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Sandia National Laboratories
Waste Isolation Pilot Plant (WIPP)

**Geohydrological Conceptual Model for the
Dewey Lake Formation in the Vicinity of the
Waste Isolation Pilot Plant (WIPP)
Test Plan TP 02-05, Rev. 0**

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1 DEFINITIONS OF ACRONYMS

aka	also known as
Carlsbad Field Office	CBFO (US Department of Energy)
ES&H	environmental safety and health
FEPs	features, events and processes
NWMP	nuclear waste management program
PA	performance assessment
QA	quality assurance
QAPD	Quality Assurance Program Document
SEM	scanning electron microscope
SNL	Sandia National Laboratories
T	transmissivity
TP	Test Plan
WIPP	Waste Isolation Pilot Plant
WQSP	Water Quality Sampling Program
WTS	Washington (formerly Westinghouse) TRU Solutions
XRD	x-ray diffraction

2 REVISION HISTORY

This is the original edition of this Test Plan (TP); no prior revisions exist. The purpose and content of any future changes and/or revisions will be documented and appear in this section of revised editions. Changes to this TP, other than those defined as editorial changes per Nuclear Waste Management Program (NWMP) quality assurance (QA) procedure NP 20-1 *Test Plans*, shall be reviewed and approved by the same organization that performed the original review and approval. All TP revisions will have at least the same distribution as the original document.

3 PURPOSE AND SCOPE

This Test Plan (TP) describes laboratory activities to be conducted for Sandia National Laboratories (SNL) in support of developing a conceptual geohydrologic model of the Dewey Lake Formation in the general vicinity of the Waste Isolation Pilot Plant (WIPP). The geohydrology of the Dewey Lake is of interest across organizational boundaries because of local natural saturated zones in the Dewey Lake as well as shallow zones that have been recharged recently since WIPP was constructed. The TP therefore describes a broad range of activities and interests, but the responsibility for many activities will fall to Washington (formerly Westinghouse) TRU Solutions (WTS); this TP is not a statement of the work to be undertaken by WTS. If necessary, further activities by SNL will be developed in revisions to this plan or under analysis plans.

3.1 Importance of the Dewey Lake Formation

The Dewey Lake Formation (aka Redbeds) (Figure 1) is a thick sequence of fine-grained reddish-brown clastic sediments overlying the Rustler Formation. Although the Dewey Lake is considered unsaturated over most of the WIPP Site, water has been encountered in some drillholes in the southern part of the site (e.g., Jones, 1978; Mercer, 1983; Beauheim and Ruskauff, 1998). The single test of a natural saturated zone in the Dewey Lake, at drillhole WQSP 6A (see Figure 2 for drillhole locations), provides an estimate of transmissivity (T) of $3.9 \times 10^{-4} \text{ m}^2/\text{s}$ (Beauheim and Ruskauff, 1998, p. 193), a value approximately five times larger than the largest value of T for the Culebra Dolomite Member of the Rustler Formation within the WIPP boundaries.

ERATHEM		SYSTEM		Group	Formation	Members
		Series				
CENOZOIC	QUATERNARY	Holocene		Dockum	Dune sand/Berino	
		Pleistocene			Mescalero caliche	
	NEOGENE	Miocene			Gatuña	
MESOZOIC	TRIASSIC				Santa Rosa	
		Ochoan		Dewey Lake		
PALEOZOIC	PERMIAN				Rustler	<i>Forty-niner</i> <i>Magenta Dolomite</i> <i>Tamarisk</i> <i>Culebra Dolomite</i> <i>Los Medanos</i>

TP02-05 Fig 1a.ai

Figure 1. Simplified stratigraphy of the WIPP Site.

Dewey Lake hydraulic properties affect several processes: a) vertical recharge to underlying units such as the Culebra Dolomite, b) how water and solutes move in saturated zones, and c) the fate of groundwater created recently in the vicinity of WIPP surface facilities (Intera, 1997). The results of further examination of Dewey Lake geohydrology may be evaluated for 1) effects on features, events, and processes (FEPs), 2) performance assessment (PA), and 3) monitoring programs. Study of the Dewey Lake contributes to a fundamental understanding of the geohydrologic setting near WIPP, which is a requirement for continued certification by the Environmental Protection Agency (EPA).

