691 (105.895) | 1.5 (3.81) | 1.16 (2.95) | 29 | |
| W170, S232 | A-C | 6/21/2005 | 8.358 (21.229) | 0.65 (1.65) | 0.56 (1.42) | 16 | |
| W170, S3310 | A-C | 5/31/2005 | 4.16 (10.566) | 1.94 (4.93) | 1.45 (3.68) | 34 | |
| S1000, E160 | A-C | 6/28/2005 | 6.293 (15.984) | 0.81 (2.06) | 0.69 (1.75) | 17 | |
| S3310, W100 | A-C | 06/1/2005 | 4.536 (11.521) | 1.99 (5.05) | 1.77 (4.5) | 12 | |

*Chord is defined in "Geotechnical Analysis Report for July 2004–June 2005 Supporting Data."
[a] Increase in convergence rate is calculated from the difference between the 2004–2005 rate and the 2003–2004 rate.

## 4.4 Excavation Performance

Approximately 500 readings are collected and assessed regularly from convergence point arrays throughout the WIPP underground. Convergence rates continue to vary seasonally, typically increasing during the warmer and more humid summer months and decreasing during the cooler and drier winter months.

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

## 5.0 PERFORMANCE OF WASTE DISPOSAL AREA

The Waste Disposal Area as of June 30, 2005, consists of Panels 1, 2, 3, and 4. Panel 1 is closed. Panel 2 and 3 are currently being used for waste disposal, with Rooms 2, 3, 4, 5, 6 and 7 of Panel 2 filled and closed. Panel 4 mining is ongoing as shown in Figure 1-2.

### 5.1 History

Excavation of the Panel 1 waste disposal area began in May 1986 with the mining of the access entries. 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. Four short access drifts designed to lead to smaller test alcoves were excavated north off the S-1600 drift and Rooms 4-7 in June 1989. Only the access drifts to the alcoves were completed; the alcoves themselves were not excavated. Panel 1 waste emplacement (in Rooms 1, 5, 6, 7, and S-1950) is complete, and the panel is closed to all access. The Panel 1 access entries, S-1600 and S-1950, which extend from the E-300 drift to the isolation walls, remain open, and the instrumentation in this area will continue to be replaced and monitored.

Excavation of the Panel 2 waste disposal area began in September 1999 with the mining of access entries. 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 Panel 3 waste disposal rooms began in May 2002 with the mining of access entries to Panel 3. As with Panel 2, initially, the disposal rooms and drifts were developed as pilot drifts that were trimmed to finished dimensions. All the rooms were excavated to final dimensions by the end of March 2004.

