

Geotechnical Analysis Report for July 1998 - June 1999

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FOREWORD AND ACKNOWLEDGMENTS

This report contains an assessment of the geotechnical status of the Waste Isolation Pilot Plant (WIPP). During the excavation of the principal underground access and experimental areas, the status was reported quarterly. Since 1987, when the initial construction phase was completed, reports have been published annually. This report presents and analyzes data collected from July 1, 1998, to June 30, 1999.

This Geotechnical Analysis Report was written to meet the needs of several audiences. This report satisfies the requirements presented in the WIPP Hazardous Waste Permit¹ and the certificate of compliance with Title 40 *Code of Federal Regulations* (CFR) §§ 191 and 194. It focuses on the geotechnical performance of the various components of the underground facility, including the shafts, shaft stations, access drifts, and waste disposal areas. The results of investigations of excavation effects and other geologic studies are also included. The report compares the geotechnical performance of the repository to the design criteria. It describes the techniques that were used to acquire the data and the performance history of the instruments. The depth and breadth of the evaluation of the different components of the underground facility vary according to the types and quantities of data available and the complexity of the recorded geotechnical responses. Graphic documentation of data and tabular documentation of instrument history can be provided upon request.

This Geotechnical Analysis Report was prepared by Westinghouse, Waste Isolation Division, for the U.S. Department of Energy (DOE), Carlsbad Area Office, Carlsbad, New Mexico. Work was supported by the DOE under Contract No. DE-AC04-86AL31950.

¹New Mexico Environment Department (NMED), 1999, "Waste Isolation Pilot Plant Hazardous Waste Facility Permit," NM4890139088-TSDF, Santa Fe, New Mexico.

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ACRONYMS AND ABBREVIATIONS

b.p.	before present
CAO	Carlsbad Area Office
CFR	<i>Code of Federal Regulations</i>
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 information system
in.	inch(es)
KPa	kilopascal(s)
lb	pound(s)
m	meter(s)
Ma	millions of years
MB	marker bed
NMED	New Mexico Environment Department
OMB	orange marker bed
psi	pound(s) per square inch
SDD	system design description
SNL/NM	Sandia National Laboratories/New Mexico
SPDV	Site Preliminary Design Validation
TRU	transuranic
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
yr	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 during operations.

GARs have been available to the public since 1983. During the Site and Preliminary Design Validation (SPDV) Program, the architect/engineer for the project produced these reports on a quarterly basis to document the geomechanical performance during and immediately after excavation of the underground facility. Since the completion of the construction phase of the project in 1987, the management and operating contractor for the facility has prepared these reports annually. This report describes the performance and condition of selected areas from July 1, 1998, to June 30, 1999. It is divided into nine chapters. The remainder of Chapter 1.0 provides background information on the WIPP, its mission, and the purpose and scope of the geomechanical monitoring program. Chapter 2.0 describes the local and regional geology of the WIPP site. Chapters 3.0 and 4.0 describe the geomechanical instrumentation located in the shafts and shaft stations, present the data collected by that instrumentation, and provide interpretation of these data. Chapters 5.0, 6.0, and 7.0 present the results of geomechanical monitoring in the three main portions of the WIPP underground facility (the access drifts, the Northern Experimental Area, and the Waste Disposal Area). Chapter 8.0 discusses the results of the Geoscience Program, which includes fracture mapping, borehole logging, and borehole observations. Chapter 9.0 summarizes the results of the geomechanical monitoring and compares the current excavation performance to the design requirements.

1.1 Location and Description

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

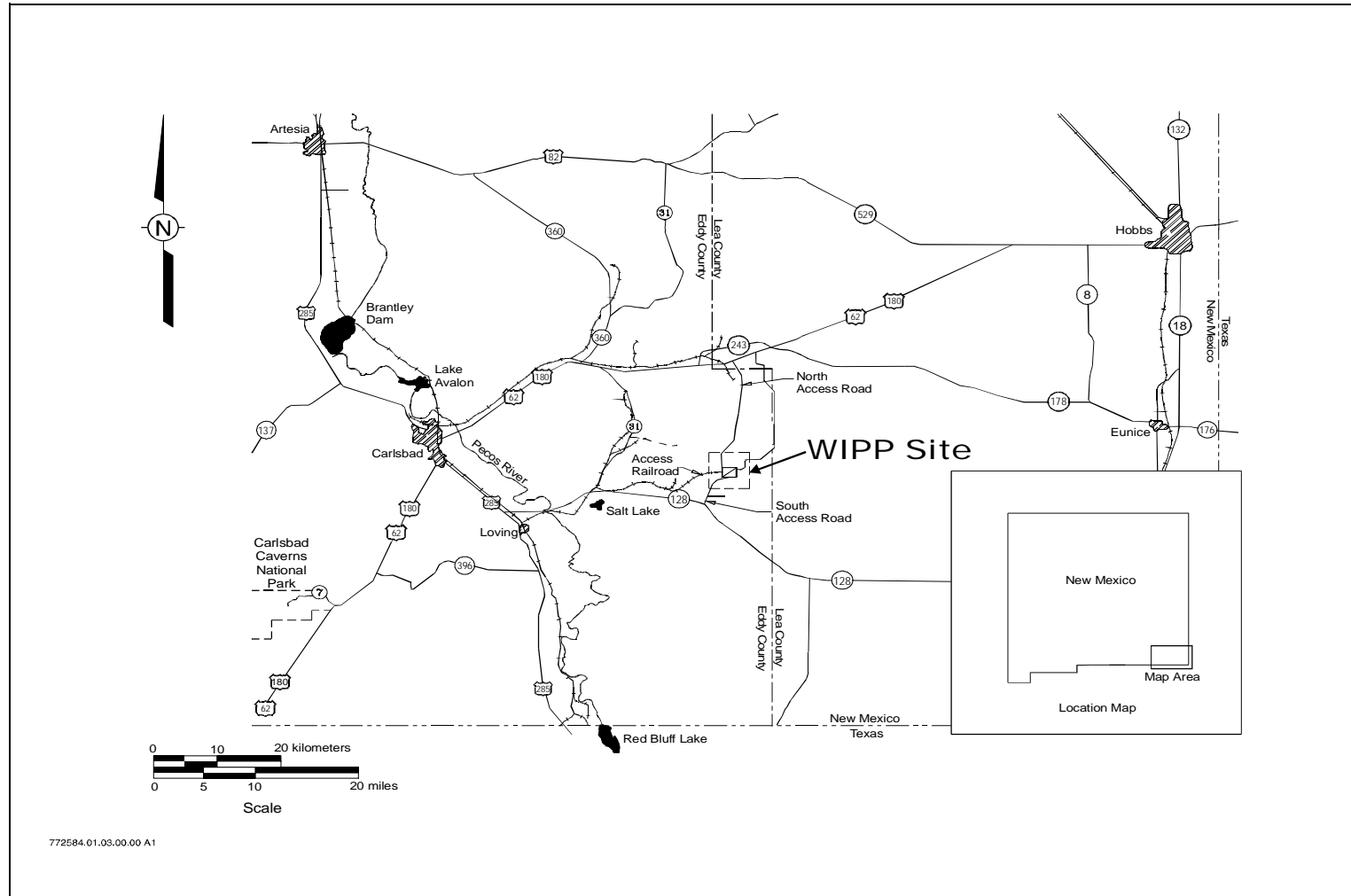


Figure 1-1 - WIPP Location

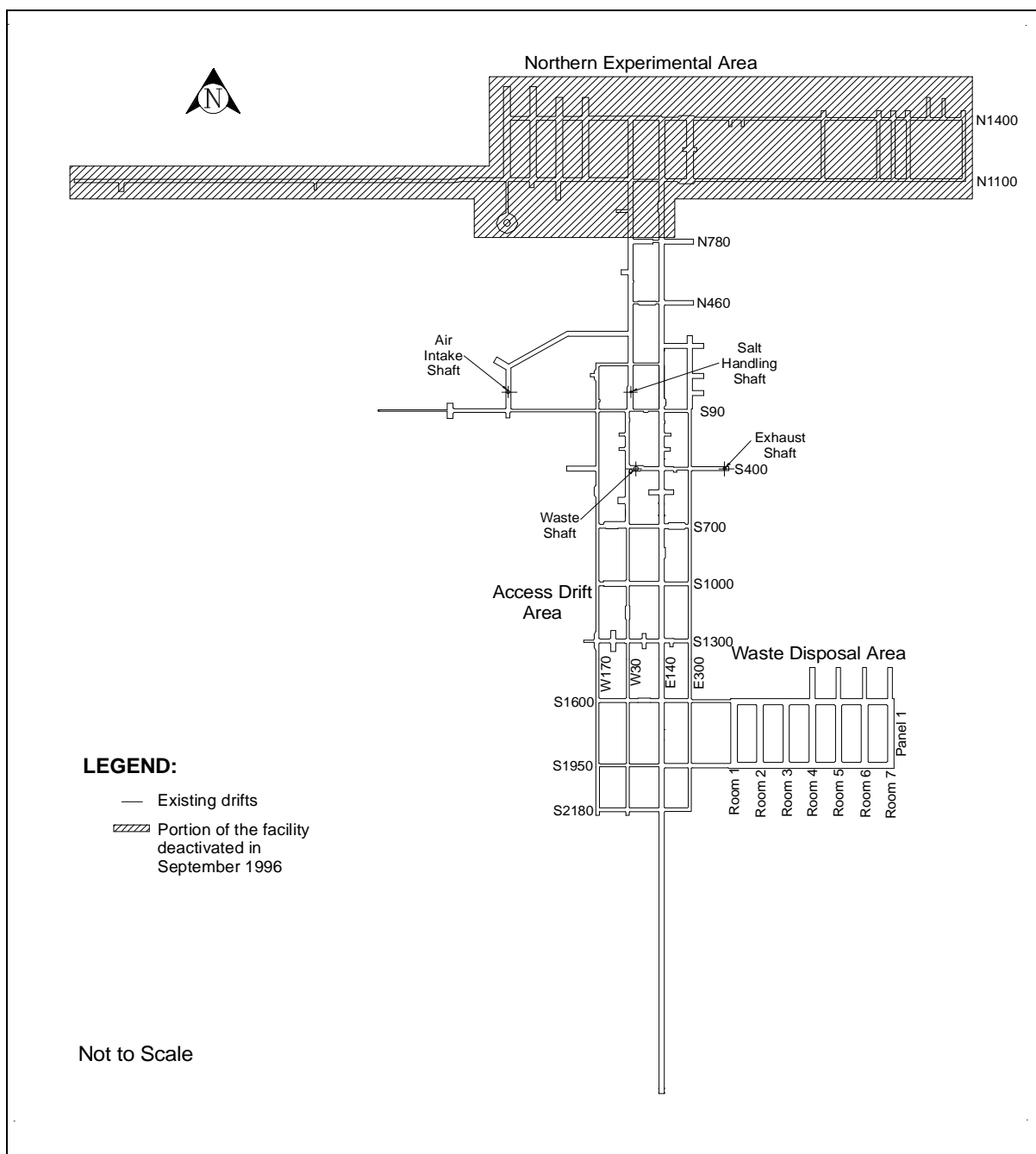


Figure 1-2 - Current Underground Configuration

1.2 Mission

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

1.3 Development Status

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

Based upon the favorable results of the SPDV investigations, additional activities were initiated in 1983. These included the construction of surface structures, conversion of the ventilation shaft for use as the waste shaft, excavation of the exhaust shaft, development of additional access drifts to the Waste Disposal Area, excavation of the air intake shaft, and excavation of additional experimental rooms to support research and development activities. Geotechnical data acquired during this phase were used to evaluate the performance of the excavations in the context of established design criteria (DOE, 1984). Results of these evaluations were reported in Geotechnical Field Data and Analysis 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 the 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 original design for the waste disposal rooms allowed for a relatively short time in which to mine the salt and emplace waste. Each panel, consisting of seven disposal rooms, was scheduled to be mined, filled with waste containers, and closed in fewer

than five years. Field studies, as part of the SPDV Program, proved that unsupported openings of a typical disposal room configuration at the WIPP would remain stable and safe during the 5-year period following excavation, and that closure from creep would not affect the operation of large equipment during that time. 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 was intended to receive waste for an initial operations demonstration and pilot plant phase that was scheduled to start in October 1988. This original plan was to place drums of contact-handled (CH) TRU waste in the disposal rooms for a period of up to five years. The waste in the disposal rooms would not be easily accessible, but the option to reenter would be maintained so that the waste could be removed, if required. To maintain roof stability for possible reentry, rock-bolts were installed in the rooms.

The operations demonstration was deferred, and the pilot plant phase was modified to use CH TRU waste in bin-scale tests in Room 1, Panel 1. The purpose of this program, referred to as the test phase, was to investigate whether waste disposal at the WIPP could be conducted in compliance with environmental standards and regulations. The decision to conduct these bin-scale tests in Room 1, Panel 1, was made in June 1989, when it was anticipated that the initial shipment of waste would be received in 1990. An additional seven years was required of the room for the on-site bin-scale tests beginning in July 1991. These added requirements led to more stringent criteria for roof support systems. In late 1993, however, the DOE decided to conduct the test phase off site and established 1998 as a new date for first receipt of waste. Additional delays in obtaining a permit from the New Mexico Environment Department for disposal of the hazardous chemical components of waste have postponed the receipt of mixed TRU waste to 1999.

In October 1996, the DOE submitted to the U.S. Environmental Protection Agency (EPA) a compliance certification application in accordance with Title 40, Sections 191 and 194, of the Code of Federal Regulations, "Compliance Certification Application," which addressed the long-term (10,000-year) performance criterion for the disposal system. On May 13, 1998, the EPA issued final certification that allows for the receipt of TRU waste at the WIPP. Immediately prior to this certification, the DOE Carlsbad Area Office (CAO) completed the WIPP Operational Readiness Review, which is required before the startup of a nuclear waste repository. As a result of the review, the CAO notified the Energy Secretary on April 1, 1998, that the WIPP is operationally ready to receive waste. On March 26, 1999, the first shipment of TRU waste was received at the WIPP site from Los Alamos National Laboratory. By the end of April, 1999, shipments of TRU waste were being received at the WIPP site from both Los Alamos National Laboratory and Idaho National Engineering and Environmental Laboratory.

1.4 Purpose and Scope of Geomechanical Monitoring Program

As specified in the WIPP Hazardous Waste Permit (NMED, 1999), the purpose of the geomechanical monitoring program is to obtain in situ data to support the continuous

assessment of the design for underground facilities. Specifically, the program provides for:

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

Polling of the geomechanical instrumentation is performed at least monthly with higher frequency in some areas as deemed necessary. The data taken from the geomechanical instrumentation are evaluated and reported in this Geotechnical Analysis Report. 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 Permit (NMED, 1999), and 40 CFR § 191.14, "Assurance Requirements" implemented through the provisions of 40 CFR § 194.

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

1.4.1 Instrumentation

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

Table 1-1
Geomechanical Instrumentation System

Instrument Type	Measures	Range ^a	Resolution ^a
Sonic probe borehole extensometer	Cumulative deformation	0-2 in.	0.001 in.
Convergence points	Cumulative deformation	2-50 ft.	0.001 in.
Wire convergence meters	Cumulative deformation	2-50 ft	0.001 in.
Sonic probe convergence meters	Cumulative deformation	2-50 ft	0.001 in.
Embedded strain gauges	Cumulative strain	0-3000 μ in./in.	1 μ in./in.
Spot-welded strain gauges	Cumulative strain	0-2500 μ in./in.	1 μ in./in.
Rock-bolt load cells	Load	0-50 tons	40 lb
Earth pressure cells	Pressure	0-1000 psi	1 psi
Piezometers	Fluid pressure	0-500 psi	0.5 psi
Joint Meters	Cumulative deformation	0-4 in.	0.001 in.
Vibrating wire borehole extensometer	Cumulative deformation	0-4 in.	0.001 in.
Borehole lateral displacement sensor	Lateral offset	0-3 in.	0.003 in.
Linear potentiometric borehole	Cumulative deformation	0-6 in.	0.001 in.

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

ft = foot (feet)

in. = inch(es)

μ in. = microinch(es)

psi = pound(s) per square inch

lb = pound(s)

1.4.2 Data Acquisition

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

The underground data acquisition system consists of instruments, polling devices, and a communications network. One or more instruments are connected to a polling device. The polling devices are installed in boxes or cabinets near the location of the instrument to facilitate queries of each individual instrument. The polling devices are connected by datalink cables and modems 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.¹

1.4.3 Data Evaluation

Closure measurements are acquired manually from convergence point anchors and remotely from convergence meters. The plots are presented as ground displacement monitored over time and plotted as either surface displacement versus time or closure versus time.

Extensometers provide relative displacement data acquired from sensors installed in a borehole. The displacement is the measure of movement at various depths in the rock strata intercepted by the extensometer borehole. Displacement is measured relative to a fixed point. Extensometers consist of rods that are anchored in a borehole at various depths. The deepest anchor is fixed in what is assumed to be undisturbed ground and is used as the reference point. Typically, the plots will show greater relative ground movement near the collar (i.e., the opening of the hole).

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

Earth pressure cells and strain gauges are used to determine the stresses and deformations in and around the shaft liners, and data are depicted in time-based plots. These instruments monitor stress in the shaft lining systems.

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

1.4.4 Data Errors

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

¹Instrumentation data and data plots are available in "Geotechnical Analysis Report for July 1998-June 1999 Supporting Data." This document is available upon request from Westinghouse Waste Isolation Division. See Foreword and Acknowledgments for details and addresses.

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

2.0 GEOLOGY

This chapter provides a summary of the stratigraphy of the WIPP region and the facility stratigraphy. Readers desiring further geologic information can consult one of the references cited in the Selected Bibliography, Section 10.2. In particular, the "Geological Characterization Report, WIPP Site, Southeastern New Mexico" (Powers et al., 1978) was developed as a source document on the geology of the WIPP site for individuals, groups, or agencies seeking basic information on geologic history, hydrology, geochemistry, or detailed information, such as physical and chemical properties of repository rocks. A more recent survey of WIPP stratigraphy is included in Holt and Powers (1990).

2.1 Regional Stratigraphy

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

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

2.1.1 Castile Formation

The Castile Formation, lowermost of the four Ochoan formations, is approximately 380 m (1,250 ft) 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.

2.1.2 Salado Formation

The Salado Formation comprises nearly 610 m (2,000 ft) of 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, 655 m (2,150 ft) below the surface.

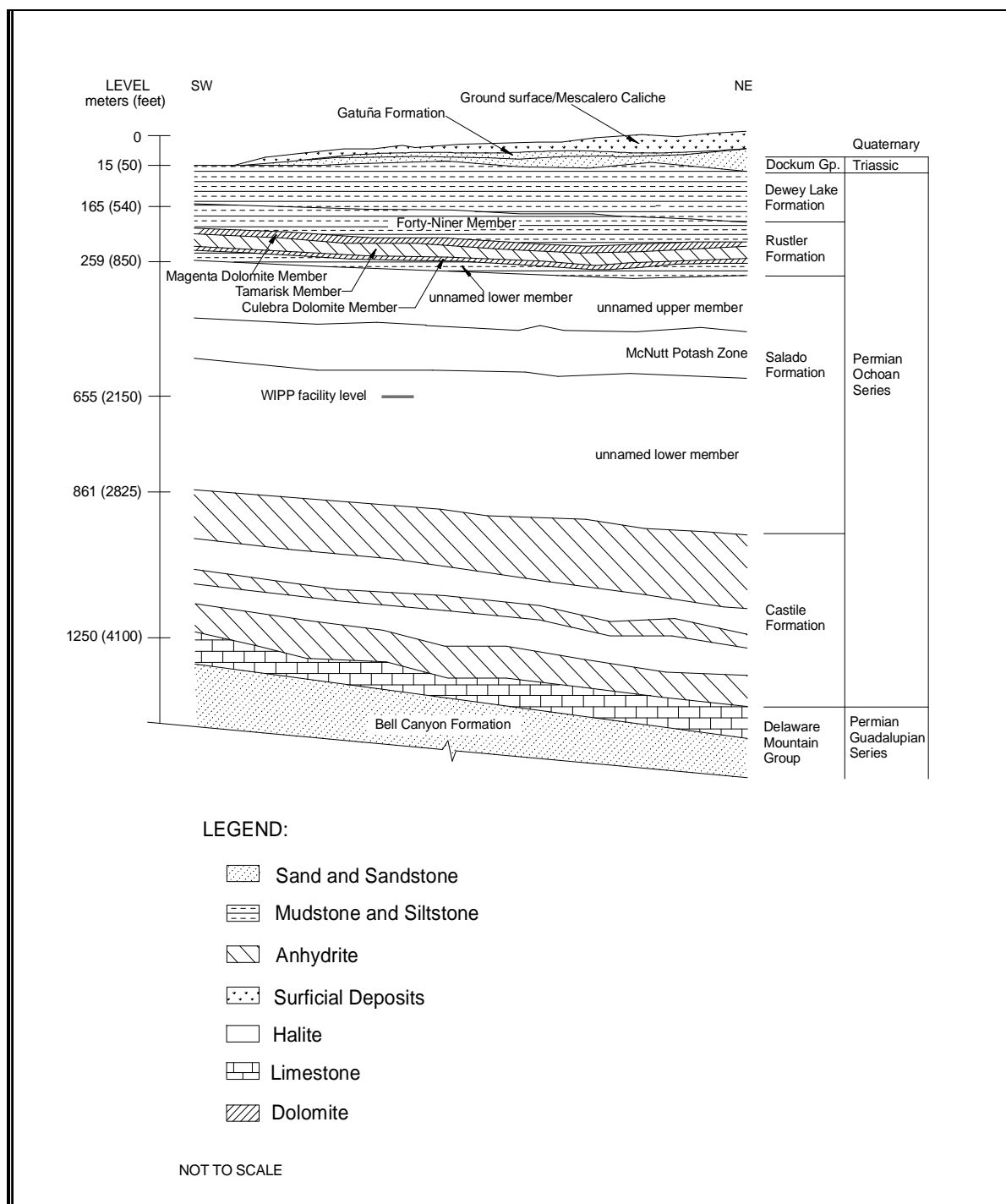


Figure 2-1 - Regional Geology

2.1.3 Rustler Formation

The Rustler Formation is the uppermost of the three Ochoan evaporite formations and contains the largest proportion of clastic material of the three. The Rustler is subdivided into five members as follows (from the base): an unnamed lower 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 about 95 m (310 ft) thick and thickens to the east. The lower portion (the unnamed lower 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 is a mudstone that displays sedimentary features and bedding relationships indicating sedimentary transport and deposition on a mudflat. East of the site area, halite correlates with the mudstone. The Culebra and Magenta Dolomite members are persistent and serve as important marker units.