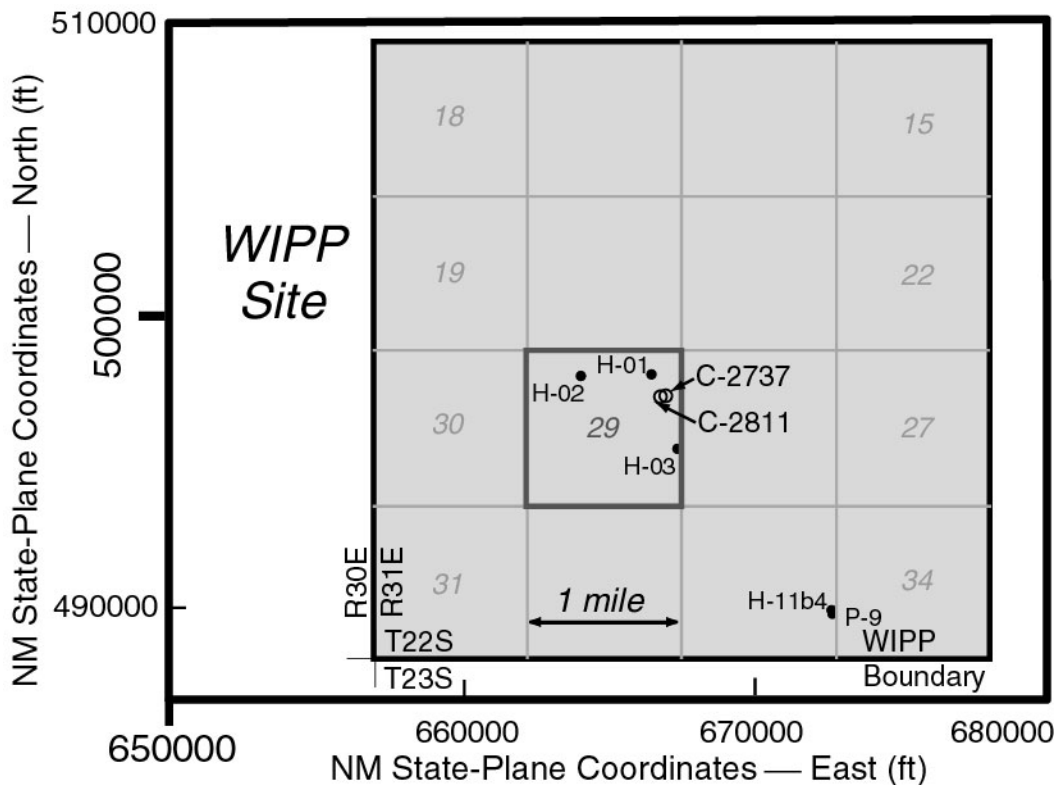


Figure 2. WIPP Site and location of drillholes referred to in TP.

3.2 Strategy of the Test Plan

The laboratory tests described in this TP are the responsibility of SNL. The tests are designed to supplement existing information about the way in which matrix and natural mineral cements in the Dewey Lake control infiltration and cementation. Based on previous work that has not yet been fully described, Powers (2002) related changes in natural cements in the upper Dewey Lake at drillhole C-2737 to changes on downhole resistivity logs (Figure 3). Above 202 ft depth, the C-2737 core is more porous, has carbonate cement, and has a lower resistivity. Below 202 ft., the core is less porous, is dominated by sulfate cement, and the resistivity sharply increases. Resistivity indicates some combination of factors of porosity and resistivity of the liquid in the pores, whether saturated or not. At drillhole H-11b4, resistivity increases sharply

(Figure 4) just below the zone where natural groundwater was reported in drillhole P-9 (Jones, 1978), located on the same drilling pad as H-11b4. The resistivity change in drillhole H-11b4 occurs at a stratigraphically different position from the change in resistivity in C-2737. The laboratory investigations focus on identifying matrix and cement changes in cores from different drillholes to establish more firmly the correlation with resistivity logs or other logs (e.g., acoustic velocity or density). The cement change and geophysical log responses are expected to be a significant key to understanding the current geohydrological architecture of the Dewey Lake and estimating the effects of this geohydrological architecture on the broader hydrological processes important to the WIPP Site.