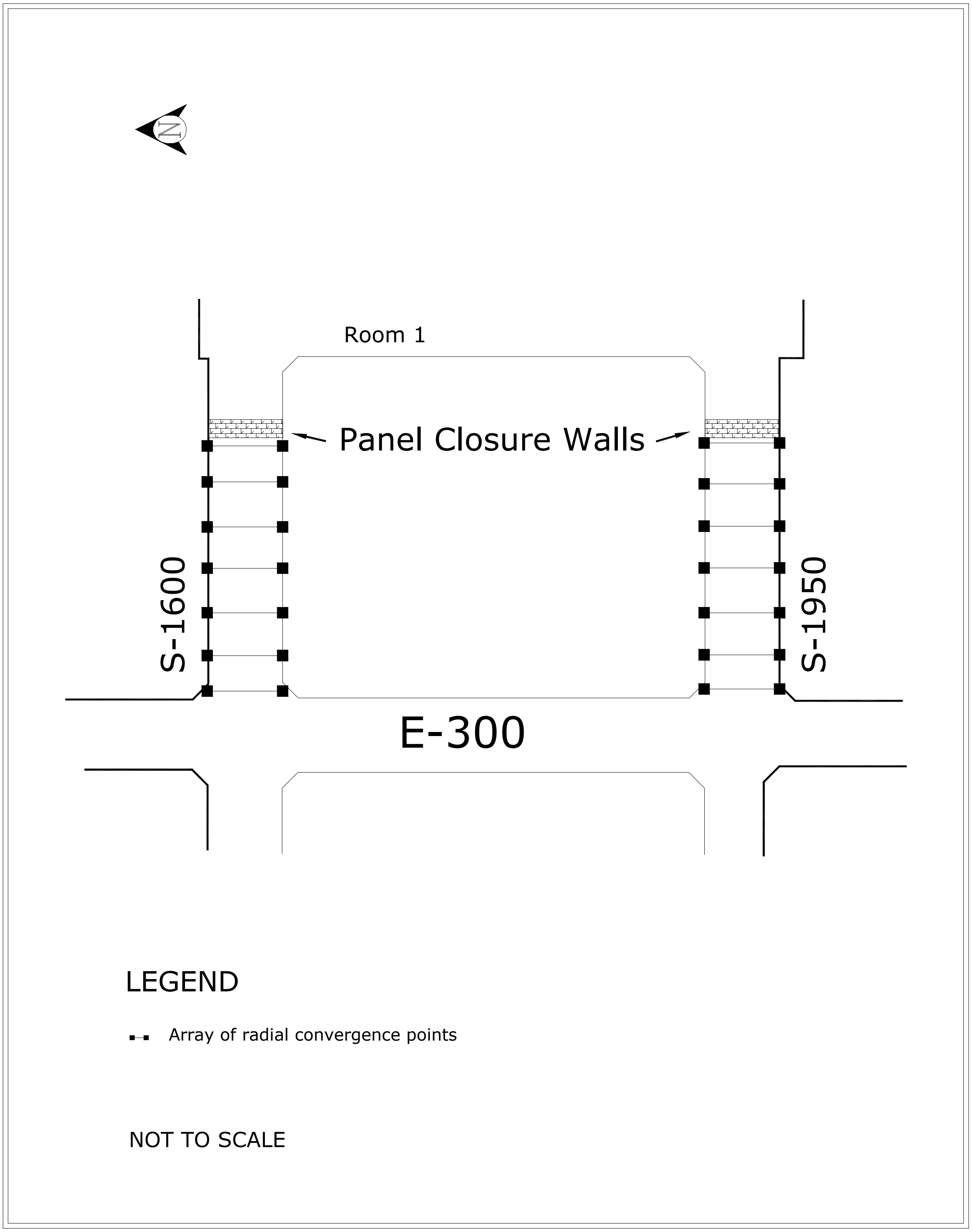


Figure 5-1 – Location of Panel 1 Entry Geotechnical Instruments

## 5.2 Modifications to Excavations and Ground Control Activities

There were no new excavations mined in Panel 2 during the reporting period. Panel 3 mining was completed by the end of March 2004. Mining of Panel 4 was initiated, but not completed during this reporting period. 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 of the disposal panels. The floor was trimmed in Rooms 1 and 2 of Panel 2 and in portions of S-2180 and S-2520 to re-establish the minimum operating height required for waste disposal activities. Supplemental bolts were installed in all Panel 3 rooms and access drifts. Table 6-1 summarizes the ground control activities performed in the disposal panels during this reporting period.

## 5.3 Instrumentation

There were no changes to the Panel 2 instrumentation layout. Monitoring of manually read instruments continued until access was no longer available due to waste disposal. Remote monitoring of the borehole extensometers continued through this reporting period.

The instrumentation of Panel 3 was completed. Convergence points were installed in all of the disposal rooms, intersections, and at selected mid-pillar locations in the access drifts. A borehole extensometer was installed in the roof at each room center. Roof bolt load cells were installed at selected locations throughout the panel.

Instrumentation of the newly mined areas of Panel 4 was initiated. Convergence points were installed in Rooms 1 and 2, and in selected locations in the access drifts. A borehole extensometer and a rock bolt load cell were installed in the roof at the center of Room 1. Figure 6-1 shows the location of the various types of geotechnical instruments in the Panel 1 entries, and Figures 6-2 and 6-3 show the instrumentation layout for Panels 2 and 3.

**Table 5-1 – Summary of Modifications and Ground Control Activities in the Waste Disposal Area from July 1, 2004, to June 30, 2005**

| Location | Work Performed |
|---|---|
| Panel 1 entries, S-1600 and S-1950 | Routine replacement of broken bolts |
| Panel 2, Rooms 1 through 2, S-2180 and S-2520 | Trimmed floor |
| Panel 3, Rooms 4 and 7 | Pattern bolting |
| Panel 3, Rooms 3 and 6 | Installed supplemental ground support |
| Panel 3, S-2750 and S-3080 | Installed supplemental ground support |
| Panel 4, Panel entries, Rooms 1 and 2 | Initial mining complete, Room 1 to full dimensions |
| Panel 4, S-3310 and S-3650 | Initial mining and bolting complete to approximately E-920 |
| Panel 4, Room 1 | Pattern bolting complete |