2.1.4 Dewey Lake Redbeds

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

2.1.5 Dockum Group

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

2.1.6 Gatuña Formation, Mescalero Caliche, and Surficial Sediments

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

The Mescalero Caliche (approximately 500,000 years b.p.) is about 1.2 m (4 ft) thick in the WIPP vicinity. The Mescalero is a hard, resistant soil horizon that lies beneath a cover of windblown sand. The horizon is petrocalcic, or very strongly cemented with calcium carbonate. Petrocalcic horizons form slowly beneath a stable landscape at the average depth of infiltration of soil moisture and are an indicator of stability and integrity of the land surface. Many of the surface buildings at the 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 $330,000 \pm 75,000$ years ago.

2.2 Underground Facility Stratigraphy

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

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

2.2.1 Disposal Horizon Stratigraphy

Most underground excavations are located within the disposal horizon (see Figure 2-2). In this horizon, the Orange Marker Bed (OMB) typically occurs near mid-rib. The OMB is a laterally consistent unit of moderately to light reddish-orange halite, typically about

15 centimeters (cm) (6 inches [in.]) thick that is used as a point of reference for disposal area excavation.

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

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

Above clay F, another sequence of halite begins that, as in lower sequences, becomes increasingly argillaceous upward. This sequence terminates at the clay G/Anhydrite "b" interface, about 2 m (6.5 ft) above the roof of most disposal horizon excavations forming the first roof beam. The roof or "back" of some disposal horizon excavations has been excavated to the clay G/Anhydrite "b" interface. Another depositional sequence begins with Anhydrite "b" and progresses upward to the clay H/Anhydrite "a" interface, typically about 4 m (13 ft) above the roof. Where disposal horizon excavations have been trimmed to the clay G/Anhydrite "b" interface (e.g., E140 drift between S1000 and S1950), this sequence between the clay G/Anhydrite "b" interface and the clay H/Anhydrite "a" interface forms the first roof beam.

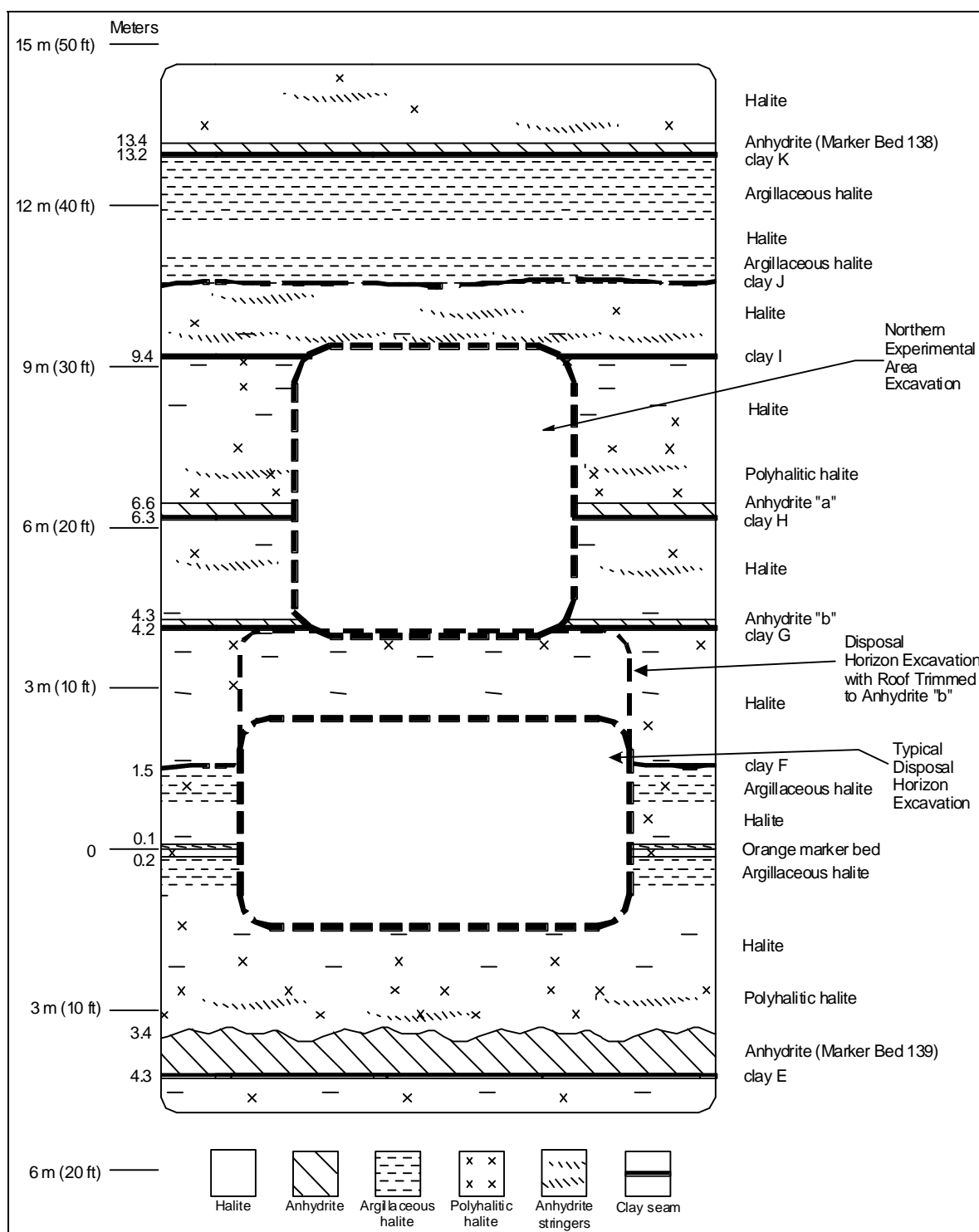


Figure 2-2 - Repository Level Stratigraphy

2.2.2 Experimental Area Stratigraphy

Some experimental excavations, located in the eastern wing of the Northern Experimental Area (deactivated and closed during this reporting period), lie at a higher stratigraphic level than the disposal excavations. These excavations typically have

floors excavated at Anhydrite "b." As in the lower units, the halite intervals between the clay seams/anhydrite beds contain relatively pure halite that becomes increasingly argillaceous upward.

Above clay I, two more halite intervals complete the underground facility stratigraphy. Clay J at the top of the first of these intervals may occur as a distinct seam or merely an argillaceous zone. Clay K tops the second interval and is overlain by anhydrite MB138.

3.0 PERFORMANCE OF SHAFTS AND KEYS

Four shafts connect the surface with the WIPP underground facility. The four shafts are the Salt Handling Shaft which is primarily used for removing excavated salt from the underground; the Waste Shaft which is the primary shaft for transporting men and materials between the surface and the underground and is used for transporting the transuranic waste to the underground disposal area; the Exhaust Shaft 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.

3.1 Salt Handling Shaft

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

The Salt Handling Shaft is lined with steel casing and has a 3-m (10-ft) inside diameter from the ground surface to the shaft key at a depth of 258 m (846 ft). The steel liner has a thickness of 1.6 cm (0.62 in.) at the top, increasing with depth to a thickness of 3.8 cm (1.5 in.), including external stiffener rings, at the key. Cement grout is placed between the liner and rock face. The 3-m (10-ft) diameter extends through the concrete shaft key to a depth of 268 m (880 ft). The shaft key is an 11.4 m (37.5 ft) long, reinforced-concrete structure at the base of the steel liner. The shaft from the key to the bottom of the shaft, at a depth of 700 m (2,298 ft), has a nominal diameter of 4 m (12 ft). Wire mesh anchored by rock-bolts is installed in this portion as a safety screen to contain rock fragments that may become detached. The shaft extends approximately 43 m (140 ft) below the facility horizon in order to accommodate the skip loading equipment and to act as a sump.

3.1.1 Shaft Observations

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

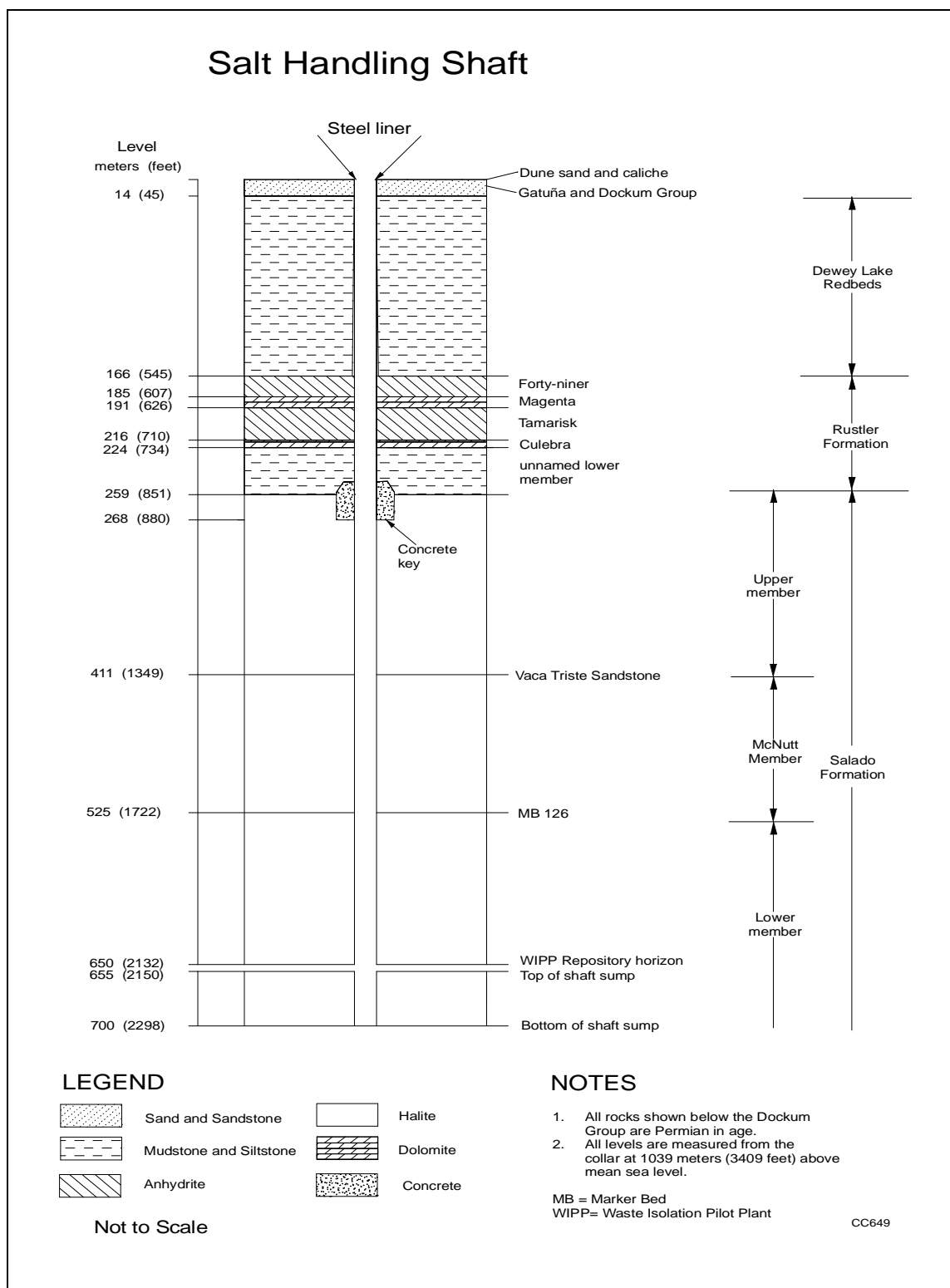


Figure 3-1 - Salt Handling Shaft Stratigraphy

3.1.2 Instrumentation

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

Currently, only one of the original nine extensometers (37X-GE-00209 located at level 627 m [2,057 ft]) remains functional. Data from this extensometer indicate that the collar displacement on the date of the last reading, May 5, 1999, was 1.97 cm (0.775 in.) with a calculated displacement rate of 0.103 cm/yr (0.041 in./yr). This represents an increase in displacement rate for this reporting period of greater than 50 percent compared to the displacement rate of 0.066 cm/yr (0.026 in./yr) calculated for the previous reporting period (July 1, 1997, through June 30, 1998). The present displacement rate of 0.103 cm/yr (0.041 in./yr) is not considered to be excessively high and is actually less than the extensometer anchor displacement rates observed at similar depths in the Waste Shaft and Exhaust Shaft presented below. The other eight extensometers have not functioned properly since 1993.

All 12 piezometers continue to provide data. The fluid pressures recorded at the end of this reporting period range from approximately 640 kilopascals (KPa) (93 pounds per square in. [psi]) at the 177-m (580-ft) level in the Forty-Niner member to over 1,400 KPa (200 psi) at the 189-m (620-ft) level in the Magenta dolomite member. The recorded pressure of 1,400 KPa (200 psi) at the Magenta dolomite represents a 50 percent increase over the recorded pressure in the same location at the end of the previous reporting period. The pressure is still within the design restraints for the shaft liner and the pressure will continue to be monitored on a regular basis.

Four earth pressure cells were installed in the key section of the Salt Handling Shaft during concrete emplacement at the 262-m (860-ft) level. These instruments measure the normal stress between the concrete key and the Salado Formation as the creep effects load on the key structure. Three of the four earth pressure cells continue to provide data, although all three are reporting negative pressures. The contact pressures recorded by the instruments for this reporting period ranged from -47 to -214 KPa (-7 to -31 psi). These pressures are in line with the pressures recorded during the previous reporting period.

Sixteen spot-welded and twenty-four embedment strain gages were installed on and in the shaft key concrete at both the 261-m (856.3-ft) level and at the 262.9-m (862.4-ft) level. The two functioning spot-welded strain gages located at the 261-m (856.3-ft) level reported strains of 616 and 711 microstrain. The strains reported for this reporting period from the 12 embedment strain gages located at the 261-m (856.3-ft) level ranged from -678 microstrain to 952 microstrain. The strains recorded from both the spot-welded strain gages and the embedment strain gages are very similar to the recorded strains from these instruments at the end of the previous reporting period.

The functioning spot-welded strain gages located at the 262.9-m (862.4-ft) level reported strains ranging from 293 microstrain to 1,787 microstrain. The 12 embedment strain gages located at the 262.9-m (862.4-ft) level reported strains ranging from -348 to

779 microstrain. Again, all strains were very similar to those reported during the previous reporting period.

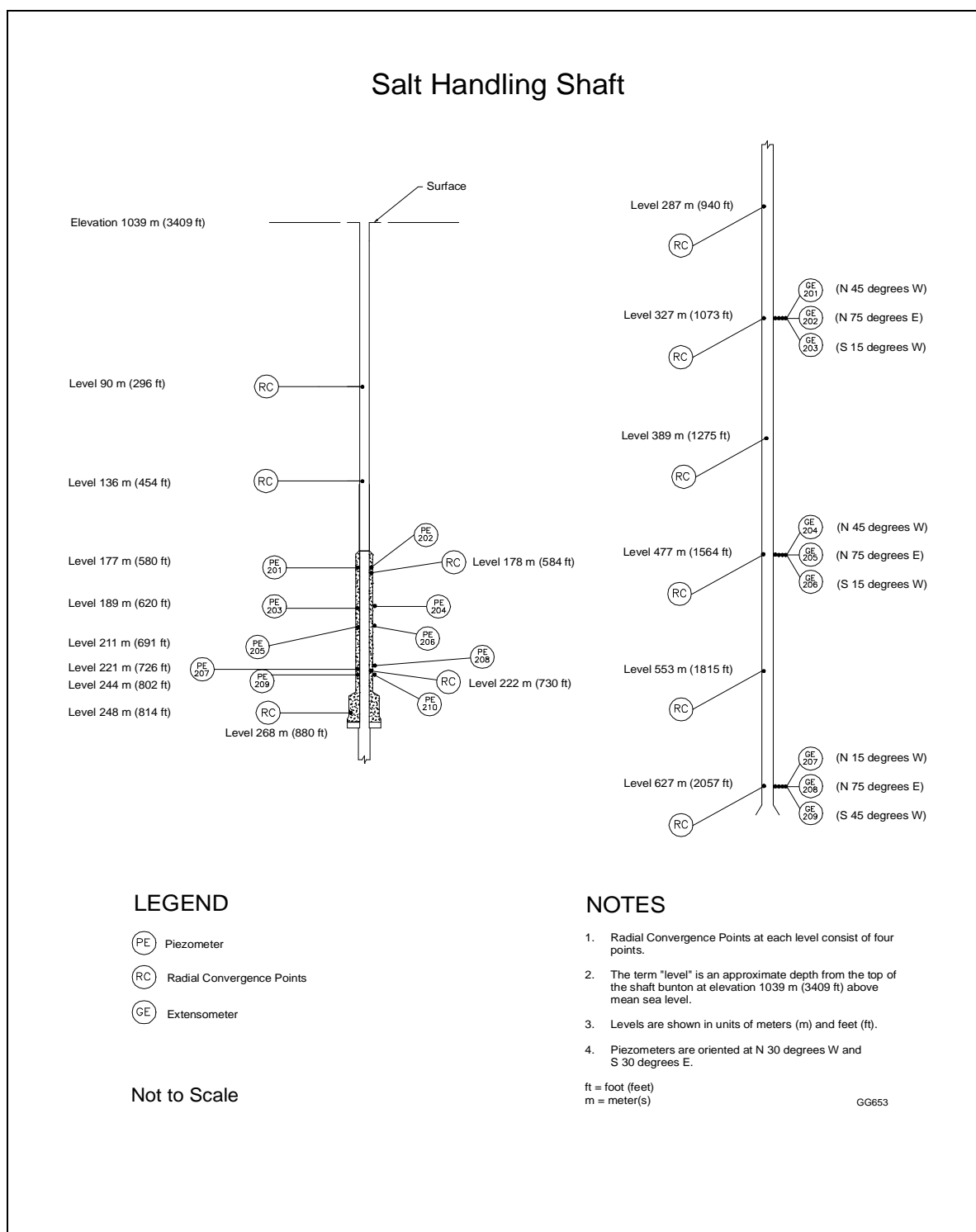


Figure 3-2 - Salt Handling Shaft Instrumentation (Without Shaft Key)

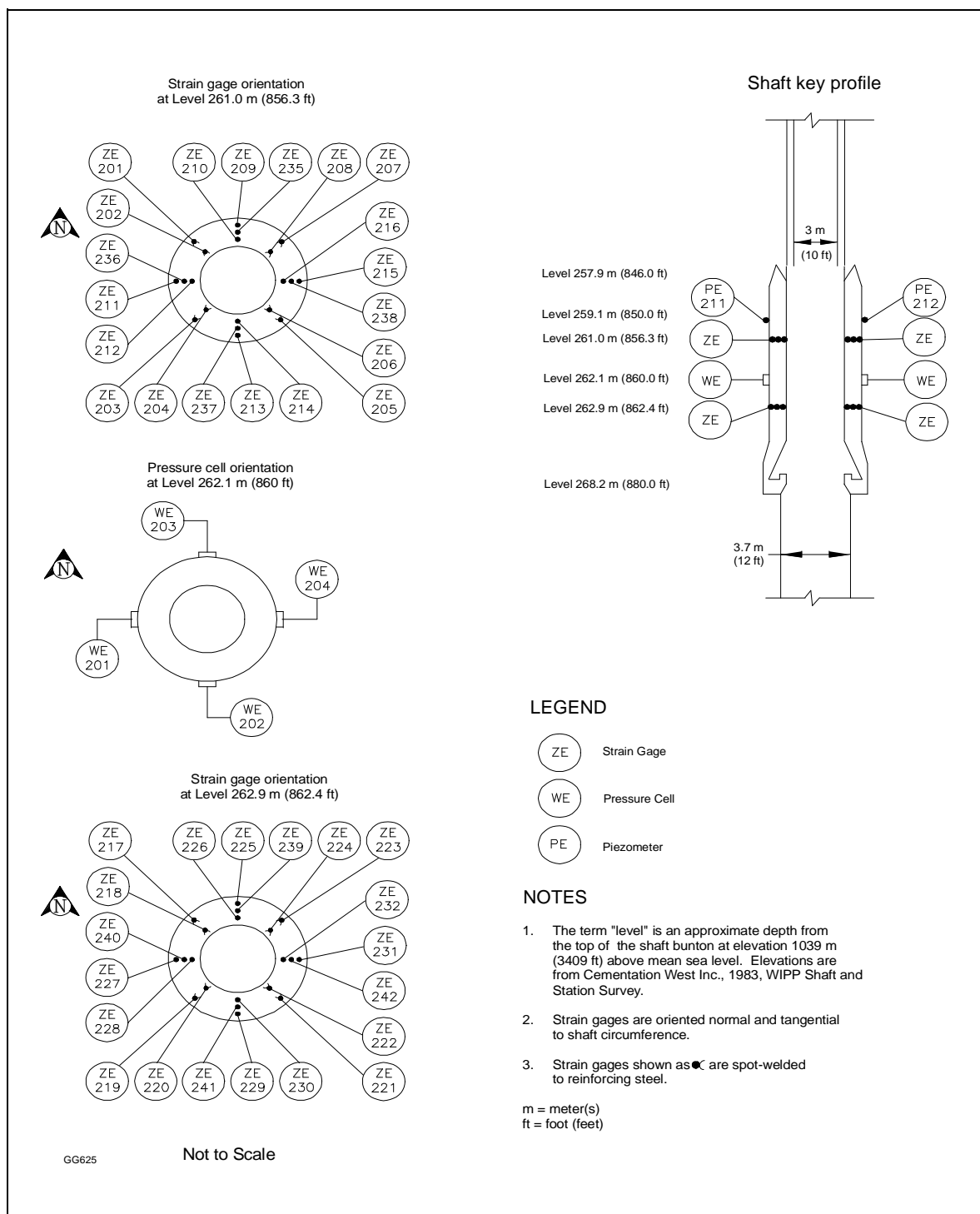


Figure 3-3 - Salt Handling Shaft Key Instrumentation

3.2 Waste Shaft

As part of the SPDV Program, a 2-m (6-ft) diameter ventilation shaft, now referred to as the Waste Shaft, was excavated from December 1981 through February 1982. This shaft, in combination with the Salt Handling Shaft, provided a two-shaft underground air

circulation system. From October 11, 1983, to June 11, 1984, the shaft was enlarged to a diameter of 6 to 7 m (20 to 23 ft) and lined. Stratigraphic mapping (Figure 3-4) was conducted during shaft enlargement from December 9, 1983, to June 5, 1984 (Holt and Powers, 1984).