3.3 Background Information and Status of Dewey Lake Geohydrology

Geological studies of the Dewey Lake¹ have been relatively limited. Miller (1955a,b, 1957, 1966) conducted a detailed petrographic study of the formation. In support of Project Gnome, Vine (1963) described the general characteristics of the unit in Nash Draw and Gard (1968) described the geology of the Dewey Lake as exposed in the Gnome shaft. Nicholson and Clebsch (1961) and Hendrickson and Jones (1952) reported only gross characteristics and distribution of the formation. The principal characteristics of the formation as described in such reports are reddish-brown color, fine grain sizes (mostly < fine sand), bedded to laminar, and marked by greenish-gray reduction spots. Quartz and feldspars are the main minerals; clay, calcite, and gypsum are the main rock cements. Some coarser sandstones were noted as having well-rounded, frosted quartz grains (e.g., Miller, 1966). Schiel (1988, 1994) developed a depositional model based on describing outcrops; she also inferred broader stratigraphic relationships from geophysical log information.

The Dewey Lake has not been a focus of geologic study for the WIPP. Various summaries based on the extant literature were included in reports (e.g., Powers et al., 1978; Mercer, 1983). The stratigraphic and basic lithology reported by Jones (1978) in support of investigations of potash resources at the WIPP, along with included geophysical logs, are the most concentrated source of geologic data for the Dewey Lake during early work at the WIPP. Basic data reports for various drillholes at the WIPP include geophysical logs and lithologic descriptions, but there is little analysis of the formation.

Holt and Powers (1990a,b) described the Dewey Lake in detail from exposures inside the large-diameter air intake shaft at WIPP. They inferred that the lower part of the Dewey Lake was similar in some respects to saline mud-flat facies within the underlying Rustler Formation. The rest of the Dewey Lake was interpreted as fluvial in origin, similar to the interpretation of Schiel (1988).

¹ In reports before about 1963, the rocks now considered the Dewey Lake Formation in southeastern New Mexico were commonly called "Pierce Canyon redbeds" (e.g., Miller, 1955a). Outcrops of reddish sedimentary rocks in Pierce Canyon, however, belong to the Gatuña Formation, which is much later in age (Miocene-Pleistocene) than the Dewey Lake. The name "Pierce Canyon" has been abandoned for this reason, and the name Dewey Lake has been extended into this area (see Schiel, 1988, for further discussion).