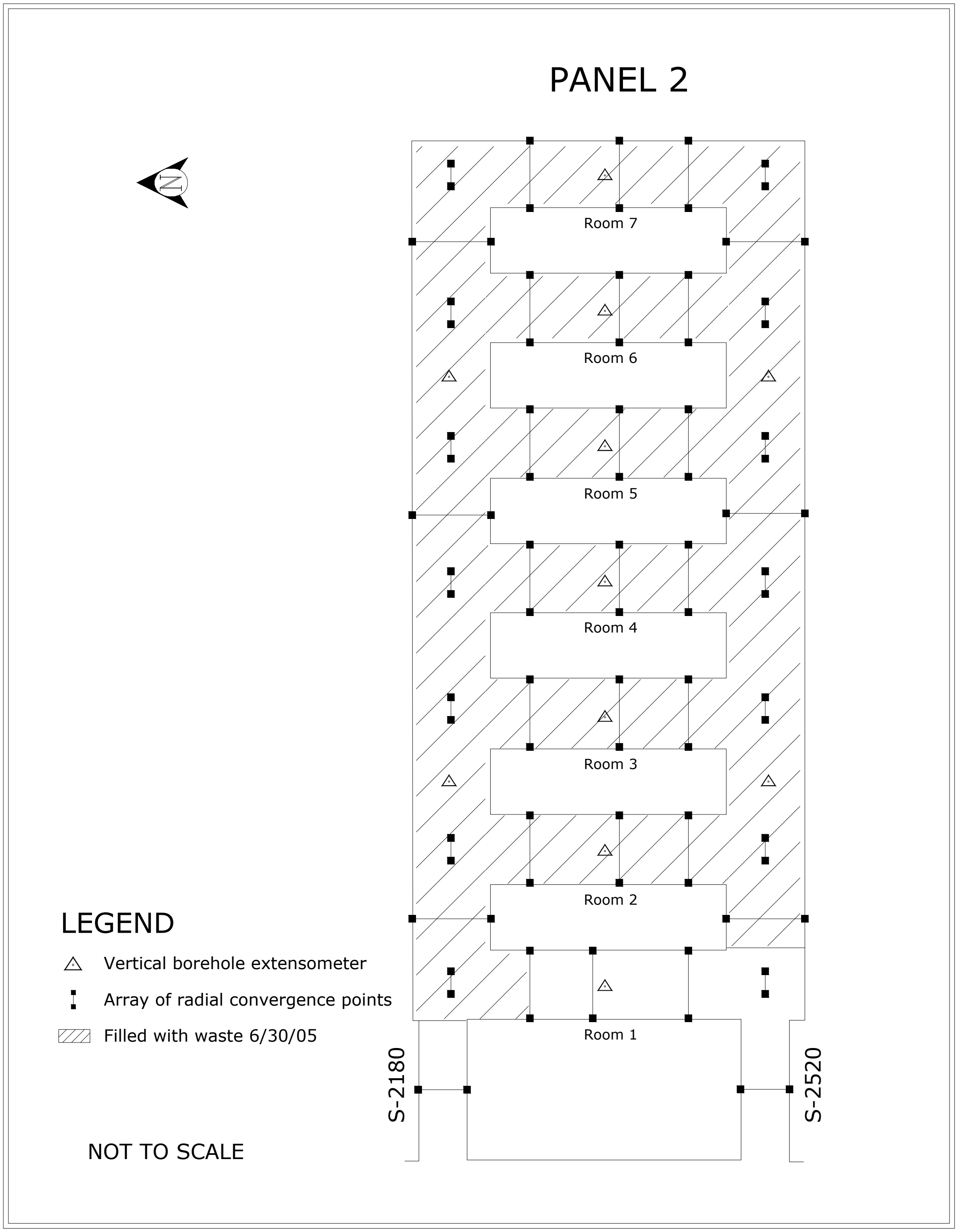


Figure 5-2 – Location of Panel 2 Geotechnical Instruments

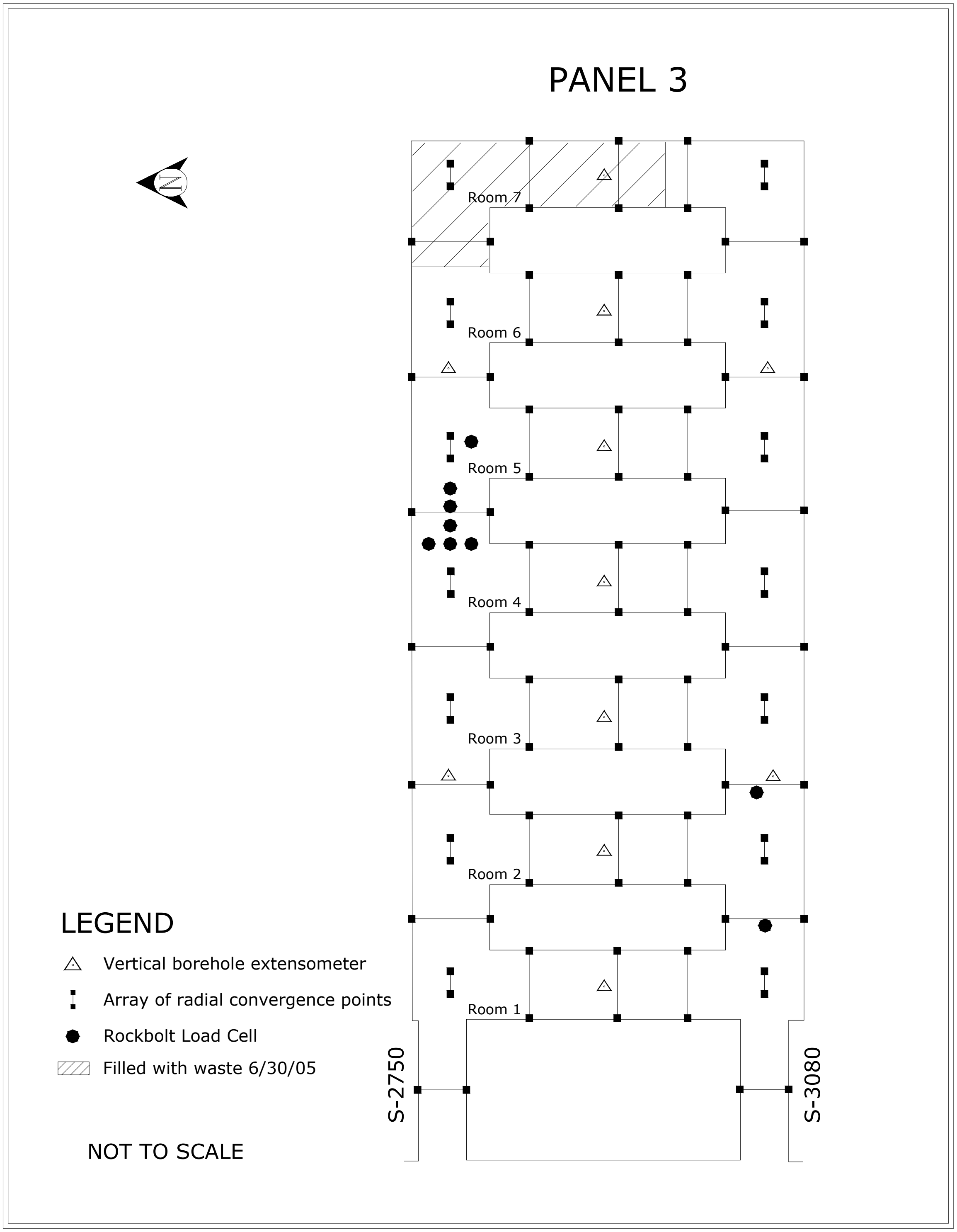


Figure 5-3 – Location of Panel 3 Geotechnical Instruments

## 5.4 Excavation Performance

Waste handling activities in Panel 1 have been completed, and geotechnical monitoring inside the panel has been discontinued. Convergence monitoring in the panel entries does not indicate an acceleration of closure rates; however, fracturing of the roof beam continues. It is anticipated that routine ground control maintenance will be sufficient to maintain access to this area.

Horizontal and vertical convergence rates, calculated at the center of each of the rooms in Panels 2 and 3, were compared between this and the previous reporting period. Generally, the convergence rates have decreased or remained similar. Increased rates observed in some areas are usually associated with areas of roof beam separation and fracturing. This additional convergence was addressed by floor trimming, to regain the required operating height, and by installing supplemental ground support

Panel 4 mining was started during this reporting period. Preliminary monitoring indicates that the early installation of the support system has reduced the generation of near-surface separations similar to those observed in Panel 3.

## 5.5 Analysis of Extensometer and Convergence Point Data

Borehole extensometers are installed in the roof at the center of each disposal room and at select locations in the access drifts of Panels 2 and 3. They show a general decrease in the rate of roof beam deformation. Some of the borehole extensometers in Panel 3 did indicate a temporary increase in rates, associated with roof beam separation at shallow anhydrite stringers. Supplemental ground control support was installed in these areas and has subsequently reduced the observed rates.

Although Panel 1 is closed, convergence monitoring continues in the panel entries between E-300 and the panel closure walls. The monitoring results indicate a steady long-term trend. The lowest closure rates were observed nearest to the rigid masonry walls.

Geotechnical monitoring in Panel 2 indicates near steady state closure since initial mining. Temporary effects, due to floor trimming and Panel 3 mining, were observed in the convergence and borehole extensometer data. The greatest deformations were from the S-2520 access drift, which is nearest to Panel 3.