The Waste Shaft is lined with nonreinforced concrete and has a 6-m (19-ft) inside diameter from the ground surface to the top of the Waste Shaft key at 255 m (837 ft). Liner thickness increases with depth from 25 cm (10 in.) at the surface to 51 cm (20 in.) at the key. The Waste Shaft key is 19 m (63 ft) long and 1.3 m (4.25 ft) thick and is constructed of reinforced concrete. The bottom of the key is 274 m (900 ft) below the surface. The diameter of the shaft is 6 m (20 ft) at the point below the key and increases to 7 m (23 ft) just above the shaft station. The shaft below the key is lined with wire mesh anchored by rock-bolts. The diameter of 7 m (23 ft) extends to a depth of approximately 697 m (2,286 ft) with the shaft sump comprising the lower 39 m (128 ft) of that interval.

3.2.1 Shaft Observations

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

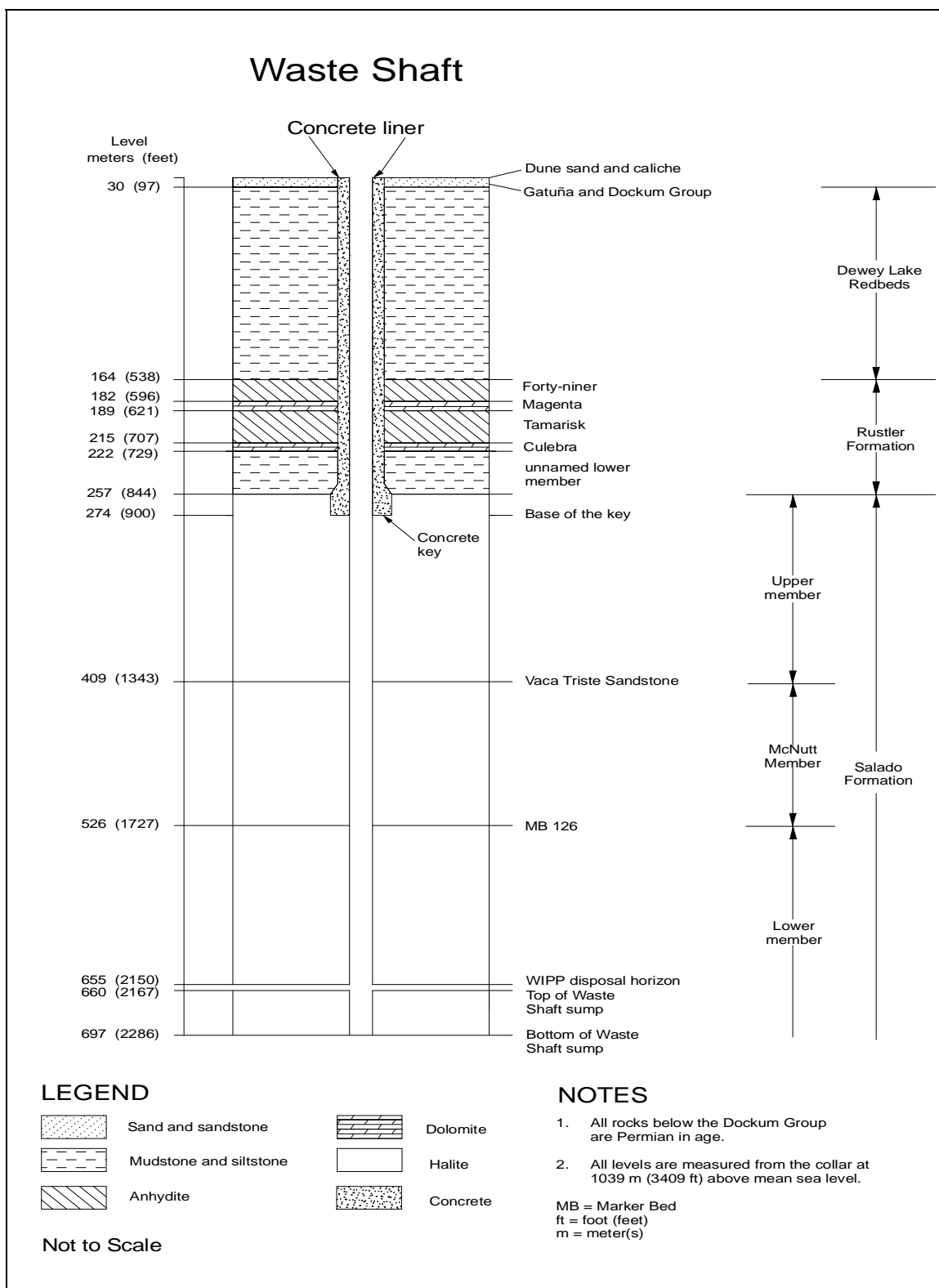


Figure 3-4 - Waste Shaft Stratigraphy

3.2.2 Instrumentation

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

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

Table 3-1
Collar Displacement at Waste Shaft Extensometers

Shaft Level meters (feet)	Extensometer Orientation	Total Collar Displacement	
		centimeters	inches
326 (1,071)	N45°W	0.597	0.235
	N75°E	Instrument malfunction	
	S15°W	0.445	0.175
477 (1,566)	N45°W	1.659	0.653
	N75°E	1.392	0.548
	S15°W	1.674	0.659
628 (2,059)	N45°W	4.216	1.660
	N75°E	3.960	1.559
	S15°W	4.460	1.756

The collar displacements at the 326-meter level (1,071 ft) indicate an annual displacement rate² of 0.028 to 0.030 cm/yr (0.011 to 0.012 in./yr). This is a relatively slow displacement rate but represents rate increases between 250 and 1,100 percent when compared to the negligible annual collar displacement rates of 0.003 and 0.008 cm/yr (0.001 and 0.003 in./yr) from the previous reporting period. Though these displacement rates show a significant percentage increase over the previous reporting period, the rates are still considered very small and are not considered a concern. The displacement rates for these two instruments during second half of this reporting period have returned to rates similar to those of the previous reporting period. These displacement readings and calculated displacement rates will continue to be monitored closely.

The collar displacement rates at the 477-meter level (1,566 ft) have also increased relative to the rates from the previous reporting period but to a much lesser degree than those from the 326-meter level. Annual displacements rates here have increased from 24-to- 34 percent. Again these rates are considered acceptable and have reduced

² Annual displacement rates are calculated as the difference in collar displacement readings from the final reading of the previous reporting period to the final reading of this reporting period divided by the time between those two readings, usually approximately one year.

during the second half of this reporting period. The displacement rates at the 628-meter level (2,059 ft) have remained relatively constant over the past two reporting periods.

Twelve piezometers were installed in the lined section of the Waste Shaft on September 7 and 8, 1984, to monitor pressure behind the shaft liner and key section in the shaft. Data continue to be received from all 12 piezometers, although 6 of the 12 report a zero or negative fluid pressure. The recorded positive fluid pressures from the remaining 6 piezometers at the end of the reporting period range from less than 200 KPa (29 psi) at the Magenta dolomite member (186-m [611-ft] depth) up to greater than 1,000 KPa (148 psi) at the level where the shaft intersects the Culebra Dolomite (218.5-m [717-ft] depth).

Four earth pressure cells were installed in the key section of the Waste Shaft during concrete emplacement between March 23 and April 3, 1984. These instruments measure the normal stress between the concrete key and the Salado Formation as the salt creep loads the key structure. The contact pressure recorded by these four instruments has remained fairly constant over the past five years. The pressures recorded during this reporting period were between 750 and 900 KPa (109 and 129 psi).

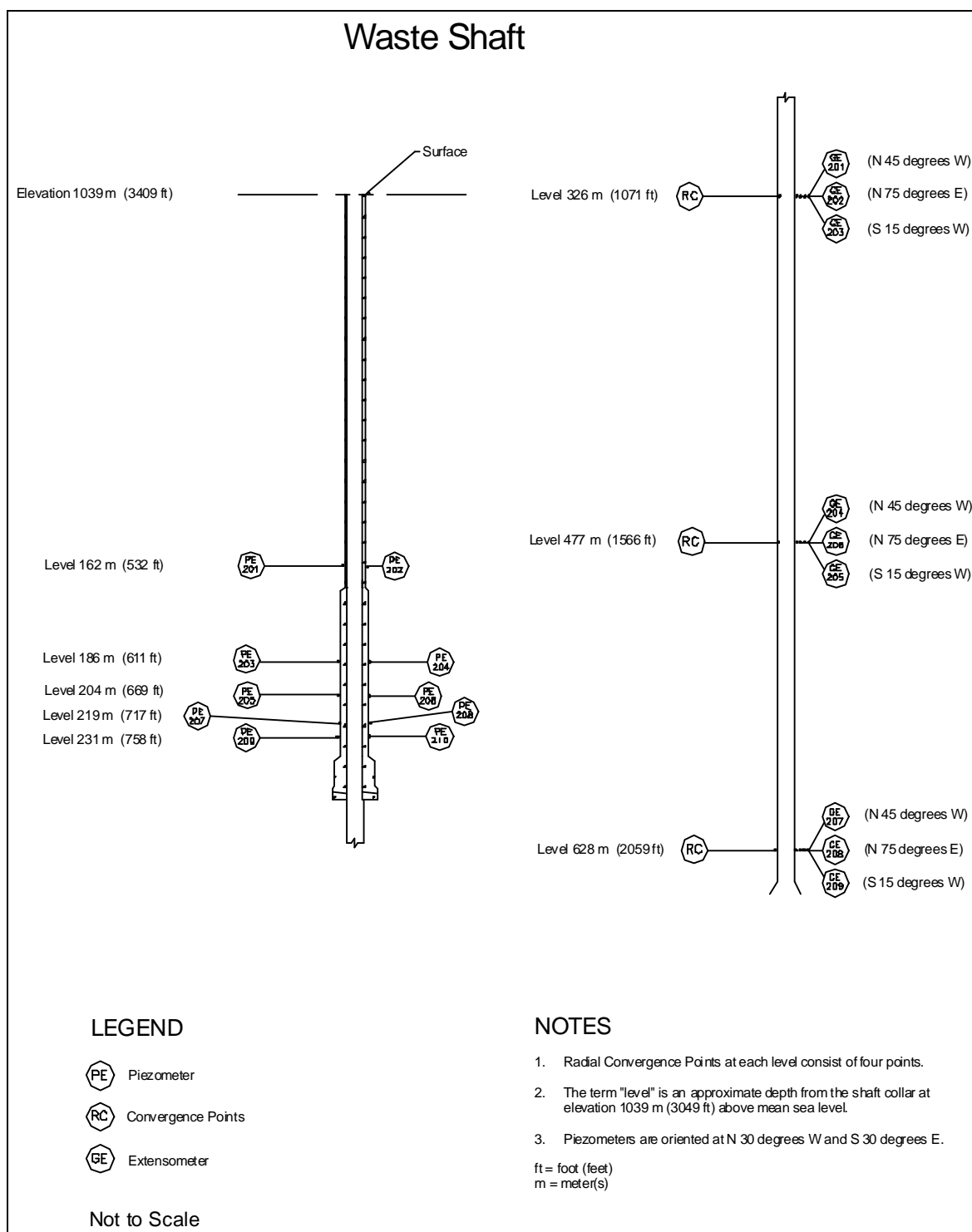


Figure 3-5 - Waste Shaft Instrumentation (Without Shaft Key)

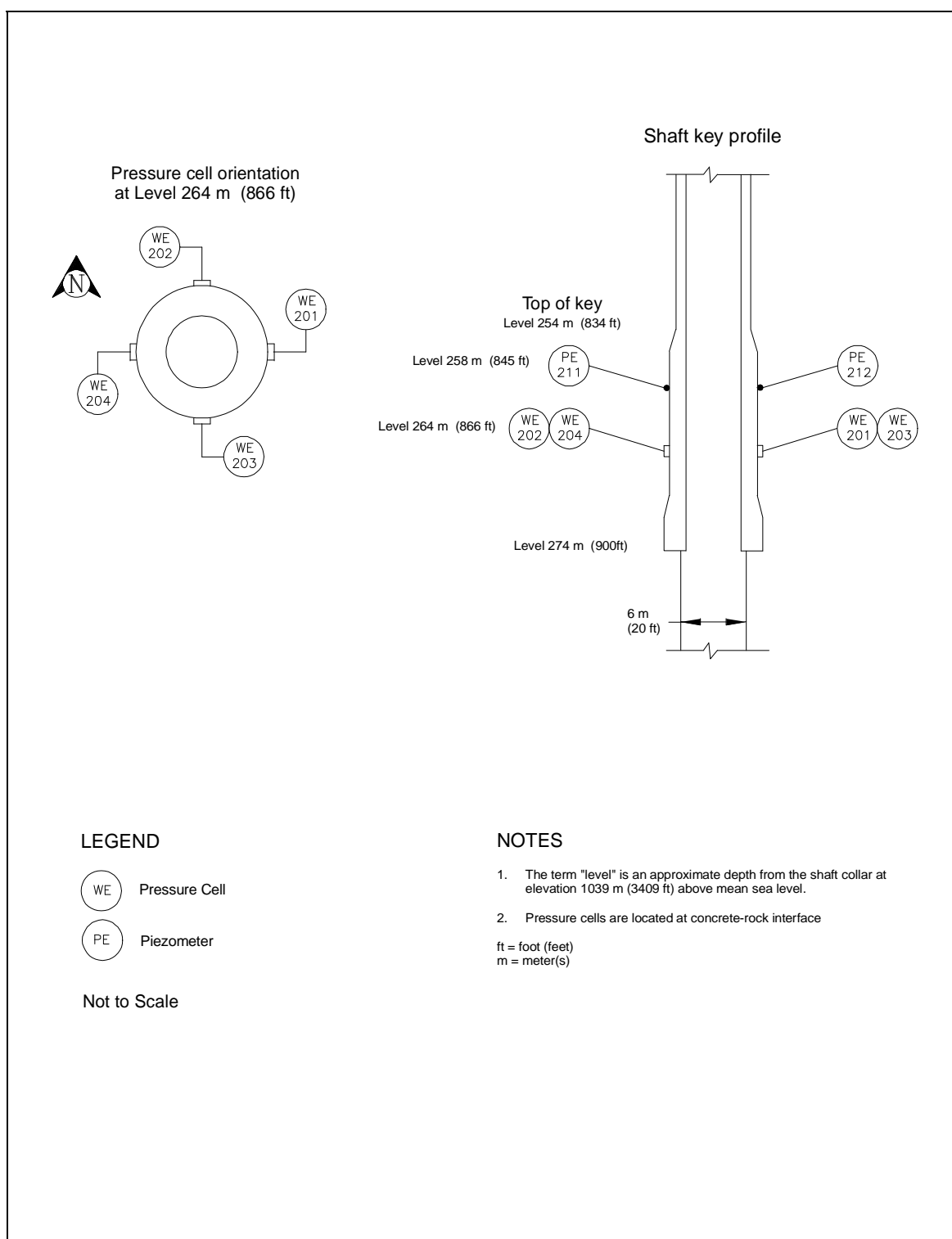


Figure 3-6 - Waste Shaft Key Instrumentation

3.3 Exhaust Shaft

The Exhaust Shaft was drilled from September 22, 1983, to November 29, 1984, to establish a route from the underground facility to the surface for exhaust air. Stratigraphic mapping was conducted from July 16, 1984, to January 18, 1985, (DOE,

1986c). The Exhaust Shaft is lined with nonreinforced concrete from the surface to the top of the shaft key at a depth of 257 m (844 ft). The liner thickness increases from 25 to 41 cm (10 to 16 in.) over that interval. The Exhaust Shaft key is 19 m (63 ft) long and 1 m (3.5 ft) thick. The shaft diameter below the key is 5 m (15 ft) and the interval below the key is lined with wire mesh anchored by rock-bolts. The shaft terminates at the facility horizon, at a depth of approximately 655 m (2,150 ft). There is no excavated shaft sump. Figure 3-7 illustrates the Exhaust Shaft stratigraphy.

3.3.1 Shaft Observations

Quarterly remote video inspections of the shaft indicate that the shaft is in satisfactory condition and no modifications were made during this reporting period.

In March 1995 a scheduled inspection revealed a thin stream of water emerging from the liner into the shaft, at a depth of approximately 23-to-24 m (75 to 80 ft) below the shaft collar. A program was initiated to investigate the source and extent of the water. Results from that program are published separately (Intera, 1997; IT, 1997). A catchment basin was installed at the base of the Exhaust Shaft in 1995 to collect the excess fluid. The volume of water removed from the Exhaust Shaft catchment basin during this reporting period ranged from 0 to over 10,500 liters (0 to 2,775 gallons) in any one week. The average weekly volume over the entire reporting period was approximately 1075 liters (285 gallons). The volume of water pumped from the Exhaust Shaft catchment basin was higher during the summer months than the winter months. The volume of brine reaching the catchment basin is also a function of the mode of ventilation, volume of ventilation air flow, and temperature and humidity of the ventilation air.

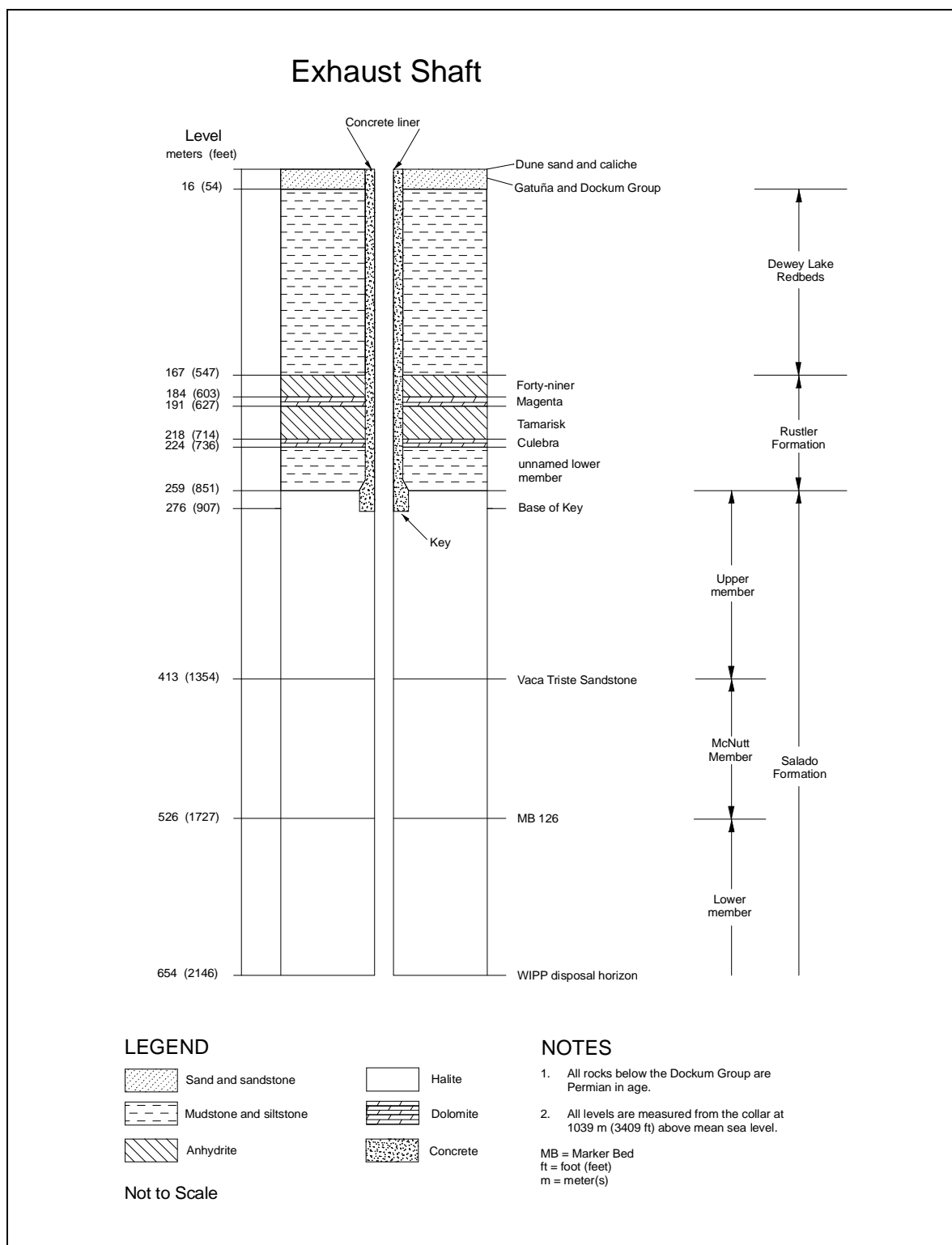


Figure 3-7 - Exhaust Shaft Stratigraphy

3.3.2 Instrumentation

The Exhaust Shaft was equipped with geomechanical instrumentation in two stages. Earth pressure cells were installed behind the liner key in November 1984. Piezometers and nine multiposition borehole extensometers were installed during November and December 1985. Figures 3-8 and 3-9 illustrate the instrumentation configuration.

Data collection from eight of the nine extensometers was restarted during this reporting period. Data acquisition problems had not allowed data collection from these extensometers since April 1996. Table 3-2 summarizes information regarding collar displacement measurements from these extensometers.

Table 3-2
Collar Displacement at Exhaust Shaft Extensometers

Shaft Level Meters (Feet)	Extensometer Orientation	Total Collar Displacement	
		Centimeters	Inches
329 (1,078)	N75°E	0.099	0.039
	N45°W	0.058	0.023
	S15°W	Instrument malfunction	
480 (1,573)	N75°E	0.701	0.276
	N45°W	0.724	0.285
	S15°W	0.752	0.296
630 (2,066)	N75°E	3.564	1.403
	N45°W	4.940	1.945
	S15°W	2.626	1.034

Thirteen of the twenty-one piezometers installed remain in working condition. The fluid pressure readings from the working piezometers at the end of the reporting period range from -30 KPa (-4.3 psi) at the 166-m (544-ft) level to almost 1,000 KPa (145 psi) at both the 220-m (721-ft) level and the 187.5-m (615-ft) level. Maximum pressure readings from the working piezometers during this reporting period were consistent with maximum readings from the previous reporting period with many of the recorded pressures having decreased slightly.

Two earth pressure cells that had been functioning properly until the last reporting period continue to provide erratic pressure readings. It is assumed that these instruments have malfunctioned. Currently there are no properly functioning earth pressure cells in the Exhaust Shaft.