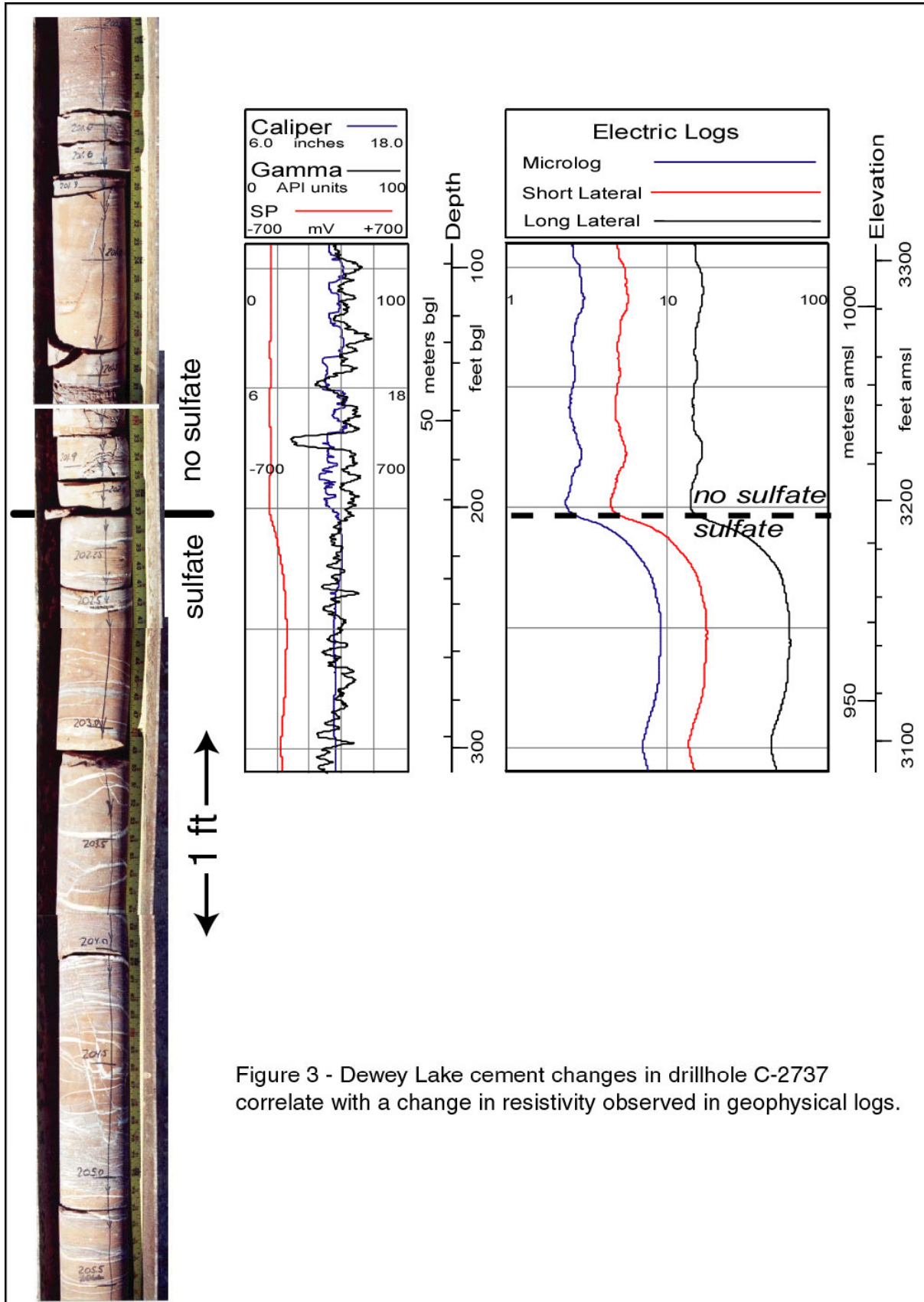


Figure 3 - Dewey Lake cement changes in drillhole C-2737 correlate with a change in resistivity observed in geophysical logs.