Convergence rates in Panel 3 are generally decreasing or approaching steady state. The initial effects due to mining decreased significantly, similar to the experience in previous panels; however, subsequent monitoring indicated some areas with increased convergence and roof beam deformation. These areas were associated with excavation of Panel 4 and the development of separations along thin anhydrite stringers, observed in the lower roof beam. The number and continuity of these stringers vary; however, the stringers are commonly observed throughout the panel.

Deformation rates in these areas have stabilized or decreased in response to the installation of ground control.

Panel 4 mining continues with the installation of pattern bolts soon after mining. Panel 4 is being bolted and monitored at an earlier stage in its development than was Panel 3. It appears from early observations that the closure rates are trending to be less than what was observed in the Panel 3. This may be due to the effect of earlier bolting on the development of separation at the anhydrite stringers in the roof beam.

## 6.0 GEOSCIENCE PROGRAM

The Geoscience Program confirms the suitability of the site through the collection of various geologic data and excavation characteristics from the underground. These include the inspection of open boreholes for fractures (separations) and offsets (lateral displacements) in roof beams and the mapping of fracture development on roof surfaces. Data collected through these activities support the design and evaluation of ground support systems.

During this reporting period, the following activities were performed:

- Borehole Inspections
- Fracture Mapping

### 6.1 Borehole Inspections

Geotechnical observation boreholes are drilled at various locations throughout the underground facility. A location may contain one or more 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 extend up past clays "G" and "H" (Figures 7-1 and 7-2).

The clay seams nearest the excavation surfaces define the immediate roof beam. The roof beam is bounded by clay "G" in most of the access drifts and Panels 1 and 2. Some areas, such as the Salt Shaft Station, portions of the E-0 and E-140 drifts, the south mains south of S-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 move toward the center of the excavation (Figures 7-3 and 7-4). 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 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 inside 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. In addition, during this reporting period, the use of a borehole camera has been introduced in conjunction with the scratch rod.