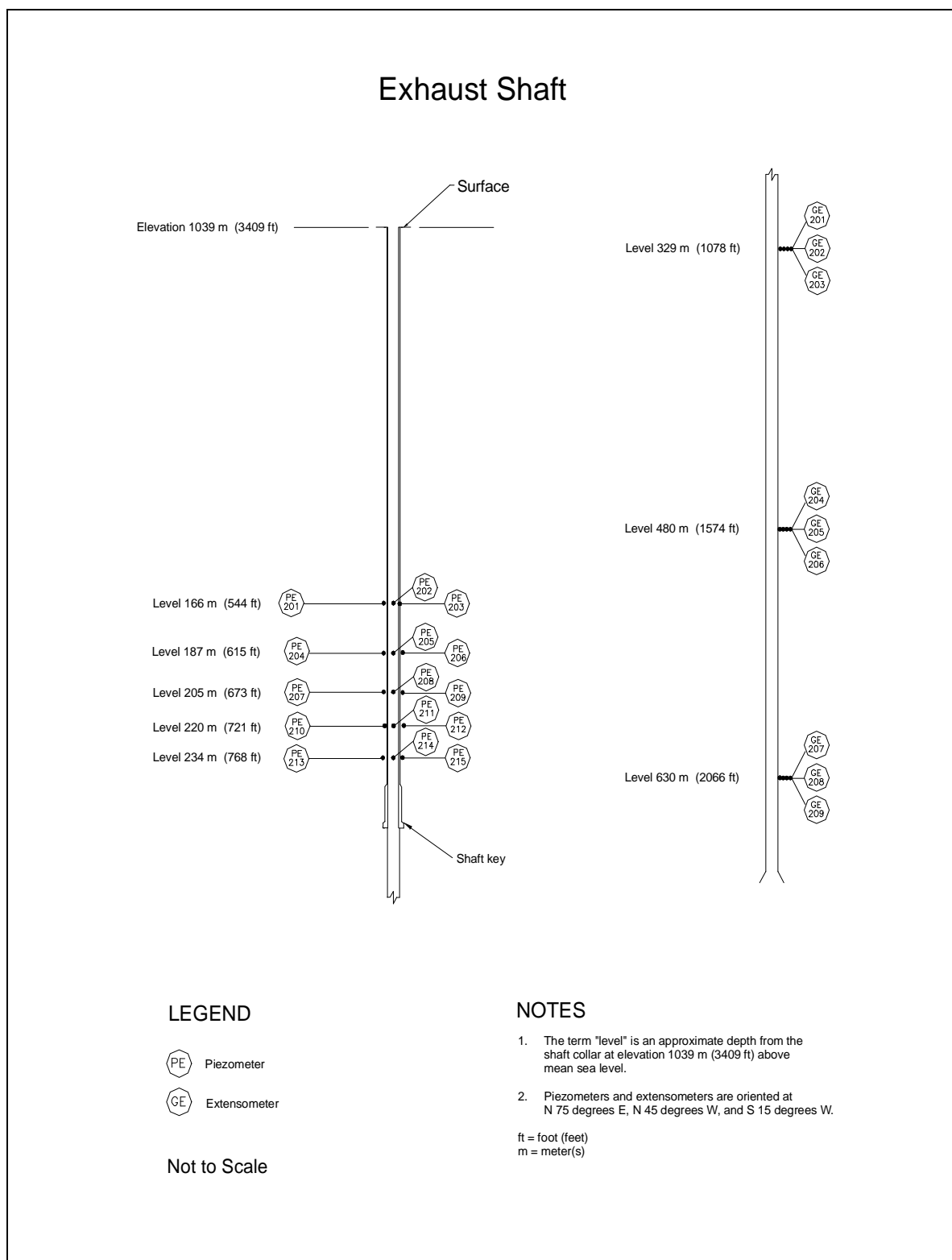


Figure 3-8 - Exhaust Shaft Instrumentation (Without Shaft Key)

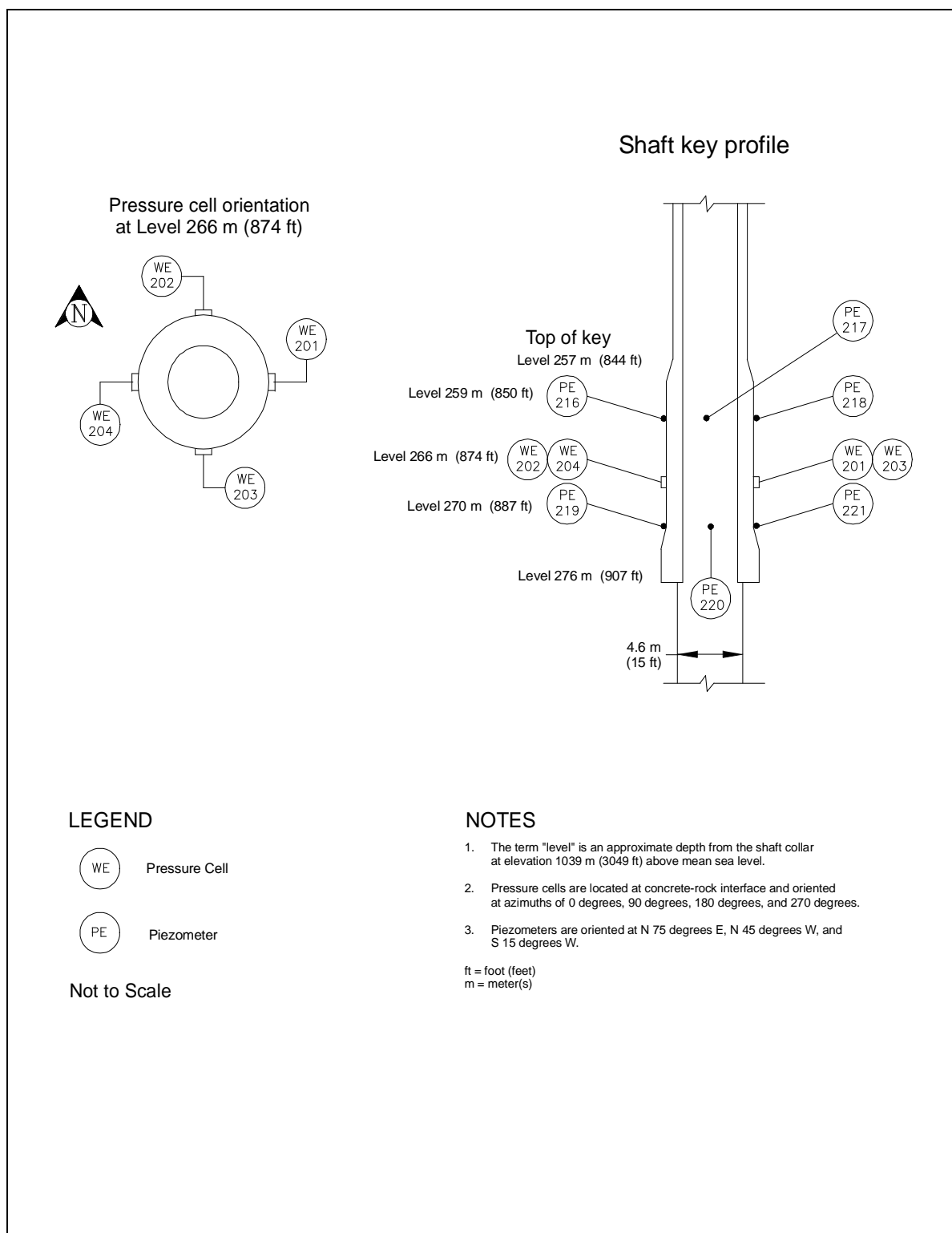


Figure 3-9 - Exhaust Shaft Key Instrumentation

3.4 Air Intake Shaft

The Air Intake Shaft was drilled from December 4, 1987, to August 31, 1988, to establish a primary route for surface air to enter the repository. Stratigraphic mapping was conducted from September 14, 1988, to November 14, 1989 (Holt and Powers, 1990). The Air Intake Shaft is lined with nonreinforced concrete from the surface to the bottom of the shaft key at a depth of 275 m (903 ft). The Air Intake Shaft key is 25 m (81 ft) long with an inside diameter of 5 m (16 ft). The diameter below the shaft key is 6 m (20 ft), and the shaft is unlined below the key to the facility horizon at a depth of 655 m (2,150 ft). The Air Intake Shaft has no sump. Figure 3-10 illustrates the Air Intake Shaft stratigraphy.

3.4.1 Shaft Performance

Weekly visual inspections were performed on the Air Intake Shaft during this reporting period and the shaft was found to be in satisfactory condition.

3.4.2 Instrumentation

Sandia National Laboratories/New Mexico (SNL/NM) installed geomechanical instruments in the shaft in 1988. SNL/NM maintains responsibility for the operation of all of the instruments located in the Air Intake Shaft as well as for data acquisition and instrument maintenance.

SNL/NM has continuously monitored these instruments since their installation. Data from these instruments are available from SNL/NM by request. Some data from these instruments have been reported by SNL/NM in two separate documents (Munson, et. al., 1995; Holcomb, 1997).

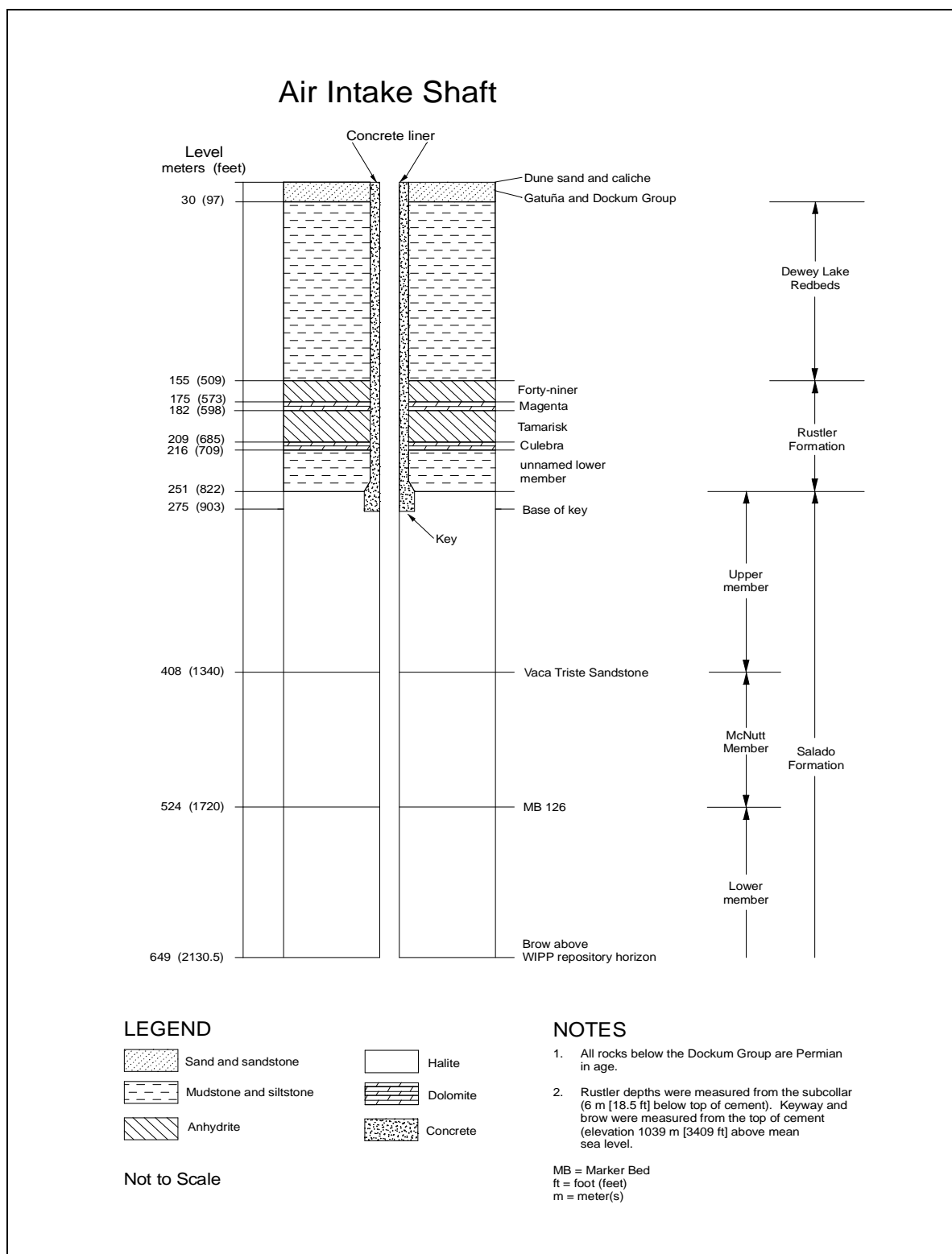


Figure 3-10 - Air Intake Shaft Stratigraphy

4.0 PERFORMANCE OF SHAFT STATIONS

This chapter describes the instrumentation and geomechanical performance of the enlarged working areas (called shaft stations) around the intersections of the Salt Handling Shaft, Waste Shaft, and the Air Intake Shaft, with the underground facility. The Exhaust Shaft does not have an enlarged shaft station.

4.1 Salt Handling Shaft Station

The Salt Handling Shaft Station was excavated between May 2 and June 3, 1982, by drilling and blasting. In 1987 the station was enlarged, removing the roof beam up to Anhydrite "b" between S90 and N20 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 27.5 m (90 ft) long and 10-to-12 m (32-to-38 ft) wide. The height of the station south of the shaft is 5.5 m (18 ft). The station dimensions north of the shaft are approximately 9 m (30 ft) long, 10- to 11-m (32- to 35-ft) wide, and 5.5 m (18 ft) high. The shaft extends approximately 43 m (140 ft) below the facility horizon in order to accommodate the skip loading equipment and to act as a sump. Figure 4-1 shows a generalized cross section of the station.

4.1.1 Modifications to Excavation and Ground Control Activities

The Salt Handling Shaft Station underwent a major refurbishing during this reporting period. Work included repair of steel sets, realignment of the shaft and pocket steel, replacement of shaft gates, installation of new deck plates around the shaft, repair of the grizzly, and the milling of the floor in the shaft station area. The work was completed during the week of March 26, 1999.

4.1.2 Instrumentation

Geomechanical instrumentation was installed in the Salt Handling Shaft Station between June 1982 and February 1983, with subsequent reinstallation of extensometers and convergence points as necessary. Figure 4-2 shows the instrument locations in the Salt Handling Shaft Station before the roof beam was removed in 1987. Affected instruments were either removed, or readings were suspended prior to mining the roof beam. Figure 4-3 shows the instrument locations after the roof beam was taken down.

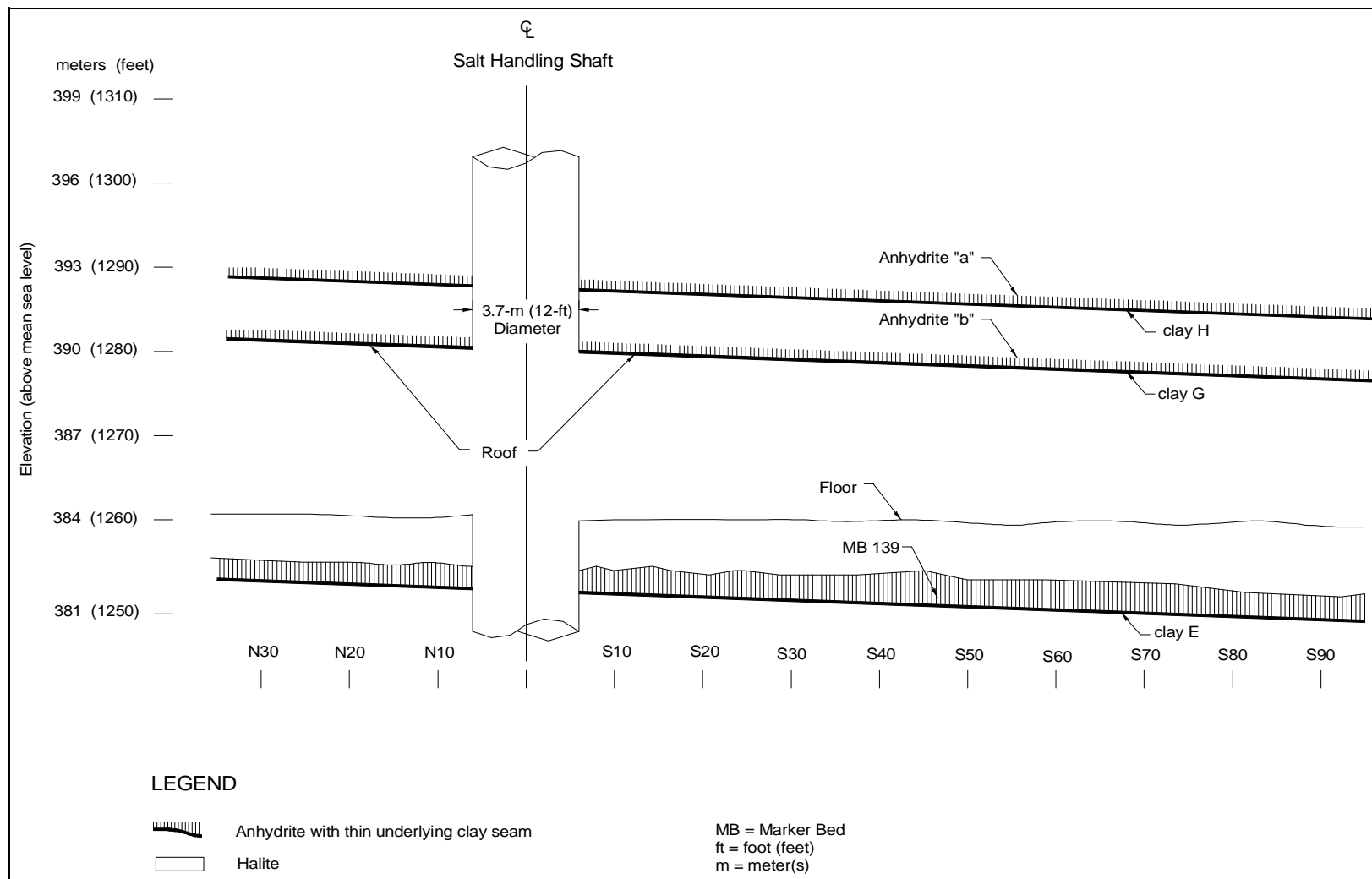


Figure 4-1 - Salt Handling Shaft Station Stratigraphy

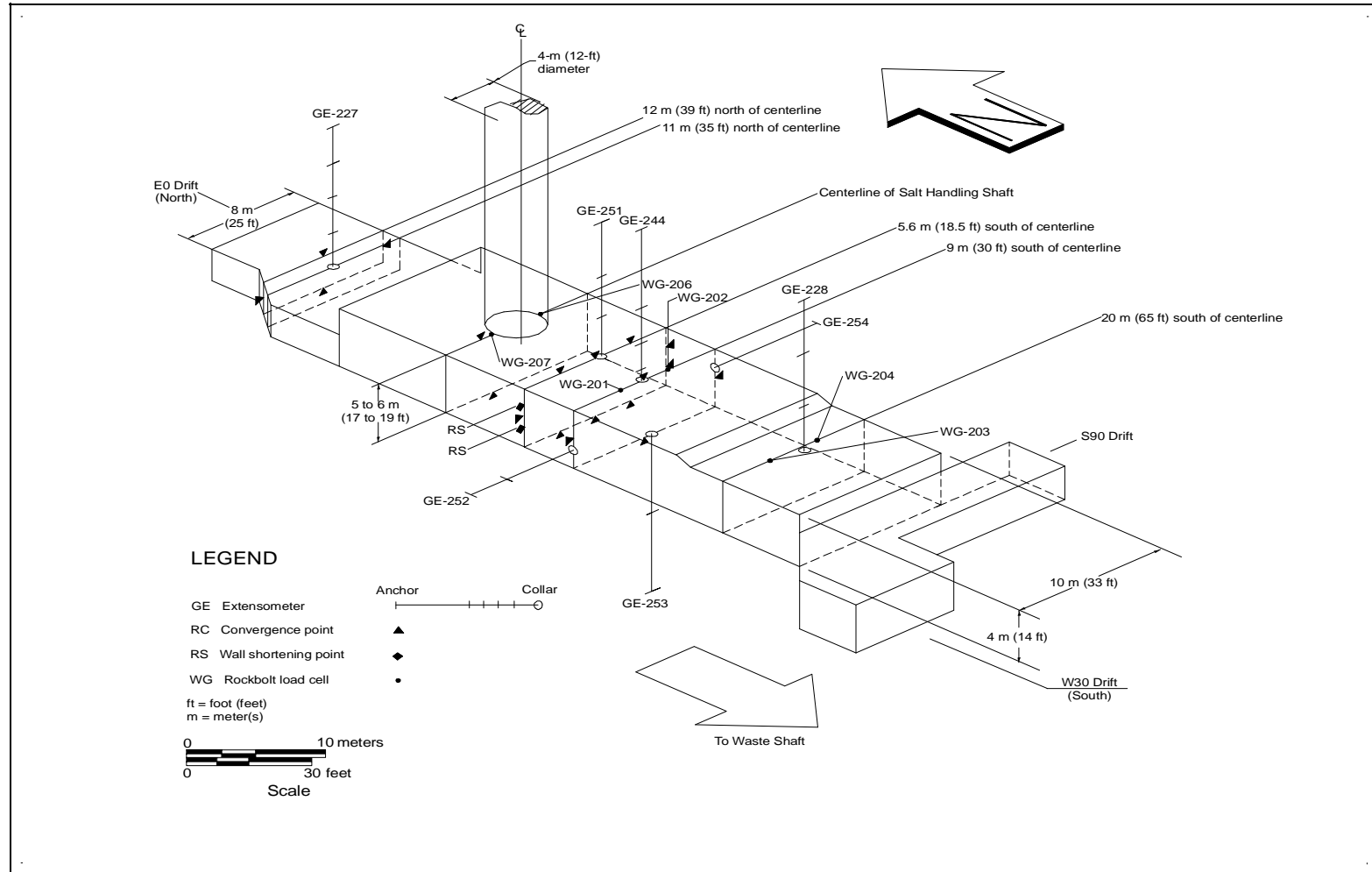


Figure 4-2 - Salt Handling Shaft Station Instrumentation Before Roof Beam Excavation