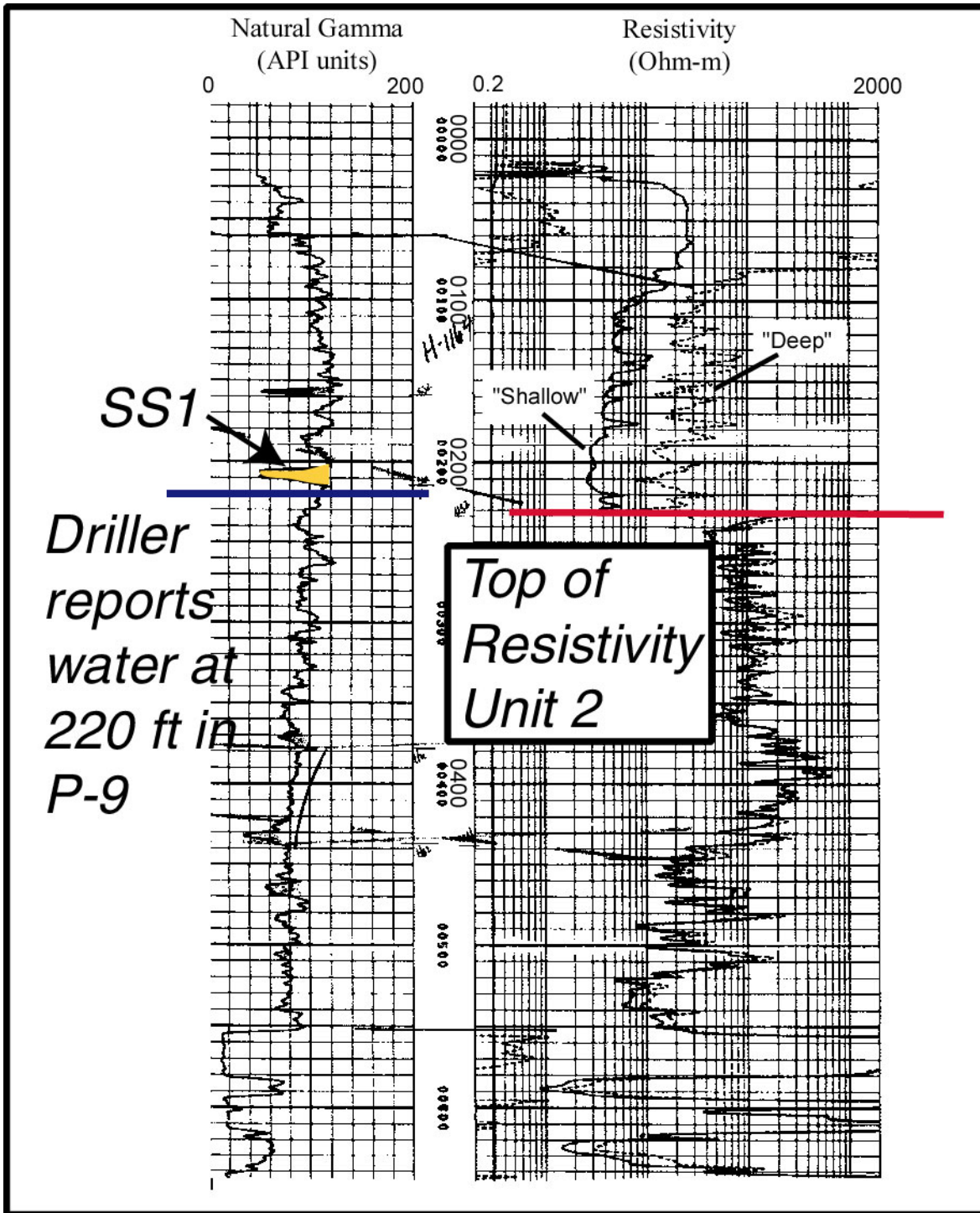


Figure 4. Water encountered while drilling P-9 occurs just above the change in resistivity in nearby H-11b4. The natural gamma log (left side) shows a sandstone bed (SS1) that was deposited over a wide area at the WIPP.

Hydrologic data about the Dewey Lake in the vicinity of the WIPP are scarce, consisting of a) one test for which a value of T was obtained, and b) several occurrences of water or moist zones noted during drilling. Some stock or ranch wells have been completed in the Dewey Lake. As noted earlier, the estimated value of T at the location of monitoring well WQSP 6A is 3.9×10^{-4} m²/s (Beauheim and Ruskauff, 1998, p. 193). This value is approximately five times larger than the largest value of T for the Culebra Dolomite Member of the Rustler Formation within the WIPP boundaries. Cooper and Glanzman (1971) summarized basic data from the area about water in formations above evaporites.