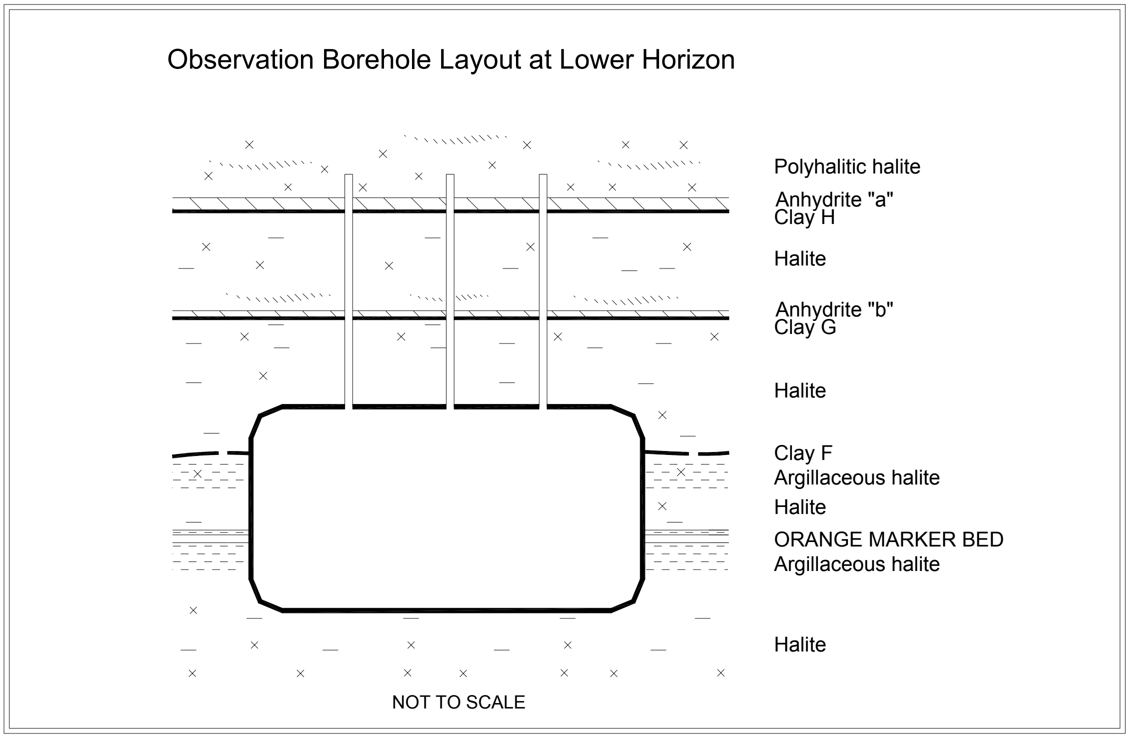


Figure 6-1 – Example of Observation Borehole Layout at Lower Horizon

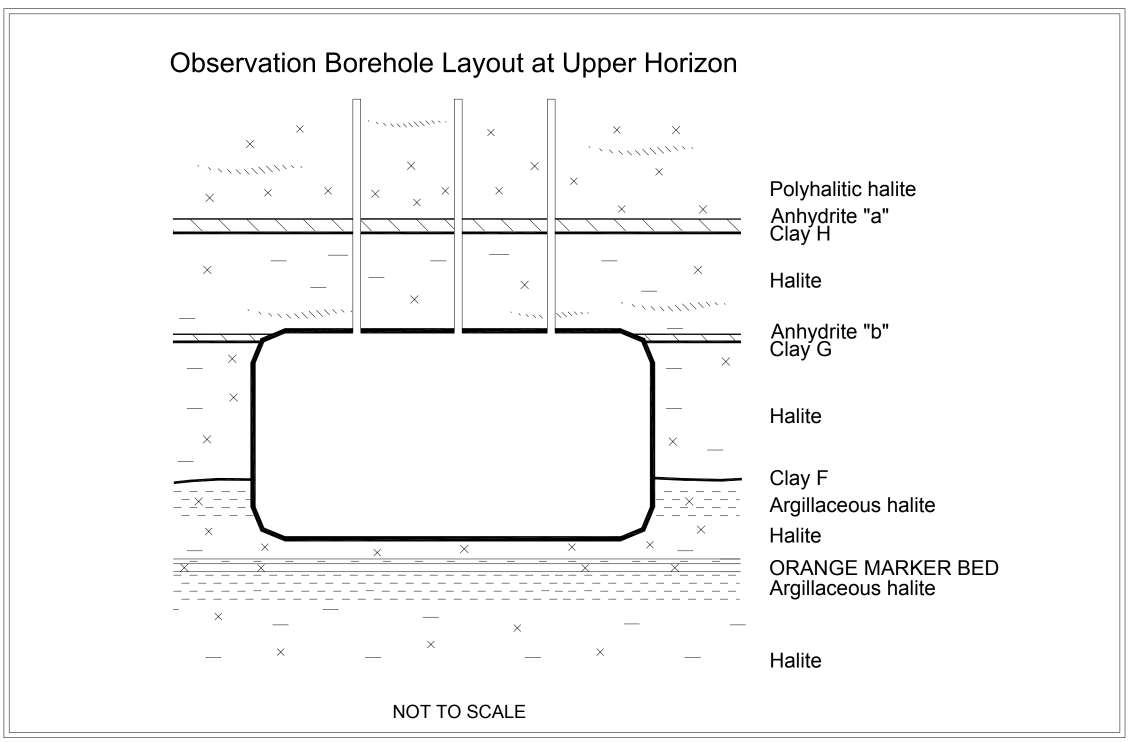


Figure 6-2 – Example of Observation Borehole Layout at Upper Horizon

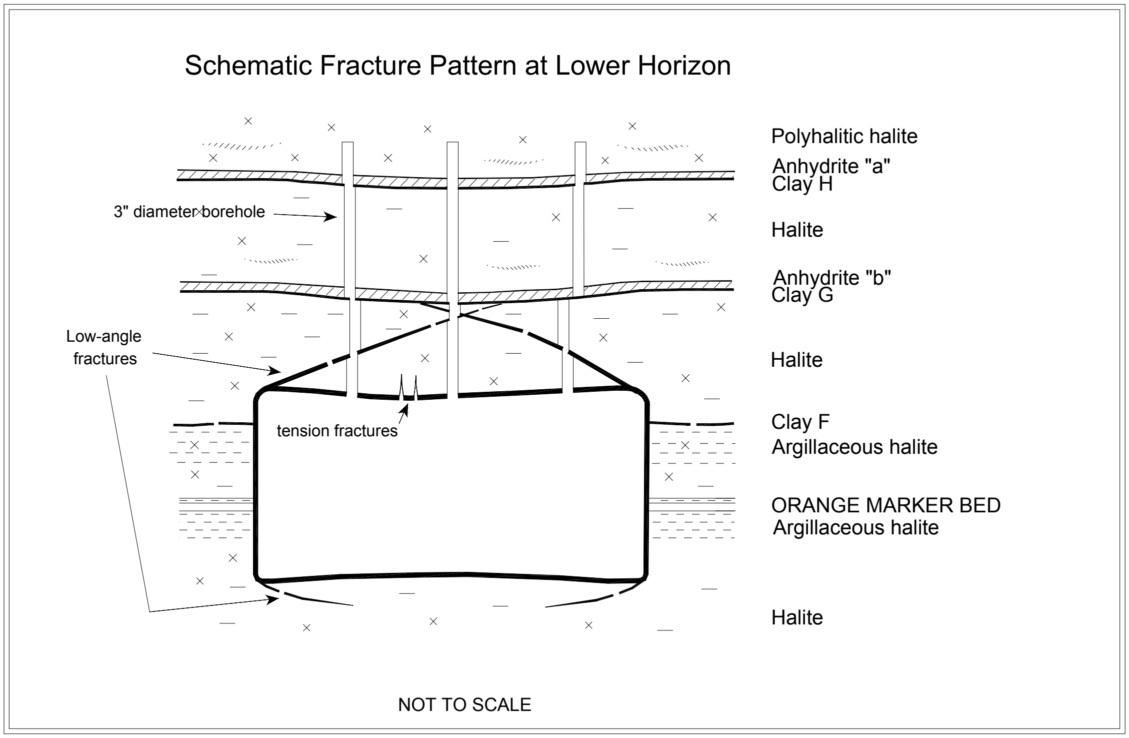


Figure 6-3 – Typical Fracture Patterns at Lower Horizon

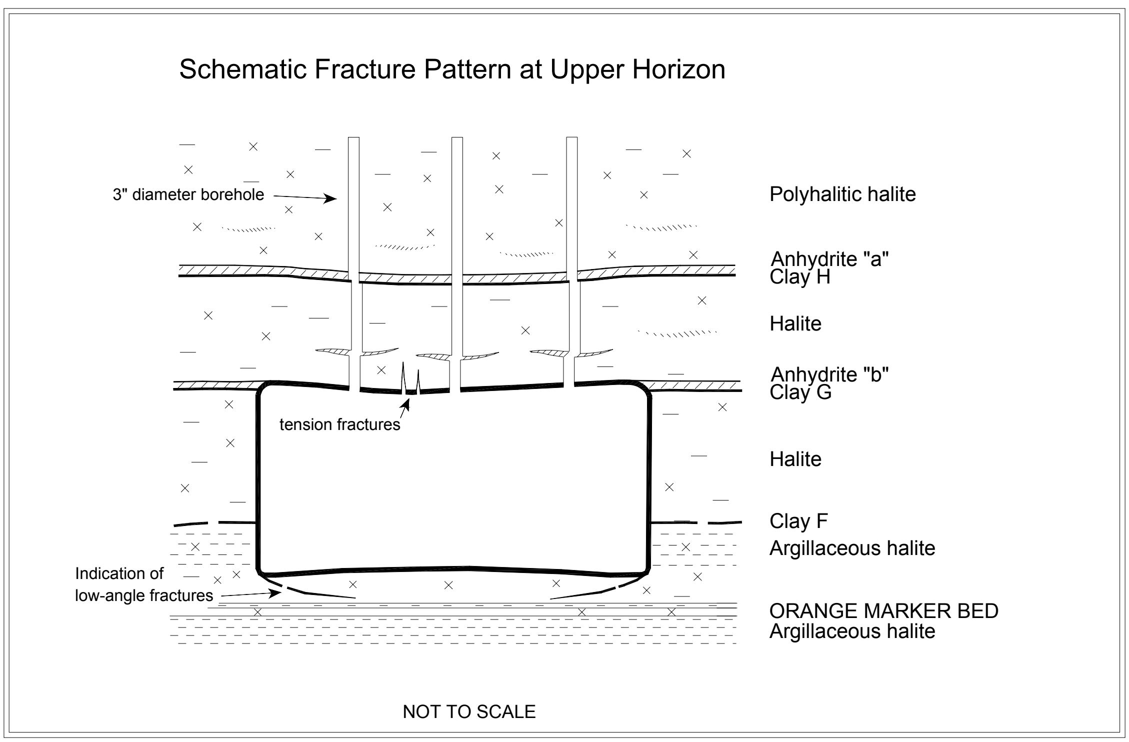


Figure 6-4 – Typical Fracture Patterns at Upper Horizon

The separation and offset data observed in accessible boreholes are presented in the supporting data document for this report. All of the observation holes exhibit some separation within the roof beam. The greatest separations are generally associated with anhydrite stringers in the lower portion of the roof beam. Forty-four of the forty-eight observation holes in Panel 3 show some offset. Most holes show offsetting along anhydrite stringers and clay layers. Only four boreholes did not indicate offsetting. One borehole at the intersection of S-3080 and Room 1 exhibited a 3-inch lateral displacement.

## 6.2 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 updated. The fracture maps facilitate the analysis of strain in the immediate roof-beam because they document the development and propagation of fractures through time. The supporting data document contains fracture maps for Panels 2 and 3. For this reporting period, Rooms 1 through2 and corresponding portions of S-2180 and S-2750 were accessible in Panel 2.