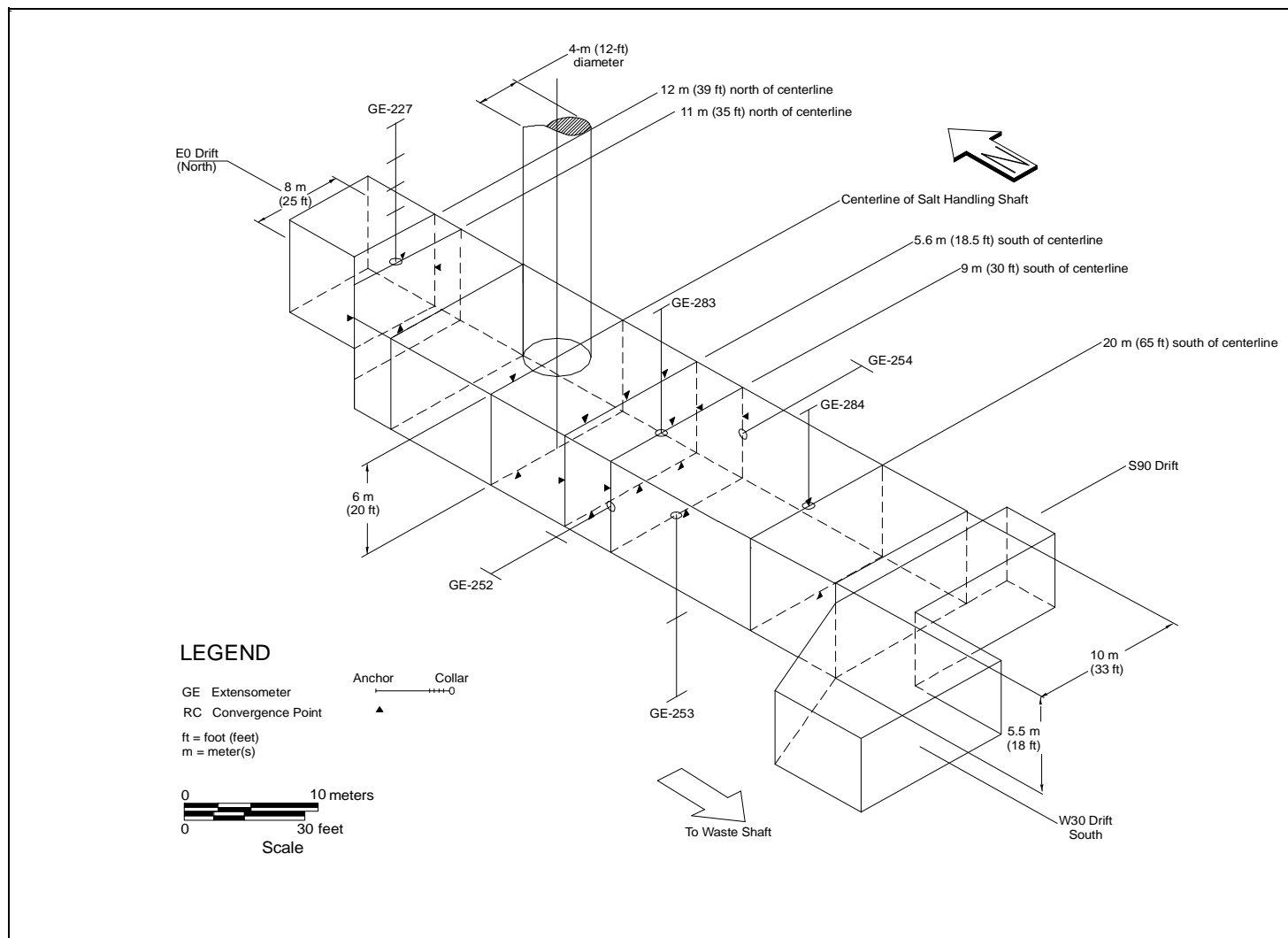


Figure 4-3 - Salt Handling Shaft Station Instrumentation After Roof Beam Excavation

There are three extensometers located in the Salt Handling Shaft Station. Because of instrument malfunctions of all three extensometers, there are no extensometer data for the Salt Handling Shaft Station for this reporting period. Five vertical convergence point arrays and one horizontal convergence chord, located at E0-N39, are currently monitored. All of the vertical convergence point arrays, except E0-S65, were replaced during the refurbishment of the Salt Shaft Station. Table 4-1 summarizes the vertical closure rates in the Salt Handling Shaft Station from June 1996 through June 1999. Salt Handling Shaft Station vertical closure rates have remained relatively consistent during the previous three reporting periods and have reduced from 4 to 27 percent during this reporting period (compared to the previous reporting period).

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

Location		June 1996 Closure Rate cm/yr (in./yr)	June 1997 Closure Rate cm/yr (in./yr)	June 1998 Closure Rate cm/yr (in./yr)	June 1999 Closure Rate cm/yr (in./yr)
E0-N39	Drift centerline	5.01 (1.97) ^a	4.76 (1.87)	4.90 (1.93)	3.71 (1.46)
E0-W12	Along west rib	2.09 (0.82)	1.87 (0.73)	2.02 (0.79)	1.75 (0.69)
E0-S18	Along east rib	4.19 (1.65)	4.37 (1.72)	3.59 (1.41)	3.44 (1.35)
E0-S18	Along west rib	2.65 (1.04)	2.42 (0.95)	2.64 (1.04)	2.10 (0.83)
E0-S18	Drift centerline	3.82 (1.50)	3.58 (1.41)	3.78 (1.49)	3.12 (1.23)
E0-S30	Drift centerline	4.06 (1.60)	3.83 (1.51)	3.92 (1.54)	3.31 (1.30)
E0-S65	Drift centerline	3.08 (1.21)	2.96 (1.16)	3.01 (1.19)	2.20 (0.87)

^a Closure rate based on data that are less than one complete reporting year.

cm/yr = centimeter(s) per year.

in./yr = inch(es) per year.

4.2 Waste Shaft Station

The Waste Shaft Station was initially excavated with a continuous miner as a ventilation connection to a 2-m (6-ft) diameter exhaust shaft in November 1982. In 1984, the station was enlarged to a height of 4.5-to-6 m (15-to-20 ft) and a width of 6-to-9 m (20-to-30 ft). The station is approximately 46 m (150 ft) long. In 1988 the station walls were trimmed and concrete was placed on the floor. In February 1991 a portion of the concrete slab approximately 16 m (53 ft) long, 7 m (23 ft) wide, and 50 cm (18 in.) thick was removed. During the 1994-1995 reporting period approximately 9 m (30 ft) of the remaining portion of the concrete slab was removed. Figure 4-4 shows a cross section of the Waste Shaft Station.

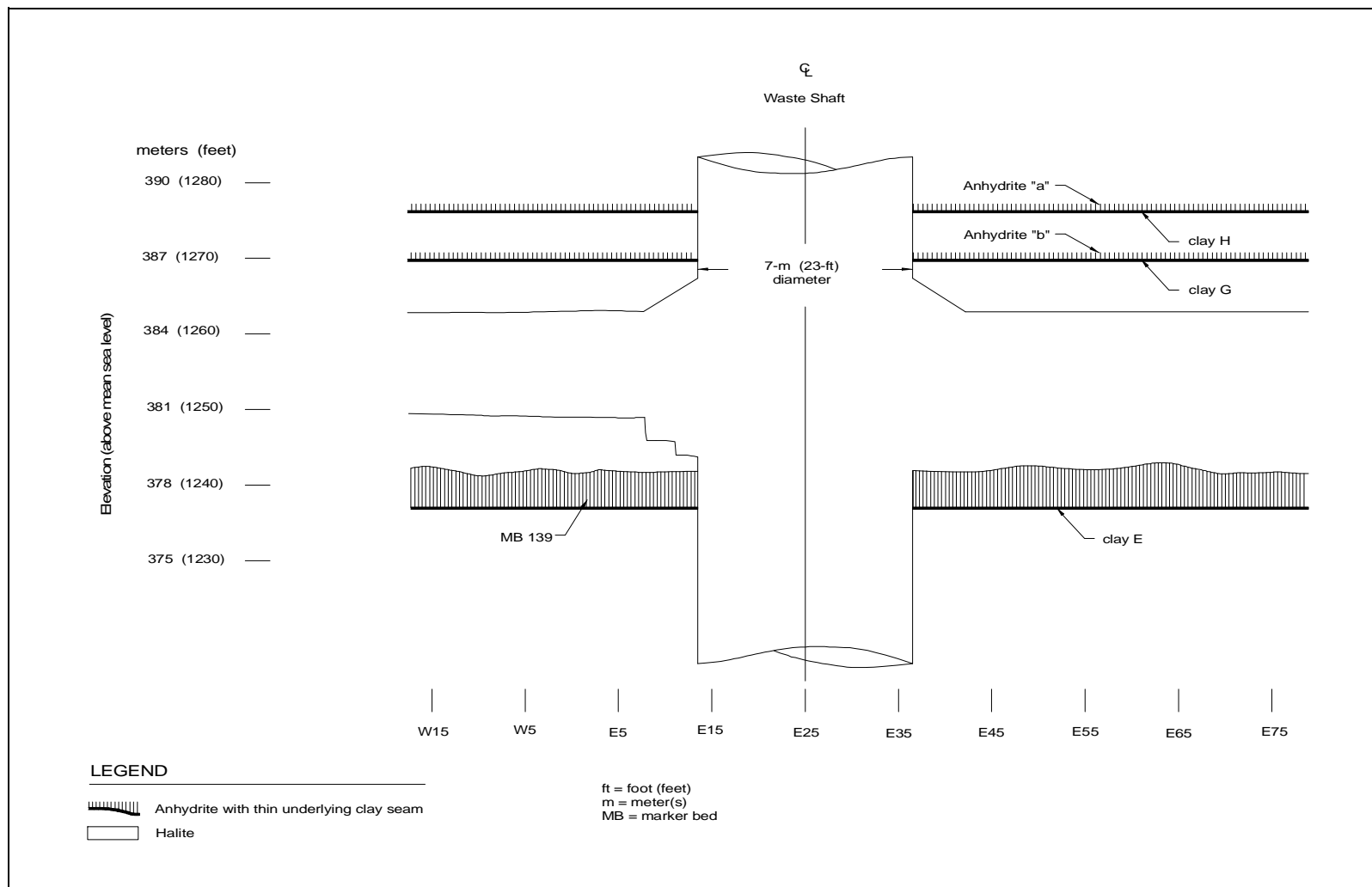


Figure 4-4 - Waste Shaft Station Stratigraphy

4.2.1 Modifications to Excavation and Ground Control Activities

The Waste Shaft Station underwent a refurbishment during this reporting period in preparation for the receipt of waste. In November 1998, crews completed the trimming of the Waste Shaft Station floor, removal of the remaining concrete, and the installation and alignment of new rail ties and rails. Other ground control activities performed in the Waste Shaft Station during this reporting period consisted of routine rib maintenance and the routine replacement of failed rock-bolts.

4.2.2 Instrumentation

Instruments were initially installed in the Waste Shaft Station between November 12 and December 2, 1982. Figure 4-5 illustrates the instrument locations in the Waste Shaft Station before it was enlarged in 1988. Figure 4-6 illustrates the locations after enlargement. Currently there are three working extensometers in the roof of the Waste Shaft Station (located at W30, E35, and E140). In addition, convergence points are monitored at E30 (horizontal convergence points only) and E90.

Table 4-2 summarizes the history of the roof extensometers in the Waste Shaft Station. The extensometers remain in good working condition and the data indicate a relatively steady displacement rate. The annual displacement rate calculated for extensometer 51X-GE-00279, located in S400 drift at E140 is considerably higher than the rate calculated for the previous reporting period. However, the rate from the previous reporting period appears to be anomalously low and the rate from the present reporting period is consistent with historic displacement rates for this instrument.

Table 4-3 summarizes the annual vertical closure rates calculated from convergence point data for the 1996 through 1999 reporting periods. The data indicate an increase in vertical closure rates along the drift centerline and north rib of S400 (Waste Shaft Station) at S90 of 21 and 18 percent, respectively, relative to the annual rate of closure from the previous reporting period. This area will continue to be monitored closely for any signs of opening instability.

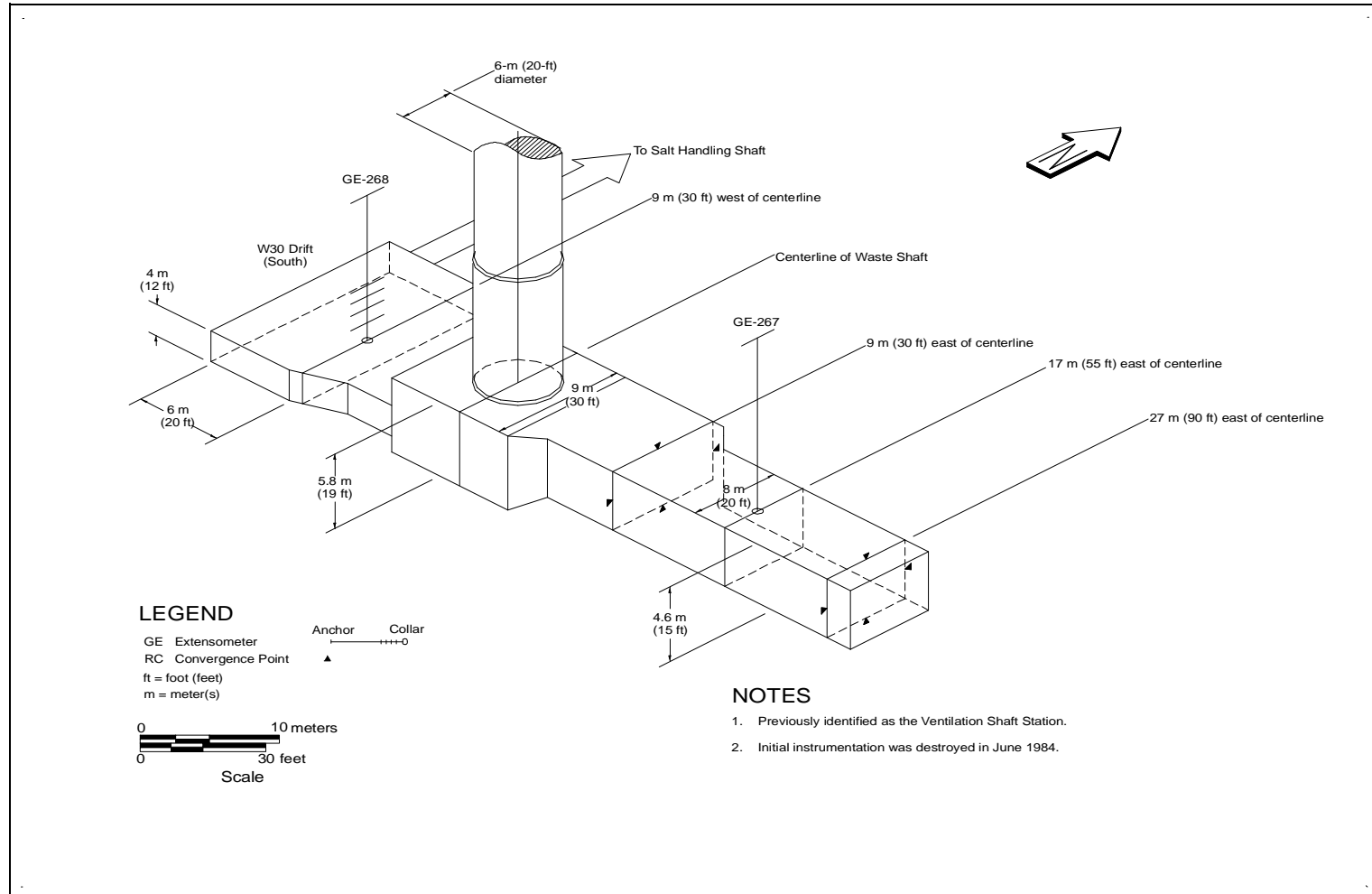


Figure 4-5 - Waste Shaft Station Instrumentation Before Wall Trimming

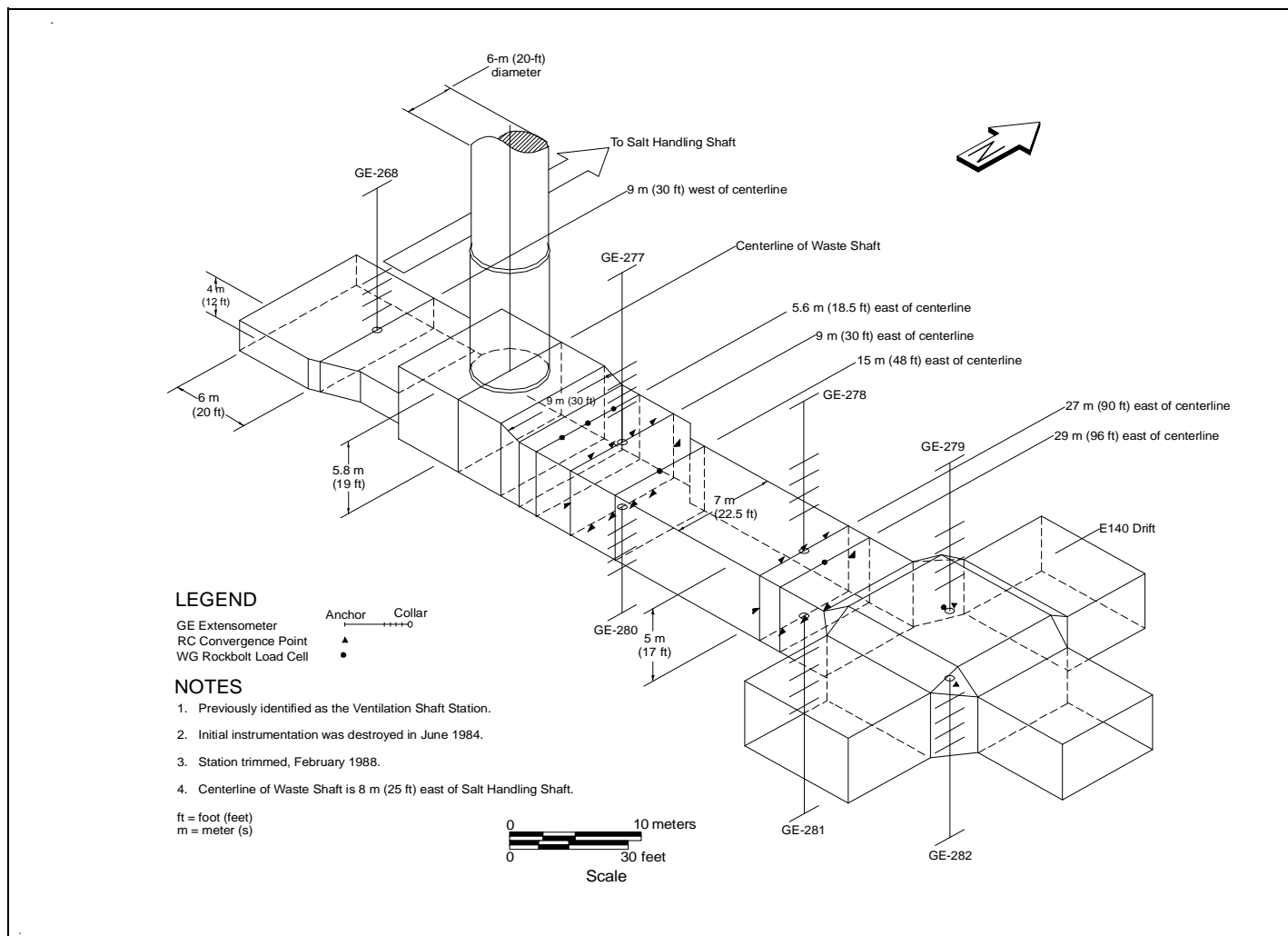


Figure 4-6 - Waste Shaft Station Instrumentation After Wall Trimming

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

Instrument	Location	Date Installed	Last Date Read	Collar Displacement Relative to Deepest Anchor cm (in.)	Displacement Rate cm/yr (in./yr)
51X-GE-00268	S400-W30	10/24/1984	6/7/1999	16.599 (6.535)	0.875 (0.344)
51X-GE-00277	S400-E35	11/29/1988	6/22/1999	19.545 (7.695)	0.501 (0.197)
51X-GE-00279	S400-E140	11/29/1988	6/22/1999	18.603 (7.324)	1.715 (0.675)

cm = centimeter(s)

in = inch(es)

m = meter(s)

yr = year

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

Location		1996 Closure Rate cm/yr (in./yr)	1997 Closure Rate cm/yr (in./yr)	1998 Closure Rate cm/yr (in./yr)	1999 Closure Rate cm/yr (in./yr)
S400-E90	Along North Rib	3.26 (1.28)	3.40 (1.34)	3.50 (1.38)	4.23 (1.67)
S400-E90	Drift Centerline	4.77 (1.88)	4.73 (1.86)	4.66 (1.83)	5.49 (2.16)
S400-E90	Along South	4.51 (1.77)	4.23 (1.66)	4.29 (1.69)	4.36 (1.72)

cm/yr = centimeter(s) per year.

in./yr = inch(es) per year.

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

4.3 Air Intake Shaft Station

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

4.3.1 Modifications to Excavation and Ground Control Activities

No modifications or ground control activities were performed in the Air Intake Shaft Station during this reporting period.

4.3.2 Instrumentation

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

5.0 PERFORMANCE OF ACCESS DRIFTS

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

5.1 Modifications to Excavation and Ground Control Activities

In preparation for extending the four major north-south access drifts toward Panel 2, E140 drift and W170 drift were enlarged along with S2180 crosscut drift. Trimming, scaling, and floor milling activities were performed as necessary in many areas throughout the WIPP underground. Table 5-1 summarizes these activities. Table 5-1 also summarizes ground control activities (e.g., rock-bolting and installing wire mesh) performed in various locations in the access drifts.

5.2 Instrumentation

Figure 5-1 shows the location of all of the geotechnical instruments within the WIPP access drifts. This section discusses instrumentation details and locations for each instrumentation type.

5.2.1 Borehole Extensometers

There were no new extensometers installed during this reporting period. All operating underground extensometers continue to be monitored. Remotely and manually read extensometers are typically read monthly, although some instruments may be read more frequently.

5.2.2 Convergence Points

Instrumentation installed during this reporting period was limited to the installation and replacement of convergence point arrays. Convergence points were reinstalled in various locations throughout the WIPP underground where rib, back, or floor trimming activities had been performed during this and the previous reporting period. Horizontal and vertical convergence point arrays were installed in the W170 drift between S90 and S2180 to replace points that were removed when the W170 drift was trimmed in preparation as the main haulage route for mining toward Panel 2. 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. Figure 5-1 shows the locations of all of the monitored convergence point arrays in the WIPP access drifts.