Powers (1997) summarized the geologic data obtained during an investigation of shallow water under the facilities at WIPP. The saturated zone, created since construction investigations for the WIPP, is the basal Santa Rosa Formation overlying the Dewey Lake. Holt and Powers (1990a,b) recorded a change in natural cements from sulfate (below) to carbonate (above) in the upper Dewey Lake while mapping in the air intake shaft. Powers (1997) reviewed drilling records for the WIPP area and known encounters of natural Dewey Lake waters. Powers (1997) suggested that natural waters in the Dewey Lake accumulated on this surface at the change in cements. It was proposed that this surface is irregular and is lower stratigraphically in the Dewey Lake from the center of the site to the south and west. At the site center, however, the upper surface of the Dewey Lake has, at least temporarily, retarded downward infiltration of the modern water (Powers, 1997).

In work in progress, Powers has followed up this preliminary version of a geohydrological conceptual model for the Dewey Lake. Drillhole B-25, located near WIPP shafts, obtained cores and a good suite of geophysical logs. It is near the air intake shaft, and it has been possible to establish a clear correspondence between natural cement changes and formation resistivity (Figure 5), which is related to the porosity and pore fluids of the formation. The set of drillholes with comparable resistivity logs through the Dewey Lake is relatively small, and all known logs in the area come from the WIPP project. The logs illustrate that the stratigraphic position of the resistivity change (and by inference change in hydraulic properties) differs most across the southwestern part of the WIPP Site, and that specific encounters of natural waters in the Dewey Lake during drilling can be correlated with this change in resistivity properties. Drillhole C-2737 (Figure 3) shows the correspondence again between natural cements and formation resistivity (Powers, 2002).

Water encountered while drilling the upper Dewey Lake at C-2737 and C-2811, adjacent to C-2737, is at a depth of less than 20 m below the ground surface. Given the general drilling history of this area, this water is believed to be an extension of the shallow water under the WIPP facilities. The zone may have become saturated within the last few years. The current stratigraphic position of this water is well above the change in cements, but it is below very thin (< 2 m thick) Santa Rosa sandstones at this location. Multiple hardened zones were noted in the upper Dewey Lake at C-2737 (Powers, 2002) and in twelve piezometer holes drilled within and adjacent to the secure area of the WIPP (Powers, 1997), and these hardened zones may indicate thin beds that impede vertical infiltration. Abandoned stock wells in section 15, T22S, R31E in the northeastern part of the WIPP Site noted by Cooper and Glanzman (1971) produced from the lower Santa Rosa.