## 7.0 SUMMARY

At the inception of the WIPP, criteria were developed that address the design requirements (DOE, 1984). They 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's 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 8-1 shows the comparison of these design requirements with conditions actually observed in the underground from July 2004 through June 2005.

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. In a thick roof beam, 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 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; however, this process may take a long time (years) to develop.

At the upper repository horizon, clay or anhydrite stringers exert significant influence over the effective thickness of the roof beam. The presence of these stringers causes the roof beam to behave as a series of thin independent beams. Little or no tensile support is provided across the stringer interface. As horizontal end-loading continues, each beam can deflect downward causing a tensile fracture to develop along the bottom of the beam. These tensile fractures can develop in relatively new excavations soon after separation occurs along the stringer interface.

The location and initiation of interface separation is also influenced by the dip of the rock layers. The roofs and floors of the disposal panels are mined level through the sloping beds. At some locations, this may result in a significant difference in roof beam thickness from one side of the excavation to the other. Areas with the thinnest beam are the most likely to develop separations and subsequent fracturing.

Normal drift and room maintenance continued during this reporting period with rib, roof, and floor scaling and trimming in various locations, and rock bolts and wire mesh installed as needed. Supplemental ground control systems consisting of resin-anchored bolts and roof mats were installed in sections of the E-140 and W-170 drifts.

New geomechanical instrumentation was installed in Panel 4 and its access drifts, as well as in various locations throughout the repository to replace mined-out instruments. Remote convergence monitoring no longer continues in non-accessible areas in the north. All accessible areas of the underground are connected to data-loggers or are monitored manually.

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 installation 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, changing the geometry of the access drifts (removing unstable roof beam or rib spalls, or milling the floor for added clearance), or additional ground control (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.

**Table 7-1 – 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.<br>No water has been observed flowing along the rock-liner interface. |
| "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 and disposal space. Ground control maintenance is performed as necessary to maintain access. |
| "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. The former experimental area, consisting of the Northeast and Northwest Areas, is now deactivated and closed to access. |
| "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 provides a summary and analysis of the geomechanical data. |

This page intentionally left blank

## 8.0 REFERENCES AND BIBLIOGRAPHY

ASTM, 2004, E29-04, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

DOE, see U.S. Department of Energy.

Public Law 96-164, Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980.

Title 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes."

Title 40 CFR Part 194, "Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations."

Holt, R.M., and D.W. Powers, 1990, *Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant*, DOE/WIPP 90-051, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

Holt, R.M., and D.W. Powers, 1984, *Geotechnical Activities in the Waste Handling Shaft, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico*, WTSD-TME 038, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

New Mexico Environment Department (NMED), 1999, Waste Isolation Pilot Plant Hazardous Waste Facility Permit, NM4890139088-TSDF, Santa Fe, New Mexico.

Powers, D.W., and R.M. Holt, 1993, *The Upper Cenozoic Gatuña Formation of Southeastern New Mexico*, New Mexico Geological Society Guidebook, 44th Field Conference, Carlsbad Region, New Mexico and West Texas, D.W. Love et al., Eds., pp 271–282.

Powers, D.W., and R.M. Holt, 1995, *Gatuña Formation (Miocene to Pleistocene) Geology and Paleohydrology*, prepared for Westinghouse Waste Isolation Division by International Technology Corporation, Albuquerque, New Mexico.

Powers, D.W., S.J. Lambert, S.E. Shaffer, L.R. Hill, and W.D. Weart, Eds.,1978, *Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico*, Vols. I and II, SAND 78-1596; Sandia National Laboratories, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), 2000, *Brine Generation Study*, DOE/WIPP 00-2000, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

U.S. Department of Energy (DOE), 1986a, *Interim Geotechnical Field Data Report*, DOE/WIPP 86-012, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

U.S. Department of Energy (DOE), 1986b, *Waste Isolation Pilot Plant Design Validation Final Report*, DOE/WIPP 86-010; Prepared by Bechtel National, Inc., for the U.S. Department of Energy, San Francisco, California.

U.S. Department of Energy (DOE), 1986c, *Geotechnical Activities in the Exhaust Shaft*, DOE/WIPP 86-008, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

U.S. Department of Energy (DOE), 1985, *Quarterly Geotechnical Field Data Report*, DOE/WIPP-221, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

U.S. Department of Energy (DOE), 1984, *Design Criteria, Waste Isolation Pilot Plant (WIPP) Revised Mission Concept-IIA*, DOE/WIPP-071; Waste Isolation Pilot Plant, Carlsbad, New Mexico.

U.S. Department of Energy (DOE), 1983, *Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program*, DOE/WIPP-161; Waste Isolation Pilot Plant, Carlsbad, New Mexico.