Table 5-1
Summary of Modifications and Ground Control Activities in the Access Drifts
July 1, 1998, Through June 30, 1999

Date Completed	Location	Work Performed
July 1998	W170 from S1000 to S1600	Installation of wire mesh anchored by rock-bolts on back and west rib
July 1998	W170 from S90 to S300	Trimming and scaling of ribs and installation of wire mesh on back and ribs
July 1998	N150 overcast – East brow	Installation of steel mats supported by rock-bolts
August 1998	S90 from W170 to Room Q entry	Trimming and scaling of south rib
August 1998	E140 from S2050 to S2200	Installation of wire mesh anchored by rock-bolts on east rib
August 1998	E140 from S700 to S1950	Floor milling
September 1998	S1950 from W170 to E140	Floor milling
October 1998	W170 from S90 to S2180	Floor milling
October 1998	W30 from S300 to S375	Installation of wire mesh anchored by rock-bolts to contain low angle fracture
October 1998	E300 at S1950 intersection	Installation of wire mesh anchored by rock-bolts in rib and brow
October 1998	E300 from S1600 to S1900	Installation of wire mesh anchored by rock-bolts
October 1998	S90 from W640 to W820	Installation of wire mesh anchored by rock-bolts on south rib
November 1998	W170 from S450 to S700	Installation of wire mesh anchored by rock-bolts on east roof
November 1998	S2180 from W30 to W170	Trimming of north rib and install wire mesh anchored by rock-bolts
November 1998	E140 from S1950 to S2185	Installation of roof support system using rock-bolts
December 1998	E140 from S120 to N150	Installation of rock-bolts in roof
January 1999	E140 from S2000 to S2180	Trimming of west rib
January 1999	W170 from S1080 to S1280	Installation of wire mesh anchored by rock-bolts
January 1999	W170 from S90 to N150	Floor milling
February 1999	N300 at W400	Trimming and scaling of north rib; Installation of wire mesh anchored by rock-bolts
March 1999	S2180 from W30 to E140	Trimming of north rib; Installation of wire mesh anchored by rock-bolts
May 1999	S2180 from W30 to E140	Trimming of south rib; Installation of wire mesh anchored by rock-bolts
May 1999	E300 at S90	Trimming of east rib
May 1999	S400 at E300 intersection	Installation of wire mesh anchored by rock-bolts at intersection miters
June 1999	W170 from N150 to N100	Trimming of east rib
June 1999	S1600 from E200 to E250	Installation of wire mesh anchored by rock-bolts on south rib
June 1999	S90 from E140 to E300	Trimming of south rib
June 1999	E300 from S90 to S200	Trimming of east rib; Rock-bolting of west rib

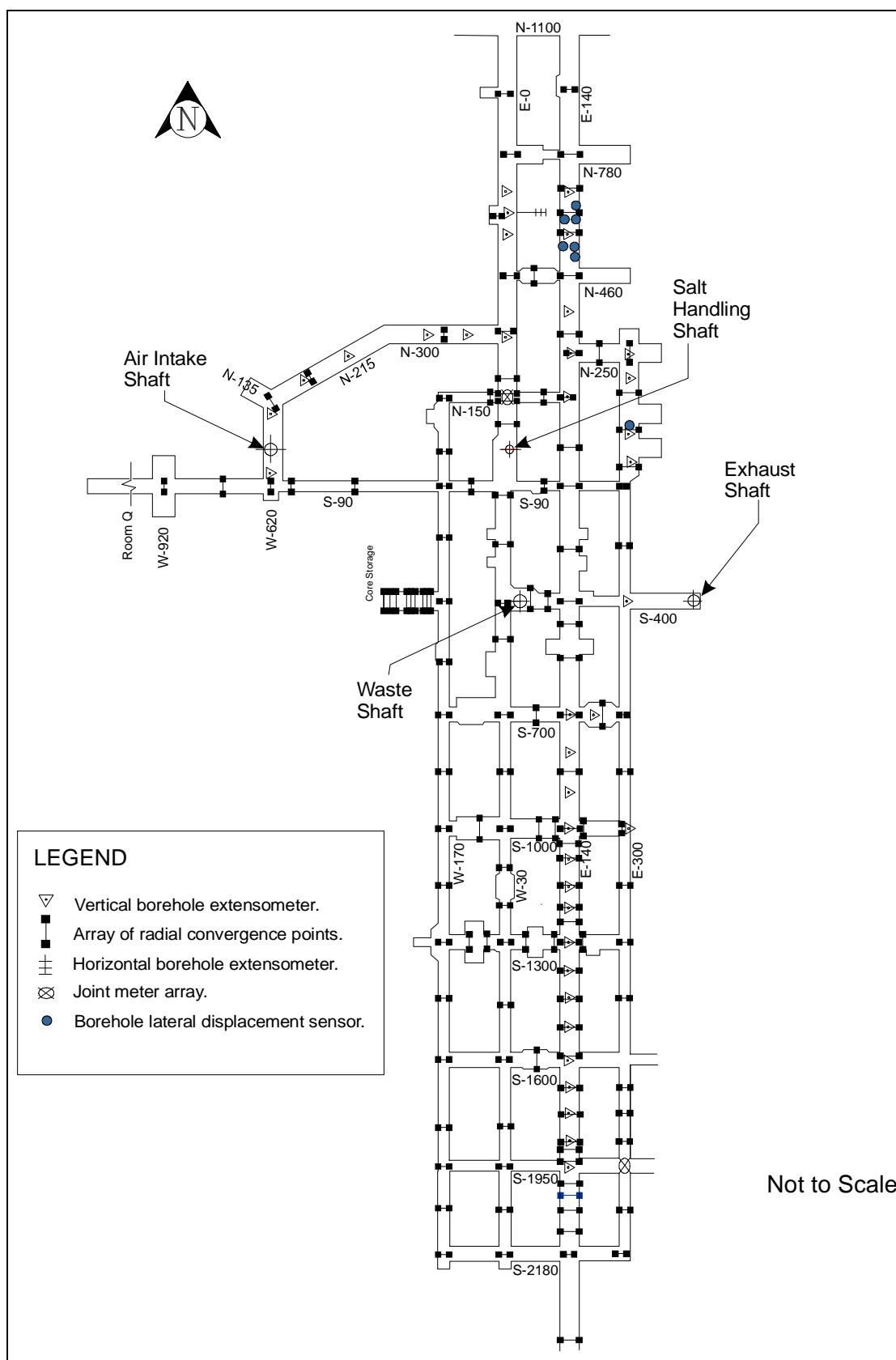


Figure 5-1 - Location of Geotechnical Instruments in the Access Drifts

Table 5-2
New and Replaced Convergence Points Installed in the Access Drifts
July 1, 1998, Through June 30, 1999

Instrument Type	N/R	Field Tag	Location	Date Installed
Convergence Points	R	N140-W50-2 (B-D)	N150 Drift at W50 (Rib-to-Rib)	9/10/1998
Convergence Points	R	N215-W500-2 (B-D)	N215 Drift at W500 (Rib-to-Rib)	9/10/1998
Convergence Points	R	S90-W770-2 (B-D)	S90 Drift at Room Q entry (Rib-to-Rib)	9/10/1998
Convergence Points	R	W170-S1600-2 (A-C)	W170 Drift at S1600 Drift (Roof-to-Floor)	10/30/1998
Convergence Points	R	W170-S1779-2 (A-C)	W170 Drift at S1779 (Roof-to-Floor)	10/30/1998
Convergence Points	R	W170-S1950-2 (A-C)	W170 Drift at S1950 Drift (Roof-to-Floor)	10/30/1998
Convergence Points	R	W170-S2060-2 (A-C)	W170 Drift at S2060 (Roof-to-Floor)	10/30/1998
Convergence Points	R	W170-S2180-2 (A-C)	W170 Drift at S2180 Drift (Roof-to-Floor)	10/30/1998
Convergence Points	R	W170-S1445-3 (A-C)	W170 Drift at S1445 (Roof-to-Floor)	10/30/1998
Convergence Points	R	W30-S700-2 (A-C)	W30 Drift at S700 Drift (Roof-to-Floor)	10/30/1998
Convergence Points	R	E140-S1456-3 (A-G)	E140 Drift at S1456 (Roof-to-Floor)	11/10/1998
Convergence Points	R	N300-W170-1 (B-D)	N300 Drift at W170 (Rib-to-Rib)	1/26/1999
Convergence Points	R	W170-S90-1 (A-C)	W170 Drift at S90 Drift (Roof-to-Floor)	1/26/1999
Convergence Points	R	W170-S850-5 (A-E, H-F)	W170 Drift at S850 (Roof-to-Floor; Rib-to-Rib)	1/26/1999
Convergence Points	R	W170-S1000-1 (A-C)	W170 Drift at S1000 Drift (Roof-to-Floor)	1/26/1999
Convergence Points	R	W170-S1150-3 (A-E, B-D)	W170 Drift at S1150 (Roof-to-Floor; Rib-to-Rib)	1/26/1999
Convergence Points	R	E0-N80-1 (A-C)	E0 Drift at N80 (Roof-to-Floor)	4/13/1999

N = New instrument

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

5.3 Analysis of Extensometer and Convergence Point Data

Extensometer data are obtained by measuring the displacement from the instrument head (collar) to each fixed anchor of the extensometer. 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. Convergence measurements are a primary means of identifying areas where conditions may be becoming unstable. These measurements are made, at a minimum, every two months throughout the WIPP underground. Extensometer displacement rates and convergence 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.

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

There are 38 active borehole extensometers being monitored at various locations in the access drifts. The majority of these instruments are located in the E140 drift. Where data are available annual displacement rates were calculated for each of the active extensometers and compared to the annual displacement rates from the previous reporting period. Significant percentage increases in displacement rates were observed in the E140 drift at the intersection with S700 drift, in the S700 drift at E220, and in the E0 drift at N300. Percentage increases in displacement rates at these locations were 86.5%, 22.8 percent, and 21.9 percent, respectively. Annual displacement rates at each of these three locations during this reporting period were 2.609 cm/yr (1.027 in./yr) at E140/S700, 1.416 cm/yr (0.557 in./yr) at S700/E220, and 1.727 cm/yr (0.680 in./yr) at E0/N300.

Where possible, annual closure rates were calculated from convergence point array data from the access drifts. A complete tabulation of these convergence point data and calculated closure rates are presented in the supporting data document for this report.³ Locations with increases in annual vertical and horizontal closure rates of greater than 10 percent are listed in Table 5-3 and Table 5-4.

Further analysis of these accelerations has shown many of them to be relatively insignificant. Others, such as in W170 drift, had the rates reduce back to previous reporting period rates after the drift was trimmed. This short-term increase in rate is

³Instrumentation data and data plots are available in "Geotechnical Analysis Report for July 1998-June 1999 Supporting Data." This document is available upon request from Westinghouse, Waste Isolation Division. Refer to Foreword and Acknowledgments for details and address.

likely due to the large scale trimming being performed in the W170 drift. An analysis using the running median of the convergence rate was used on the locations in Tables 5-3 and 5-4 where ground control measures (trimming or rock-bolting) were not instituted during this reporting period. None of the convergence point pairs showed a trend of increasing convergence rates over the long-term median convergence rate.

Some of the increases in convergence rate reported in Tables 5-3 and 5-4 may be the result of inconsistencies in application of the rate calculation method. The annual vertical convergence rate for this reporting period at E140-S400 was calculated on only four months of data (June 1, 1998, through October 5, 1998 -- the last reading for this instrument). The four month period on which the rate is calculated is during the warmer summer months when rates have been observed to increase (see Section 5.4 below). Likewise, the increase in rate at E0-N80 after trimming is based on a closure rate calculated from only one reading, taken in June 1999 after the instrument was replaced on April 13, 1999.

5.4 Excavation Performance

Bimonthly assessments of underground excavations continue to indicate that convergence rates vary with seasonal temperature variations; typically increasing during the warmer summer months and decreasing during the cooler winter months. Over 400 readings are collected and assessed from convergence point pairs located throughout the WIPP underground on a regular basis.

The performance of the access drift excavations during this reporting period was within acceptable criteria. Only standard remedial ground control maintenance was required to maintain the performance of the excavations.

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

Location	Date Excavated	Convergence Rate 6/97 to 6/98 cm/yr (in./yr)	Convergence Rate 6/98 to 6/99 cm/yr (in./yr)	Increase in Convergence Rate ^a % increase	Comments
E140-S400 (A-C)	11/18/1982	4.62 (1.82)	6.07 (2.39)	31.6%	Instrument last read 10/5/1998
E140-S1150 (B-F)	12/13/1982	4.16 (1.64)	4.61 (1.81)	10.8%	
E140-S1378 (A-E)	12/17/1982	3.93 (1.55)	4.46 (1.76)	13.5%	
E140-S1378 (H-F)	12/17/1982	4.93 (1.94)	5.47 (2.15)	11.0%	
E140-S1456 (A-G)	12/17/1982	4.64 (1.83)	6.27 (2.47)	35.1%	Rate after trimming has reduced to 4.82 cm/yr
E140-S1456 (B-F)	12/17/1982	4.86 (1.91)	5.69 (2.24)	17.1%	
E140-S1534 (A-E)	12/19/1982	5.27 (2.07)	6.76 (2.66)	28.3%	
E140-S1534 (H-F)	12/19/1982	4.91 (1.93)	5.44 (2.14)	10.8%	
E140-S1917 (A-C)	12/23/1982	3.93 (1.55)	5.16 (2.03)	31.3%	Present rate of 5.16 cm/yr is less than rate during 1996 and 1997 of 6.20 cm/yr
E0-N80 (A-C)	10/15/1982	3.97 (1.56)	4.40 (1.73)	10.9%	Rate after trimming has increased to 4.71 cm/yr
W30-S700 (A-C)	8/8/1984	2.72 (1.07)	4.12 (1.62)	51.5%	Rate after trimming has reduced to 2.36 cm/yr
W30-S2180 (A-C)	7/18/1988	2.65 (1.04)	2.95 (1.16)	11.6%	
W170-S90 (A-C)	8/4/1984	1.63 (0.64)	2.96 (1.17)	81.9%	Rate after trimming has reduced to 1.93 cm/yr
W170-S1000 (A-C)	8/19/1984	1.82 (0.72)	2.32 (0.91)	26.9%	Rate after trimming has reduced to 1.89 cm/yr
W170-S1150 (A-E)	8/20/1984	1.66 (0.65)	2.01 (0.79)	21.1%	Rate after trimming has reduced to 0.75 cm/yr
W170-S1600 (A-C)	9/3/1984	2.01 (0.79)	2.29 (0.90)	14.0%	Rate after trimming has reduced to 2.02 cm/yr
W170-S2180 (A-C)	8/2/1988	2.07 (0.81)	2.46 (0.97)	19.3%	Rate after trimming has reduced to 2.19 cm/yr
S90-W100 (A-C)	7/1/1985	1.35 (0.53)	1.50 (0.59)	11.2%	

^a Increase in convergence rate is calculated from the difference between the 1997-1998 rate and the 1998-1999 rate.

cm/yr = centimeter(s) per year.

in./yr = inch(es) per year.

Table 5-4
Increases in Annual Horizontal Convergence Rates of Greater than 10 Percent
Access Drifts

Location	Date Excavated	Convergence Rate 6/97 to 6/98 cm/yr (in./yr)	Convergence Rate 6/98 to 6/99 cm/yr (in./yr)	Increase in Convergence Rate ^a % increase	Comments
E300-S1150 (C-G)	7/23/1984	1.50 (0.59)	1.68 (0.66)	11.8%	
W30-S1775 (B-D)	2/14/1986	1.63 (0.64)	1.81 (0.71)	10.8%	
N300-W170 (B-D)	10/4/1988	2.90 (1.14)	3.28 (1.29)	13.2%	Rate after trimming has reduced to 3.17 cm/yr
N215-W500 (B-D)	12/31/1987	2.36 (0.93)	3.55 (1.40)	50.8%	Rate after trimming has reduced to 2.37 cm/yr
S90-W100 (B-D)	7/1/1985	1.35 (0.53)	1.61 (0.63)	19.2%	

^a Increase in convergence rate is calculated from the difference between the 1997-1998 rate and the 1998-1999 rate.

cm/yr = centimeter(s) per year

in./yr = inch(es) per year

6.0 PERFORMANCE OF NORTHERN EXPERIMENTAL AREA

This chapter describes the geomechanical performance of the rooms and access drifts located in the Northern Experimental Area. This area includes all excavations north of the N1100 drift including the SPDV rooms, the N1400 and N1100 drifts, the E0 and E140 drifts between N1100 and N1400, and the E300 shop. This area has been deactivated. Deactivation of this area precludes direct observation of instruments or the installation of new instruments; therefore, only data from remotely read instruments are available for analysis.

6.1 Modifications to Excavation and Ground Control Activities

Access to this area was blocked in August and September 1996 by the construction of barriers in the E0 and E140 drifts at N800; therefore, no modifications or ground control activities were performed in this area during this reporting period.

6.2 Entry into Deactivated Area

In March 1999, members of the Geotechnical Engineering Section and Underground Operations made an entry into the deactivated Northern Experimental Area. The purpose for the entry was to repair/replace a data logger located in SPDV Room 4 that had failed in October 1998. Entry was made by penetrating the Omega block walls in the E0 and E140 drifts at N820. Ventilation was established prior to personnel entry. The data logger was replaced without incident and the replacement is working properly.

6.3 Instrumentation

Active, remotely read, geotechnical instrumentation located in the Northern Experimental Area consists of borehole extensometers and wire convergence meters. Figure 6-1 shows the locations of the active and inactive instruments in the Northern Experimental Area.

6.3.1 Borehole Extensometers

Data were collected remotely from seven extensometers located in the Northern Experimental Area during this reporting period. Table 6-1 presents the collar displacement relative to the deepest anchor at the end of this reporting period and the calculated displacement rate for this and the previous reporting period for each of these extensometers.

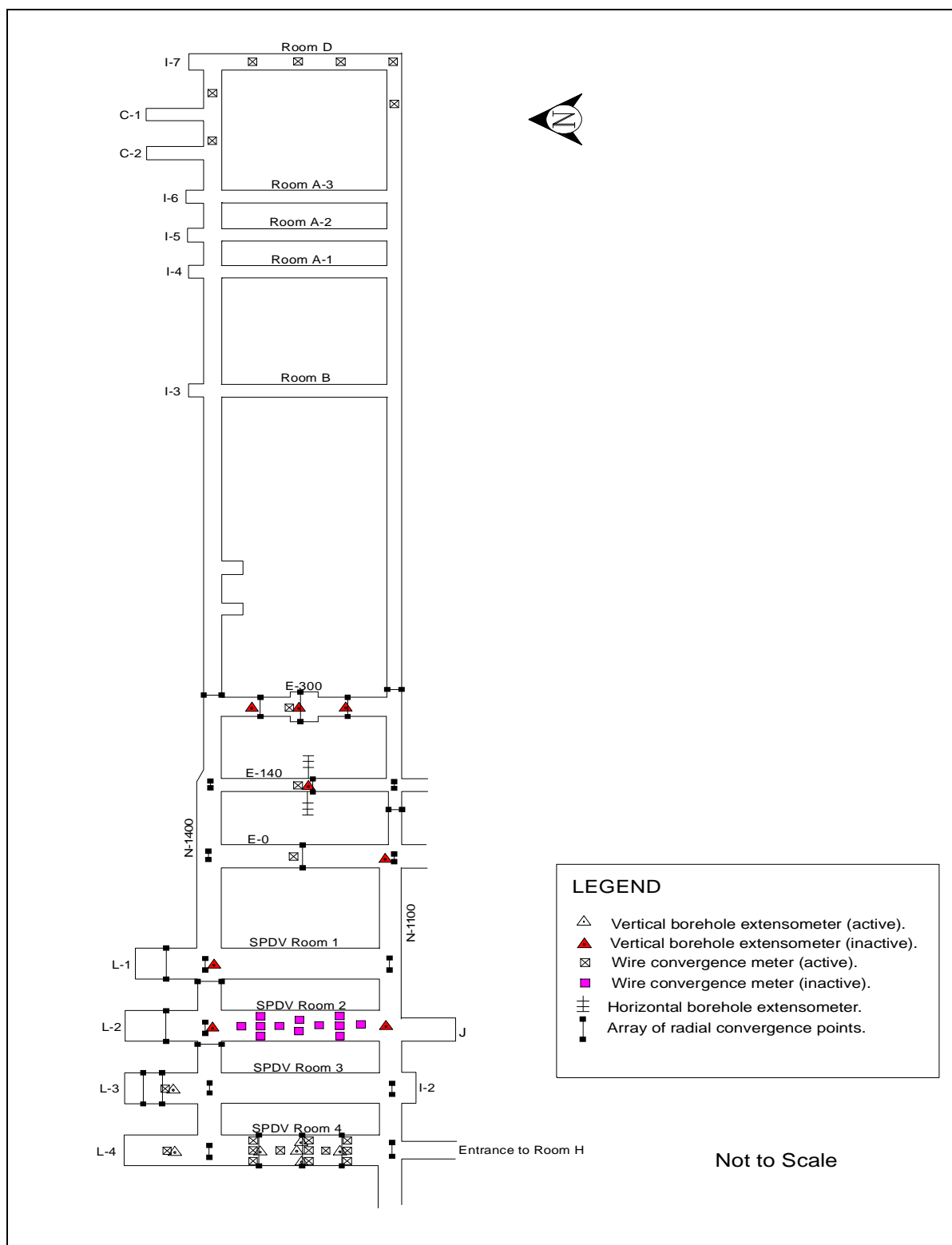


Figure 6-1 - Location of Active and Inactive Geotechnical Instruments in the Northern Experimental Area

Table 6-1
Results of Remotely Read Extensometers in the Northern Experimental Area

Location		Date of Last Reading	Collar Displacement Relative to Deepest Anchor		1997-1998 Displacement Rate	1998-1999 Displacement Rate	Percent Increase (decrease)
			(cm)	(in.)	cm/yr (in./yr)	cm/yr (in./yr)	%
Room L3	Roof	10/6/1998	10.384	4.088	3.95 (1.55)	2.72 (1.07)	-31.2
Room L4	Roof	6/14/1999	3.350	1.319	0.98 (0.39)	1.13 (0.44)	15.4
SPDV Room 4-N1325	Roof	6/14/1999	7.310	2.878	2.36 (0.93)	2.49 (0.98)	5.3
SPDV Room 4-N1250	East 1/4 Pt	6/14/1999	3.655	1.439	1.15 (0.45)	1.19 (0.47)	3.7
SPDV Room 4-N1250	Roof	6/14/1999	5.923	2.332	1.84 (0.72)	2.09 (0.82)	14.0
SPDV Room 4-N1250	West 1/4 Pt	6/14/1999	9.403	3.702	2.93 (1.15)	3.62 (1.43)	23.5
SPDV Room 4-N1175	Roof	6/14/1999	4.036	1.589	1.20 (0.47)	1.44 (0.56)	19.6

cm = centimeter(s)

in. = inch(es)

Pt = point

SPDV = Site Preliminary Design Validation Program

yr = year

6.3.2 Wire Convergence Meters

Twenty-three wire convergence meters were monitored remotely during this reporting period. Approximately half of these convergence meters are located in SPDV Room 4 with the remaining instruments distributed throughout the remainder of the Northern Experimental Area.