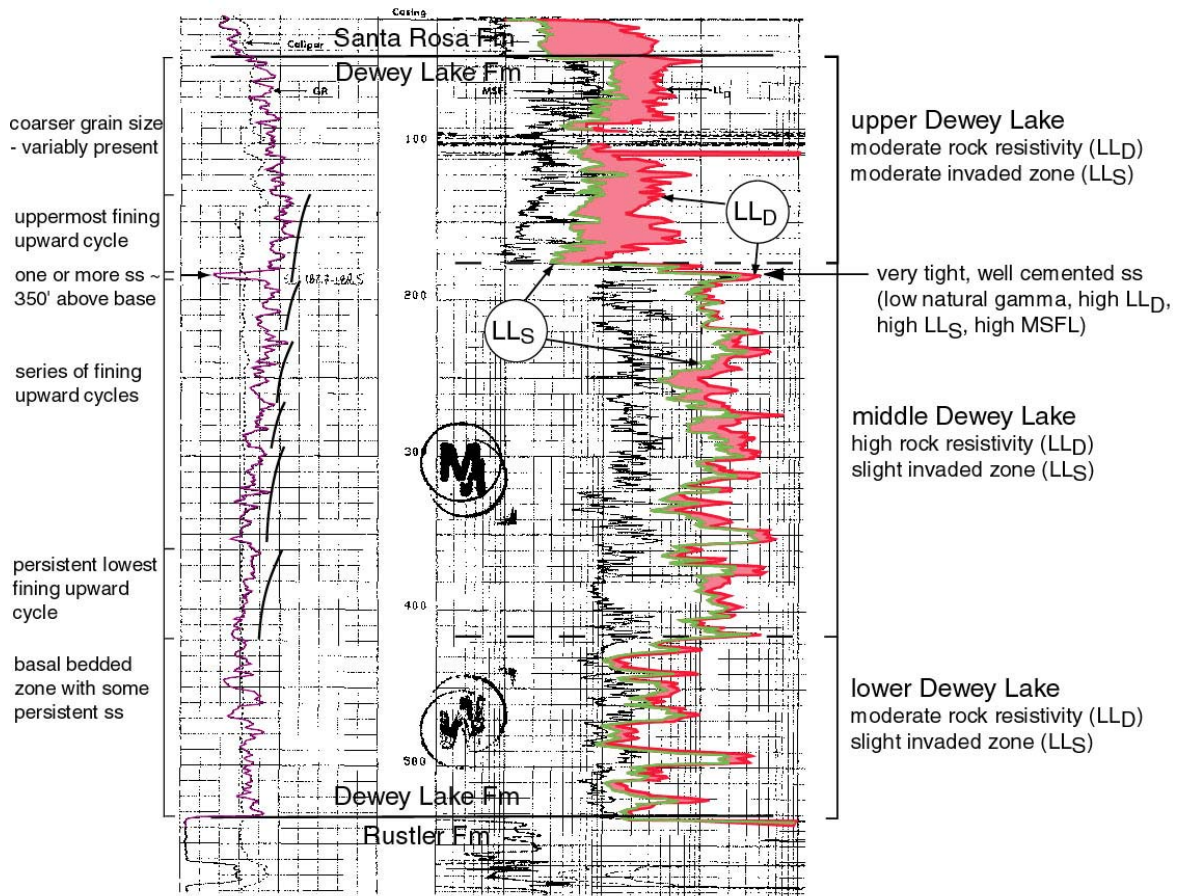


Figure 5. Natural gamma (left) and resistivity (right) log for drillhole B-25, which is located near the center of the WIPP Site. Natural gamma reveals three basic depositional subdivisions: a basal bedded zone (bbz), a general fining upward system comprising several smaller (~10 m thick) fining upward cycles, and an upper sequence that coarsens upward. The resistivity logs show a basal mixed resistivity unit corresponding to the bbz. The middle resistivity zone shows higher resistivity. The transition upward to lower resistivity corresponds to the change from sulfate cements (below) to carbonate cements (above) and higher porosity.

For the moment, the preliminary conceptual model of Dewey Lake geohydrology can be summarized as follows. The Dewey Lake is apparently unsaturated over most of the WIPP Site. South and west of the center of the WIPP Site, several drillholes have encountered natural saturated zones within the Dewey Lake, and there are a few Dewey Lake wells off the WIPP Site used mainly for stock watering. Near the site center, cores and shaft mapping reveal a boundary between natural carbonate and sulfate cements in the Dewey Lake about 50-55 m below the ground surface. Resistivity logs correlate with this cement change and show that formation porosity drops significantly across this boundary from carbonate cements (above) to sulfate cements (below). Resistivity logs and drilling records indicate this boundary trends downward stratigraphically to the south and west of the site center, and it occurs near the base of the Dewey Lake in the southwestern corner of the WIPP Site. Natural waters in the Dewey Lake southwest of the WIPP Site center are found at this boundary. A saturated zone in the uppermost Dewey Lake and basal Santa Rosa, with water of highly variable salinity, has developed at the center of the site since early investigations of the WIPP. Drillholes for engineering studies show this zone was not saturated before construction of the WIPP surface facilities. Thin hard zones in the upper Dewey Lake encountered in this area during drilling may be impeding deeper infiltration at the same time that short vertical to subvertical open fractures enhance infiltration.