6.4 Excavation Performance

Within the Northern Experimental Area, SPDV Room 4, Rooms L3 and L4, drifts E0 and E140, Room D, the E300 shop, and the east end of drifts N1100 and N1400 are regularly monitored for performance. Table 6-2 presents the final readings for this reporting period and the calculated annual closure rates from wire convergence meters located in each of these areas. Based on the extensometer and wire convergence meter data, the annual closure rates within many of these monitored rooms and drifts continue to be relatively constant. Some exceptions include the east end of both N1100 and N1420 drifts, SPDV Room L3, and some portions of SPDV Room 4. Section 6.5 below discusses these increases in detail.

Table 6-2
Vertical Convergence Readings and Rates in the Northern Experimental Area
Wire Convergence Meters

Field Tag	Location	Date of Initial Reading	Date of Last Reading	Change from Initial Reading		Closure Rate 1997 to 1998 cm/yr (in./yr)	Closure Rate 1998 to 1999 cm/yr (in./yr)	Rate Change Percent
				Centimeters	Inches			
51X-CW-00033	N1420 Drift - E1551	10/02/1995	06/30/1999	10.343	4.072	2.06 (0.81)	2.50 (0.98)	21.20%
51X-CW-00032	N1420 Drift - E1451	10/02/1995	06/30/1999	9.274	3.651	2.13 (0.84)	2.28 (0.90)	6.70%
51X-CW-00034	Room D - N1342 Centerline	10/02/1995	06/30/1999	13.261	5.221	2.95 (1.16)	3.03 (1.19)	2.70%
51X-CW-00035	Room D - N1266 Centerline	10/02/1995	06/30/1999	13.365	5.262	2.44 (0.96)	2.67 (1.05)	9.50%
51X-CW-00036	Room D - N1187 Centerline	10/02/1995	06/30/1999	12.934	5.092	2.76 (1.09)	2.70 (1.06)	-2.20%
51X-CW-00037	N1100 Drift - E1620	10/02/1995	06/30/1999	7.640	3.008	1.18 (0.46)	1.41 (0.56)	19.70%
51X-CW-00038	N1100 Drift - E1530	10/02/1995	06/30/1999	8.263	3.253	1.52 (0.60)	1.70 (0.67)	12.00%
51X-CW-00039	E300 Drift - N1275	10/02/1995	06/28/1999	30.069	11.838	8.26 (3.25)	8.51 (3.35)	3.10%
51X-CW-00031	E140 Drift - N1275 Centerline	09/03/1996	06/28/1999	16.734	6.588	4.98 (1.96)	5.27 (2.07)	5.80%
51X-CW-00030	E0 Drift - N1275 Centerline	09/03/1996	06/28/1999	23.444	9.230	7.43 (2.93)	8.10 (3.19)	9.00%
51X-CW-00028	Room L3 Centerline	05/31/1996	06/14/1999	23.655	9.313	7.57 (2.98)	8.90 (3.50)	17.50%
51X-CW-00029	Room L4 Centerline	05/31/1996	06/14/1999	14.272	5.619	4.78 (1.88)	4.78 (1.88)	0.00%
51X-CW-00027	SPDV Room 4 N1325 E 1/4 pt	05/31/1996	06/14/1999	18.397	7.243	6.00 (2.36)	6.53 (2.57)	8.80%
51X-CW-00026	SPDV Room 4 N1325 Centerline	05/31/1996	05/12/1999	17.689	6.964	6.01 (2.37)	6.73 (2.65)	12.00%
51X-CW-00025	SPDV Room 4 N1325 W 1/4 pt	05/31/1996	06/14/1999	17.549	6.909	6.05 (2.38)	6.62 (2.61)	9.40%
51X-CW-00024	SPDV Room 4 N1288 Centerline	05/31/1996	06/14/1999	19.291	7.595	6.18 (2.43)	6.98 (2.75)	12.80%
51X-CW-00023	SPDV Room 4 N1250 E 1/4 pt	05/31/1996	06/14/1999	17.612	6.934	5.80 (2.28)	5.92 (2.33)	2.00%
51X-CW-00022	SPDV Room 4 N1250 Centerline	05/31/1996	06/14/1999	17.971	7.075	5.74 (2.26)	6.54 (2.57)	13.80%
51X-CW-00021	SPDV Room 4 N1250 W 1/4 pt	05/31/1996	06/14/1999	22.553	8.879	7.32 (2.88)	8.46 (3.33)	15.50%
51X-CW-00020	SPDV Room 4 N1213 Centerline	05/31/1996	06/14/1999	16.320	6.425	5.29 (2.08)	6.12 (2.41)	15.60%
51X-CW-00019	SPDV Room 4 N1175 E 1/4 pt	05/31/1996	06/14/1999	15.474	6.092	5.10 (2.01)	5.44 (2.14)	6.70%
51X-CW-00018	SPDV Room 4 N1175 Centerline	05/31/1996	06/14/1999	16.728	6.586	4.64 (1.83)	7.61 (3.00)	63.90%
51X-CW-00017	SPDV Room 4 N1175 W 1/4 pt	05/31/1996	06/14/1999	10.998	4.330	3.49 (1.37)	4.19 (1.65)	20.30%

6.5 Analysis of Convergence Data

As described in Section 5.3, convergence measurements are a primary means of identifying areas where conditions may be becoming unstable. The convergence data collected for excavations in the Northern Experimental Area indicate that many of these excavations remain stable. As indicated above possible exceptions are the eastern end of N1100 and N1420 drifts, SPDV Room L3, and some portions of SPDV Room 4.

Wire convergence meters located at the eastern end of N1100 and N1420 drifts showed a calculated increase in annual convergence rate, relative to the rate reported for the previous reporting period, of 19.7 and 21.2 percent respectively. An analysis using the running median of the convergence rate was used on these two locations. The analysis showed no trend toward increased convergence rates at the N1100-E1620 location. The calculated convergence rate for the 1998-1999 reporting period was determined to be anomalously high because of a change data collection method at the beginning of the reporting period. At the N1420-E1551 location a significant increase in the median convergence rate was observed near the end of this reporting period but there was no overall trend towards increased convergence rate. This area will continue to be monitored closely to determine if a trend towards increased convergence rates has begun or if the increase is an anomalous short-term phenomena.

In SPDV Room L3 readings from the wire convergence meter indicated an annual convergence rate of 6.73 cm/yr (2.65 in./yr), representing a rate increase of 17.5 percent relative to the previous reporting period data. An extensometer located in SPDV Room L3 showed a decrease in displacement rate of 31.2 percent for the same period. An analysis of the running median of the convergence rate, using the wire convergence meter data, showed a short-term increase in rate during the middle of the reporting period before resuming the lower long-term rate.

The extensometer located in the roof of SPDV Room 4 at N1250 (room center) near the west rib has shown a 23.5 percent increase in the rate of collar movement during the 1998-1999 reporting period relative to the previous reporting period and an increase of 37 percent in collar movement rate during the previous reporting period relative to the 1996-1997 period. Readings from the wire convergence meters located in SPDV Room 4 at N1250 and N1175 near the west rib indicate slightly lesser annual convergence rates of 15.5 percent and 20.3 percent, respectively, over the previous reporting period rates. The convergence rate at N1250 for the present reporting period, based on the wire convergence meter data, is 8.46 cm/yr (3.33 in./yr) and the rate at N1175 is 4.19 cm/yr (1.65 in./yr). The vertical convergence rate calculated from the wire convergence meter located in SPDV Room 4 at N1175 near the room centerline was 63.9 percent higher during this reporting period than the previous with an annual convergence rate of 7.61 cm/yr (3.00 in./yr) compared to 4.64 cm/yr (1.83 in./yr) for the previous reporting period. This area is deactivated and will continue to be monitored closely for further indications of possible instability in the roof beam.

7.0 PERFORMANCE OF WASTE DISPOSAL AREA

Excavation of the waste disposal area began in May 1986 with the mining of entries to Panel 1. Initially, the disposal rooms and drifts were developed as pilot drifts that were later excavated to 4 m (13 ft) high, 10 m (33 ft) wide, and 91 m (300 ft) long. Room 1 was excavated 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 excavated to final dimensions in February and March 1988 and Rooms 4 through 7 were completed in May 1988. Short access drifts designed to lead to smaller test alcoves were excavated north off of the S1600 drift in June 1989. Only the access drifts to the alcoves were completed; the alcoves were not excavated.

7.1 Modifications to Excavations and Ground Control Activities

No new excavations were mined in the Waste Disposal Area (Panel 1) during the reporting period of July 1998 through June 1999. Routine maintenance and ground control activities in the form of trimming, scaling, rock-bolt replacement, and installing wire mesh was performed on ribs, floor, and roof throughout Panel 1. Table 7-1 summarizes the ground control activities performed in the Waste Disposal Area during this reporting period.

Table 7-1
Summary of Modifications and Ground Control Activities
in the Waste Disposal Area
July 1, 1998, Through June 30, 1999

Date Completed	Location	Work Performed
September 1998	Room 5, Panel 1	Installation of welded wire mesh panels and cable slings anchored by rock-bolts at center of room
September 1998	S1600 drift at Room 4	Installation of rock-bolts for roof/rib support in roof and north rib
December 1998	Room 3, Panel 1	Installation of wire mesh anchored by rock-bolts
December 1998	S1600 between Room 6 and 7	Scaling of the ribs
January 1999	Room 5 at S1950 Drift Intersection	Installation of wire mesh anchored by rock-bolts at southeast miter of intersection
January 1999	Room 6 at S1600 Drift Intersection	Installation of wire mesh anchored by rock-bolts at intersection
March 1999	Room 2, Panel 1	Installation of wire mesh anchored by rock-bolts on portion of west rib
March 1999	Room 3, Panel 1	Installation of wire mesh anchored by rock-bolts on portion of west rib
May 1999	S1950 Drift	Floor trimming from Panel 1 entrance to Room 7
May 1999	Room 2, Panel 1	Trimming and installation of wire mesh anchored by rock-bolts on portion of west rib

7.2 Instrumentation

No extensometers were installed or replaced in Panel 1 during this reporting period. Thirteen convergence point pairs were replaced in the S1950 drift entry (between E300 and Room 1) during this reporting period. Several of these pairs were replaced more than once during the period as additional trimming of the floor was performed. Table 7-2 lists the convergence point pairs replaced. Figure 7-1 shows the location of the various types of geotechnical instruments in Panel 1 of the Waste Disposal Area.

The 286 rock-bolt load cells of the yielding roof support system in Room 1 are monitored regularly and are detensioned as needed. As the roof beam expands the tension in the rock-bolts increases. Scheduled detensioning of the rock-bolts is performed approximately every five weeks to maintain the load supported by the rock-bolt within a specified range that allows the roof beam to continue to move. As part of the design of the yielding roof support system, the loads on these rock-bolts are typically maintained between approximately 22 and 89 kilonewtons (5,000 and 20,000 lb). However, seventeen of these rock-bolts have reached their maximum adjustment point and the load on these bolts can no longer be kept below the 89-kilonewton (20,000-lb) level. Loads on these bolts currently range from 116 kilonewtons (26,000 lb) to 242 kilonewtons (54,400 lb). Details on the design of the Room 1 yielding roof support system are found in "Waste Isolation Pilot Plant Supplementary Roof Support System, Underground Storage Area, Panel 1, Room 1" (DOE, 1991). The "Long Term Ground Control Plan for the Waste Isolation Pilot Plant," (Westinghouse WID [Waste Isolation Division], 1999) provides information on the status of the roof support system.

Table 7-2
Replaced Instrumentation in the Waste Disposal Area
July 1, 1998, Through June 30, 1999

Instrument Type	Field Tag	Location	Date Installed
Convergence Point Pair	S1950-E281-3 (A-C)	S1950 Drift Entrance at E281	7/21/1998
Convergence Point Pair	S1950-E284-3 (A-C)	S1950 Drift Entrance at E284	7/21/1998
Convergence Point Pair	S1950-E311-3 (A-C)	S1950 Drift Entrance at E311	7/21/1998
Convergence Point Pair	S1950-E311-4 (A-C)	S1950 Drift Entrance at E311	9/10/1998
Convergence Point Pair	S1950-E332-3 (A-C)	S1950 Drift Entrance at E332	7/21/1998
Convergence Point Pair	S1950-E332-4 (A-C)	S1950 Drift Entrance at E332	9/10/1998
Convergence Point Pair	S1950-E357-5 (A-C)	S1950 Drift Entrance at E357	7/21/1998
Convergence Point Pair	S1950-E357-6 (A-C)	S1950 Drift Entrance at E357	9/10/1998
Convergence Point Pair	S1950-E357-7 (A-C)	S1950 Drift Entrance at E357	4/13/1999
Convergence Point Pair	S1950-E382-4 (A-C)	S1950 Drift Entrance at E382	7/21/1998
Convergence Point Pair	S1950-E382-5 (A-C)	S1950 Drift Entrance at E382	9/10/1998
Convergence Point Pairs	S1950-E407-3 (A-G, B-F, L-H)	S1950 Drift Entrance at E407	7/21/1998
Convergence Point Pair	S1950-E407-4 (A-G)	S1950 Drift Entrance at E407	4/13/1999
Convergence Point Pair	S1950-E432-3 (A-C)	S1950 Drift Entrance at E432	7/21/1998
Convergence Point Pair	S1950-E457-3 (A-C)	S1950 Drift Entrance at E457	7/21/1998
Convergence Point Pair	S1950-E482-6 (A-C)	S1950 Drift Entrance at E482	7/21/1998
Convergence Point Pair	S1950-E503-5 (A-C)	S1950 Drift Entrance at E503	7/21/1998

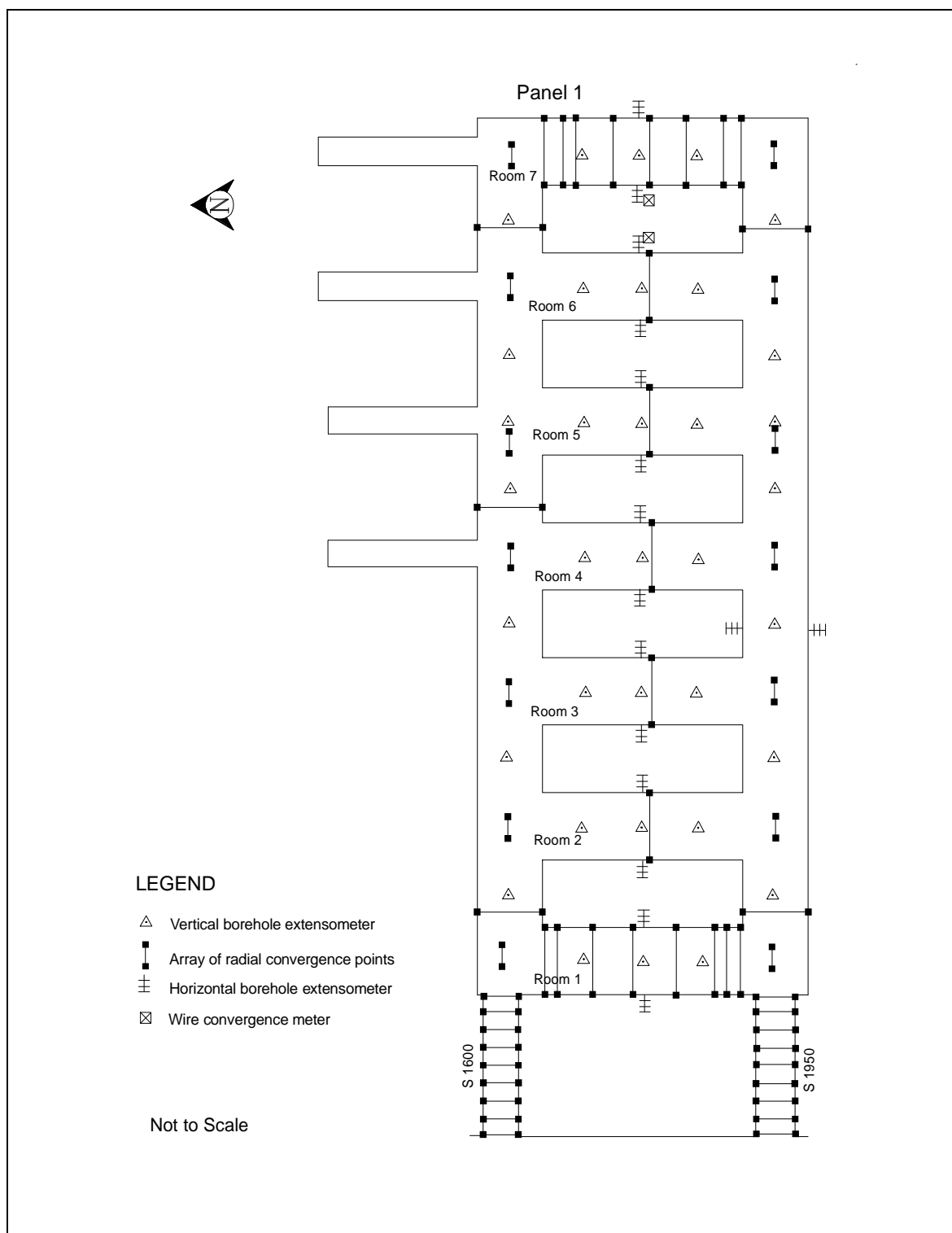


Figure 7-1 - Location of Geotechnical Instruments in the Waste Disposal Area

7.3 Excavation Performance

In order to collect early convergence data, convergence points were installed at selected locations immediately following initial excavation. Horizontal and vertical convergence rates have been calculated at the center of each of the rooms in Panel 1 for this and the previous two reporting periods. Tables 7-3 and 7-4 present these convergence rates. The vertical convergence rates at the center of each of the rooms in Panel 1 have either remained constant or decreased during the current reporting period relative to each of the two previous reporting periods. The horizontal convergence rates at each room center have also remained constant or decreased during the current reporting period relative to the previous period.

Fracturing within the immediate roof beam contributes to high convergence rates seen in some areas of Panel 1, especially portions of Room 1. The ground support systems in Rooms 1 and 2, Panel 1 are designed specifically to yield in response to deformation and, therefore, have no significant effect on the rate of roof displacement. However, if the roof fracturing increases to the point at which a large section of the rock is detached, the yielding support systems are designed to support the weight of the roof beam (Westinghouse WID, 1999). Vertical convergence rates within Room 1, Panel 1 have decreased during this reporting period at 18 of the 22 locations monitored. The convergence point pair located at the east quarter point at S1884 in Room 1, Panel 1 did exhibit a 14.3 percent increase in convergence rate during this reporting period and does now have one of the highest convergence rates in Room 1 at 7.92 cm/yr (3.12 in./yr). This area will continue to be monitored closely. If conditions in Room 1 adversely change, the ground support system will be upgraded or adjusted as necessary, or the room will be abandoned.

Table 7-3
Annual Vertical Convergence Rates at the Center of Each Waste Disposal Room

Location		Field Tag	1996-1997 Convergence Rate cm/yr (in./yr)	1997-1998 Convergence Rate cm/yr (in./yr)	1998-1999 Convergence Rate cm/yr (in./yr)
Room 1	Centerline	E520-S1802-6 A-E	7.89 (3.11)	6.79 (2.67)	6.20 (2.44)
Room 2	Centerline	E660-S1775-5 A-C	5.72 (2.25)	5.64 (2.22)	5.85 (2.30)
Room 3	Centerline	E790-S1775-3 A-C	7.76 (3.05)	6.32 (2.49)	5.60 (2.20)
Room 4	East of centerline	E920-S1775-5 A-F	5.88 (2.32)	5.40 (2.13)	5.29 (2.08)
Room 4	West of centerline	E920-S1775-4 B-E	4.42 (1.74)	4.14 (1.63)	3.90 (1.54)
Room 5	East of centerline	E1050-S1775-4 A-F	5.94 (2.34)	5.52 (2.17)	5.38 (2.12)
Room 5	West of centerline	E1050-S1775-4 B-E	5.99 (2.36)	5.32 (2.10)	5.50 (2.17)
Room 6	East of centerline	E1190-S1775-4 A-F	6.00 (2.36)	5.50 (2.17)	5.27 (2.07)
Room 6	West of centerline	E1190-S1775-3 B-E	5.89 (2.32)	5.41 (2.13)	5.08 (2.00)
Room 7	East of centerline ^a	E1320-S1775-3 A-F	5.80 (2.28)	No Data	No Data
Room 7	East of centerline ^a	E1320-S1775 B-D	No Data	5.89 (2.32)	5.44 (2.14)
Room 7	West of centerline ^a	E1320-S1775-4 B-E	5.79 (2.28)	No Data	No Data
Room 7	West of centerline ^a	E1320-S1775 H-F	No Data	6.68 (2.63)	6.02 (2.37)
Room 7	Centerline ^a	E1320-S1775 A-E	No Data	6.57 (2.59)	6.18 (2.43)

^a Convergence point pairs for Room 7 center were replaced in June 1997. New convergence point pairs are located at room centerline and at east and west quarter points.

cm/yr = centimeter(s) per year

in./yr = inch(es) per year

Table 7-4
Annual Horizontal Convergence Rates
at the Center of Each Waste Disposal Room

Location		Field Tag	1996-1997 Convergence Rate cm/yr (in./yr)	1997-1998 Convergence Rate cm/yr (in./yr)	1998-1999 Convergence Rate cm/yr (in./yr)
Room 1	Rib center	E520-S1802-3 C-G	3.49 (1.37)	3.35 (1.32)	3.14 (1.24)
Room 2	Rib center	E660-S1775-5 B-D	3.06 (1.21)	3.19 (1.26)	3.19 (1.26)
Room 3	Rib center	E790-S1775-5 B-D	4.29 (1.69)	4.33 (1.70)	4.01 (1.58)
Room 4	Above rib center	E920-S1775-5 C-H	3.85 (1.52)	3.76 (1.48)	3.66 (1.44)
Room 4	Below rib center	E920-S1775-5 D-G	3.70 (1.46)	3.72 (1.47)	3.39 (1.33)
Room 5	Above rib center	E1050-S1775-5 C-H	3.68 (1.45)	3.75 (1.48)	3.73 (1.47)
Room 5	Below rib center	E1050-S1775-5 D-G	3.72 (1.46)	3.71 (1.46)	3.64 (1.43)
Room 6	Above rib center	E1190-S1775-4 C-H	3.17 (1.25)	3.16 (1.24)	3.06 (1.20)
Room 6	Below rib center	E1190-S1775-4 D-G	3.24 (1.27)	3.22 (1.27)	3.03 (1.19)
Room 7	Above rib center ^a	E1320-S1775-5 C-H	3.14 (1.24)	No Data	No Data
Room 7	Below rib center ^a	E1320-S1775-5 D-G	3.17 (1.25)	No Data	No Data
Room 7	Rib center ^a	E1320-S1775 C-G	No Data	3.29 (1.30)	3.08 (1.21)

^a Convergence point pairs for Room 7 center were replaced in June 1997. New convergence point pair is located at rib centerline.

cm/yr = centimeter(s) per year

in./yr = inch(es) per year

7.4 Analysis of Extensometer and Convergence Point Data

As discussed in Section 5.3, extensometer data are obtained by measuring the displacement from the instrument head (collar) to each fixed anchor of the extensometer. 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 displacement rates and convergence rates are plotted against time, and comparisons are made between consecutive rates to identify any acceleration. Points that indicate an acceleration are then analyzed to determine the significance of the acceleration. Factors that are considered during the analysis include the magnitude of the respective rates, percentage increase, convergence history, and any recent excavation in the vicinity.

There are 37 active extensometers installed in the roofs and ribs of Panel 1 of the Waste Disposal Area with most being located in the disposal rooms. Two of these extensometers have shown increases in calculated displacement rates of greater than 10 percent during this reporting period. Both instruments are located horizontally in ribs and have displacement rate increases of 15.2 percent in the east rib of Room 2 and 20.6 percent in the west rib of Room 7.

Where possible, annual closure rates were calculated from convergence point array data from the access drifts. The convergence rate at most points in Panel 1 have reduced during this reporting period relative to the previous reporting period. Three pairs of convergence points were found to have increases in annual vertical or horizontal convergence rates of greater than 10 percent. An increase of 14.4 percent was calculated for one horizontal chord in S1950 drift at E407 in the Panel 1 entry. Other horizontal chords also located at E407 showed smaller increases in rate of 5.0 and 6.9 percent. The floor in this area of S1950 drift was trimmed during this reporting period and may have contributed to the increase in convergence rate. The second location is also in S1950 at E523 with an increase in vertical convergence rate of 12.9 percent. The third location is in Room 1 at S1884 and is discussed above in Section 7.3. All areas will continue to be monitored closely.

8.0 GEOSCIENCE PROGRAM

The Geoscience Program confirms the suitability of the site through the collection of geologic data from the underground facility, including documentation of the stratigraphy and excavation characteristics. Geologic data is gathered through the mapping of excavation surfaces and the logging of new boreholes. Excavation characteristics are determined from fracture mapping and the logging of fractures and offsets (lateral displacements) in open boreholes. Data collected through these activities support the design and evaluation of ground support systems (Westinghouse WID, 1999).

During this reporting period, the following activities were performed:

- Inspections of subsurface fractures and offsets in boreholes
- Mapping of fractures on excavation surfaces
- Logging of new boreholes.

8.1 Borehole Inspections

Geotechnical observation boreholes are drilled at various locations throughout the underground facility. A location may contain one or several boreholes arranged in an array. These holes are drilled to depths that allow the monitoring of fracture development and offsetting and are inspected for the development of those features.

Roof observation holes usually intersect clays G and H (Figure 8-1). Floor observation holes are no longer monitored due to infilling of the holes with crushed salt. There is no separation or offset data for floor observation holes for this reporting period.

The clay seams nearest the excavation surfaces define the immediate roof beam. Clay G defines the roof beam in most of the access drift and disposal areas. Some areas, such as the Salt Handling Shaft Station and portions of the E140 drift are excavated to clay G and so have roof beams bounded by clay H.

The offset in a borehole is determined by visually estimating the degree of borehole occlusion. The direction of offset along clay seams is observed as the movement of the strata nearer to the observer relative to the strata farther away. Typically the nearer strata moves toward the center of the excavation (Figure 8-2). Based on previous observations in the underground, the magnitude of offset is usually greater in boreholes located near ribs than in those located along excavation centerlines. Offsetting along the clay layers is observable until the total borehole offset is reached or visibility is obstructed by intervening offsets at other clay seams or fractures. Boreholes are inspected for fractures using an aluminum rod with a flattened steel wire probe attached to one end perpendicular to the rod (referred to as a "scratcher rod"). Fractures and clay seams are located by moving the probe along the sides of the borehole until it is snagged in one of these features. Depth to each feature is recorded, as is the magnitude of separations encountered.

The separation and offset data observed at clay G and clay H in accessible boreholes during this reporting period are presented in Table 7-1 of the supporting data document for this report.⁴

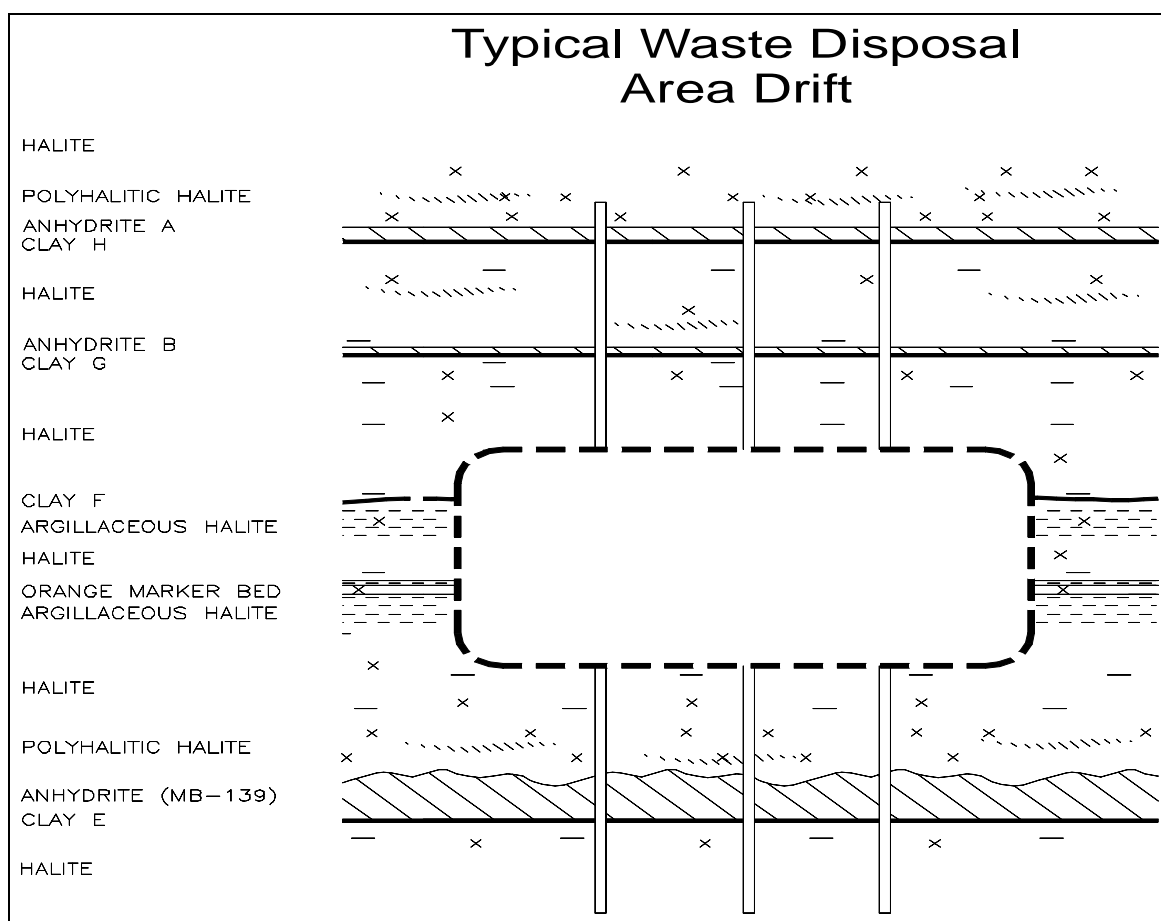


Figure 8-1 - Examples of Observation Borehole Layouts

⁴Instrumentation data and data plots are available in "Geotechnical Analysis Report for July 1997-June 1998 Supporting Data." This document is available upon request from Westinghouse, Waste Isolation Division. Refer to Foreword and Acknowledgments for details and address.

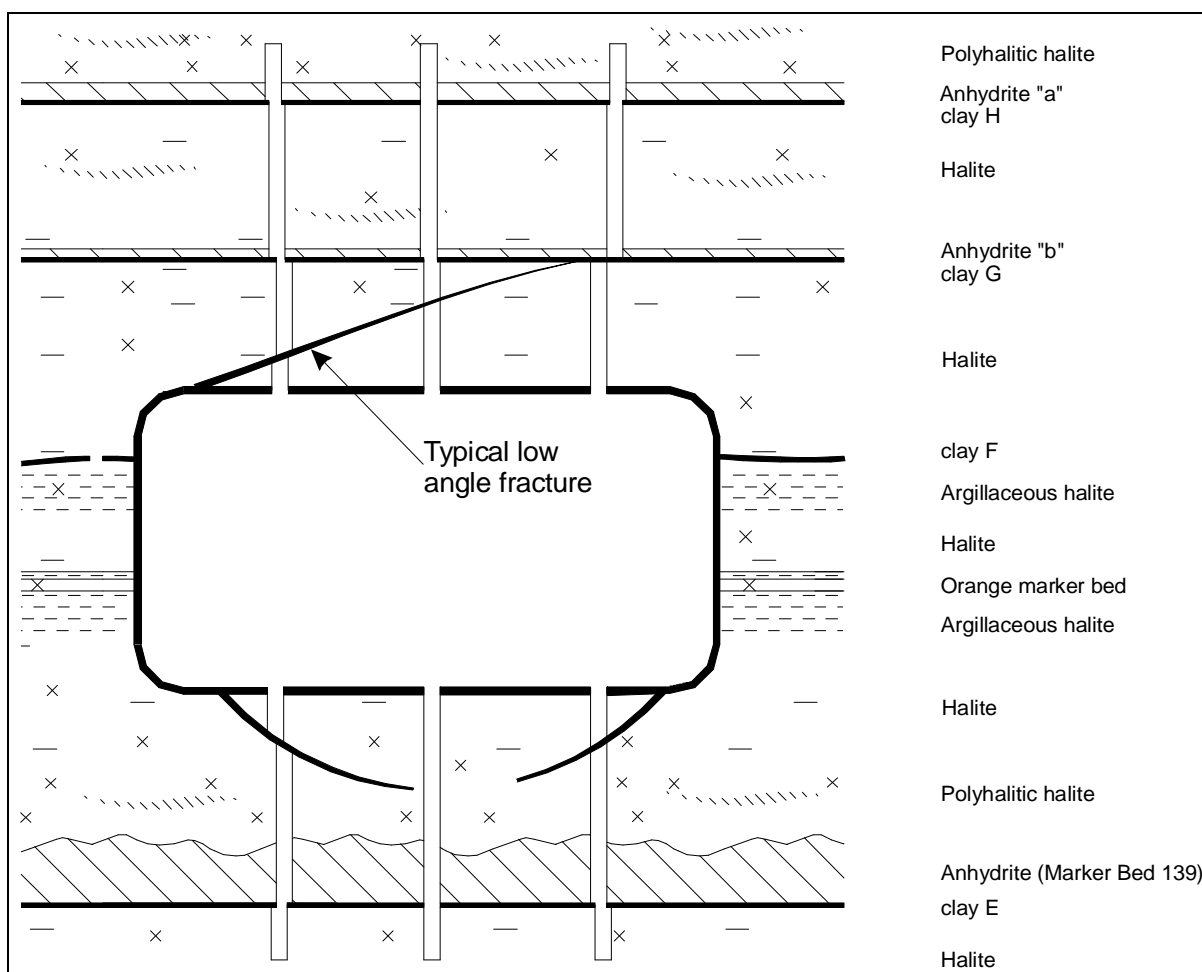


Figure 8-2 - Generalized Fracture Pattern

8.2 Fracture Mapping of Excavation Surfaces

The Geotechnical Engineering Department routinely maps the progression of back-fractures exposed on the excavation surfaces of the drifts and rooms in the underground repository. The fracture surveys are generally performed on an annual basis, and the fracture maps are recorded on Mylar sheets. The fracture maps facilitate the analysis of strain in the immediate roof-beam as they document the propagation of fractures through time.

An efficient method of incorporating back-fracture data (fracture location, fracture length, fracture type, fracture aperture, and vertical offset due to fracture) into a database has recently been developed. Using the data in the fracture database, a method has been developed of quantifying back-fracture density within a given area and creating drawings of the fracture layout as a function of date. The drawings may be used in conjunction with (superimposed upon) roof-bolt failure data and observation borehole-offset data to more accurately characterize the fracture patterns and geomechanical behavior of the roof beams. Additionally, back-fracture density data may be plotted as a function of time or position or coupled with extensometer data to

facilitate understanding of the excavation geomechanics. Figure 8-3 presents an example of an isometric drawing of the fracture mapping performed in Room 1 of Panel 1 generated from the fracture mapping database. Plan and isometric fracture mapping figures for Panel 1 are presented in the Supporting Data Document.

Figure 8-3 - Sample Isometric Drawing of Fracture Mapping Data

8.3 Borehole Logging

Newly drilled boreholes are logged either through core logging or remote observation (scratcher rod inspections) to determine the geology in selected areas or to document the location of geologic features for the placement of instruments. A total of 92 new boreholes were drilled and logged during this reporting period. Forty-four of these 92 boreholes were drilled as observation boreholes (see Section 8.1 above) and the remaining 48 of these holes were intended for the installation of extensometers. Table 8-1 of the Supporting Data Document presents a summary of new borehole logging activity performed during this reporting period.

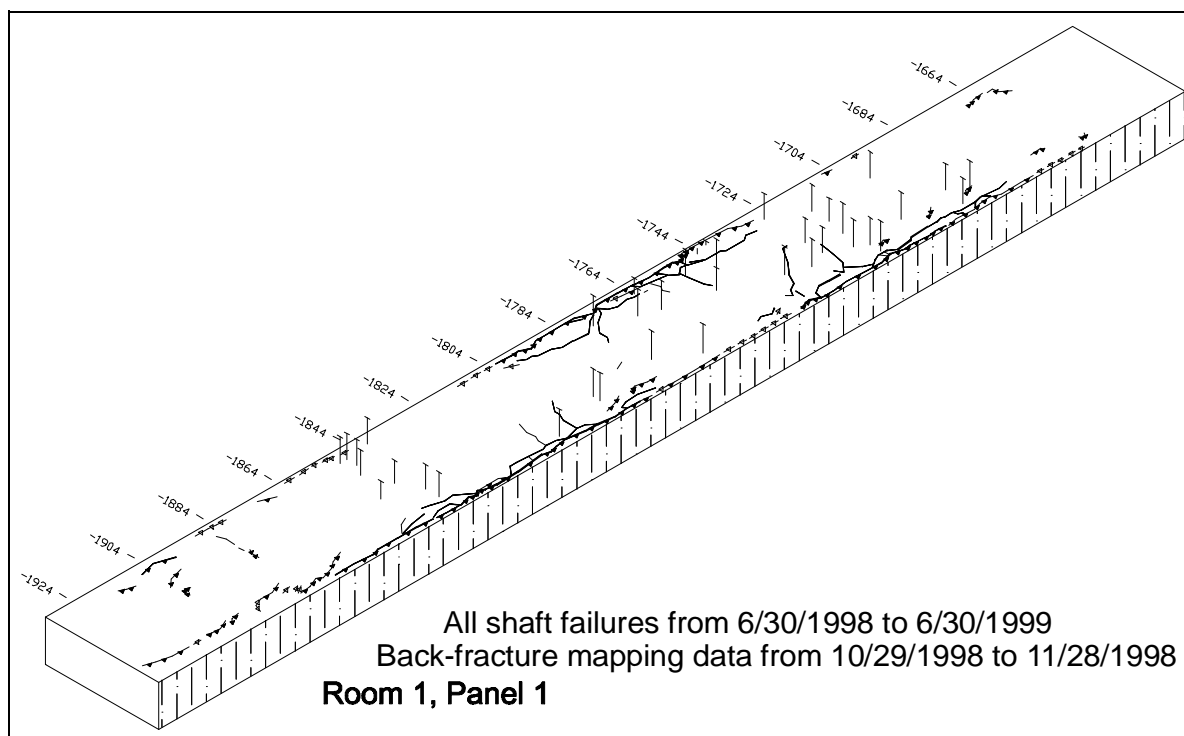


Figure 8-3 - Sample Isometric Drawing of Fracture Mapping Data

9.0 SUMMARY

At the inception of the WIPP project, criteria were developed that address the requirements for the design of the WIPP (DOE, 1984). These criteria, in the form of design requirements, pertain to all aspects of the mined facility and its operation as a pilot plant for the demonstration of technical and operational methods for permanent disposal of CH- and remote handled-TRU waste. In 1994, as the WIPP developed and the focus moved toward the permanent disposal of TRU waste, these design requirements were reassessed and replaced by a new set of requirements called system design descriptions (SDD). Table 9-1 shows the comparison of these SDDs with conditions actually observed in the underground from July 1998 through June 1999.

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

System Design Description	Requirement	Comments
SDD-UH00, <u>Underground Hoisting</u> , Section 2.1.2.6.3 Section 2.1.2.6.4 Section 2.1.2.8	"The lining shall be designed for a hydrostatic pressure. . . ."	Water pressure observed on piezometers located behind the shaft keys in the Waste Shaft and the Exhaust Shaft 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 is structurally stable. Extensometer data indicate that closure of all the shafts remains within design requirements. Data from the Air Intake Shaft indicate it is performing within design requirements. ^{a,b} Visual inspections of the shaft keys indicate that they are performing satisfactorily.
	"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."	The small amount of groundwater inflow into the shafts is effectively controlled through grouting. Seepage into the Exhaust Shaft is manageable and has reduced in volume during this reporting period. The source and content of such seepage are being characterized. ^{c,d}
SDD-AU00, <u>Underground Facilities and Equipment</u> , Section 2.2.1.2, Underground Disposal Facilities	"The underground waste disposal facilities shall be designed to provide space and adequate access for the underground equipment and temporary storage space to support underground operations."	Geomechanical instrument data and visual observations indicate that the current design provides adequate access and storage space. W170 drift was trimmed/enlarged to function as a salt haulage route for the future excavation of Panel 2.
	"The underground waste disposal facilities shall be designed to provide the capability of retrieving the emplaced CH and RH TRU waste."	Retrievability is not presently a requirement in the waste disposal program.

Table 9-1 (Continued)
Comparison of Excavation Performance to System Design Descriptions

System Design Description	Requirement	Comments
Section 2.2.1.3, Underground Shaft Pillar Facilities	"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.
SDD-EM00, <u>Environmental Monitoring</u> , Section 2.2.5.1	"Geomechanical instrumentation shall be provided to measure the cumulative deformation of the rock mass surrounding mined drifts. . . ."	Geotechnical instrumentation is operated and maintained to meet this requirement. This annual report acts to provide a summary and analysis of the geomechanical data. Geotechnical experts agree that the monitoring program at the WIPP has been proven adequate, specifically with regard to the instrumentation in Room 1, Panel 1. ^e

- ^a Munson, D. E., D. L. Hoag, J. R. Ball, G. T. Baird, and R. L. Jones, 1995, "AIS Performance Tests, (Shaft V): In situ Data Report (May1988-July 1995)," SAND94-1311, Sandia National Laboratories, Albuquerque, New Mexico.
- ^b Holcomb, D. J., 1997, Memorandum to J. R. Tillerson dated September 29, 1997, "Summary of Air Intake Shaft Measurements (October 1, 1996-September 30, 1997), WBS 1.1.03.6.1; Completion of Milestone RM103, "Summary Memo of FY97 AIS Measurements," Sandia National Laboratories, Albuquerque, New Mexico.
- ^c Intera, 1997, "Exhaust Shaft Hydraulic Assessment Data Report," DOE/WIPP 97-2219, prepared for Westinghouse Waste Isolation Division by Intera, Albuquerque, New Mexico.
- ^d IT Corporation, 1997, "Composition and Origin of Nonindigenous Brine and Water in the Vicinity of the Exhaust Shaft, Waste Isolation Pilot Plant, New Mexico," DOE/WIPP 97-2226, prepared for Westinghouse Waste Isolation Division by International Technology Corporation, Albuquerque, New Mexico.
- ^e U.S. Department of Energy, 1991b, "Report of the Geotechnical Panel on the Effective Life of Rooms in Panel 1," DOE/WIPP 91-023, Waste Isolation Pilot Plant, Carlsbad, New Mexico.

CH = contact handled

RH = remote handled

TRU = transuranic

WIPP = Waste Isolation Pilot Plant

Fracture development in the roof is primarily caused by the concentration of compressive stresses in the roof beam and is influenced by the size and shape of the excavation and the stratigraphy in the immediate vicinity of the opening. Pillar deformations induce lateral compressive stresses into the immediate roof and floor. With time the buildup of stress causes differential movement along stratigraphic boundaries. This differential movement is identified as offsets in observation boreholes and is indicated by the bends in failed rock-bolts. Large strains associated with lateral movements can induce fracturing in the roof, which is frequently seen near the ribs. This scenario of roof deterioration, combining compressive stresses, horizontal offsetting, and large strains associated with lateral movements, is substantiated by earlier observations of similar roof deterioration in SPDV Room 1, SPDV Room 2, and the E140 drift between S1000 and S1950.

Normal drift and room maintenance continued during this reporting period with floor and rib trimming in W170 drift and S2180 drift (trimmed in preparation for being used as salt haulage route during the excavation of Panel 2 and associated access drifts), rib, roof,

and floor scaling and trimming in various locations, and rock-bolting and wire mesh installation as needed. Supplemental ground support systems consisting of cable slings and welded wire mesh were installed in the center 46 m (150 ft) of Room 5, Panel 1.

New convergence point pairs were installed in the entrance to Panel 1 in S1950 drift, in the W170 drift, and in various locations throughout the repository to replace mined out instruments. Entry was made into the deactivated Northern Experimental Area to replace a malfunctioning data logger located in SPDV Room 4. Remotely read instrumentation located in this area is once again providing data for analysis.

The in situ performance of the excavations generally continues to satisfy the appropriate design criteria, although specific areas are being identified where deterioration resulting from aging must be addressed through routine maintenance and implementation of engineered systems. This deterioration has been identified through the analysis of data acquired from geomechanical instrumentation and the Geoscience Program (Chapter 8.0). If the planned life of some of the openings needs to be extended, redesigning the geometry of the access drifts (e.g., changing the horizontal and vertical dimensions) or additional ground control (e.g., installing bolts, mesh, or slings) may be necessary. The ground condition in the Waste Disposal Area and associated transuranic waste haulage routes in the WIPP underground has remained stable during this reporting period. Most of the calculated annual convergence rates for Panel 1 decreased during this reporting period relative to the rates from the previous two reporting periods.

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

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