There are several areas likely to yield further insight into a geohydrologic conceptual model for the Dewey Lake. The relationship between natural cements in cores and resistivity logs can be established more securely through studies of additional cores (the immediate objective of this Test Plan). It is possible that the cement boundary can be correlated with other log types (e.g., density or acoustic velocity) and that the boundary can be mapped over a larger area, and more thoroughly, than is possible with resistivity logs. Outcrops of the Dewey Lake along the margins of Nash Draw to the west and northwest of the WIPP Site will be examined, and several samples will be studied to relate previous outcrop studies (e.g., Miller, 1955a; Schiel, 1988) to laboratory work planned under this TP. Knowledge of hydraulic properties of the Dewey Lake may be improved with additional sample tests, tests in holes monitoring modern water, and tests of cores and any saturated zones in new drillholes. The degree of saturation of the Dewey Lake is not established, and core from a new hole should be appropriately tested. Additional geochemical and isotopic studies of Dewey Lake waters and rocks should also yield insights into the development of the current hydrologic system. Existing surface resistivity data may provide indications of the area with pre-existing saturated zones, and they may also provide help in designing new geophysical surveys to detect saturated zones in the Dewey Lake. Hydrologic modeling may be used to sharpen the geohydrologic conceptual model.

3.4 Intended Use of Data

Data obtained from laboratory studies of Dewey Lake sample mineralogy will be used to extend correlation of geophysical logs with rock properties over a larger area at the WIPP. Up to now, sample studies have been limited to drillhole B-25 as representative of Dewey Lake geology near the center of the WIPP Site. Basic descriptions of cores and cuttings from other drillholes, as well as existing geophysical logs, will be used to help guide sampling. These data will help confirm or be used to revise the geohydrologic conceptual model as it now exists.

Although the laboratory data obtained under this TP are not expected to be used directly in PA, the geohydrologic conceptual model for the Dewey Lake may be used for revising FEPs and it may affect assumptions about recharge used in PA.

4 EXPERIMENTAL PROCESS DESCRIPTION

The principal activity under this TP is to obtain laboratory data about the mineralogy and diagenesis of Dewey Lake sedimentary rocks that can be used to interpret the architecture of apparent hydraulic conductivity of the formation. The experimental process develops the details of the laboratory work. A later section shows how the information fits with other possible activities regarding Dewey Lake hydraulic properties, although those activities may be conducted under other test plans or by different organizations.

4.1 Planning, Overall Strategy and Process

For the most part, the laboratory work will be compiled into a record that shows the composite results of the mineral, texture, and porosity observations for each sample, arranged to reflect depth and stratigraphic occurrence. The history of diagenesis, to understand the development of porosity, will be interpreted using basic relationships among mineral cements or other secondary accumulations of minerals. The basic chemistry of these minerals (e.g., silicate, sulfate, carbonate) will be used to help understand the history of the fluid phases in the rock diagenesis.

After the basic laboratory data are interpreted, the information can be compared to other features, such as the resistivity or density logs for the drillholes. If the basic relationships already observed in a few drillholes hold, the geophysical logs can be used to extend inferences about the basic lithology and geohydrology of the unit.

4.1.1 Important Variables to be Measured and Controlled

The important variables for this study are the presence, relationships, and locations (i.e., depth in a particular drillhole) of natural mineral cements and matrix minerals. From previous study, these minerals are mainly carbonate and sulfate cements and clay as matrix material. Using X-ray diffraction and petrography, the presence and relative abundance of mineral phases can be established for different samples. Petrography and SEM (scanning electron microscope) can be used to establish diagenetic relationships among minerals. These are mainly qualitative observations with semi-quantitative or relative proportions being established.

4.1.2 Coordination with Organizations Providing Inputs or Using Results

Additional core samples may be requested from WTS to extend the data or to refine ideas of the location and extent of mineral cements in the Dewey Lake. Requests will be processed through normal WTS procedures.

Summary results will be distributed by a SAND document or similarly reviewed report to Sandia organizations responsible for PA, WTS organizations with responsibilities for geological and hydrological studies, and to cognizant managers at CBFO.

4.1.3 Procedures to be Used or Developed

No special procedures need to be developed and approved for this study. Sampling, sample handling and preparation, and sample study for the Dewey Lake are normal geological practices.

Three main analytical tools will be used to provide data on the Dewey Lake samples: petrographic microscope, X-ray diffraction (XRD), and scanning electron microscope (SEM). The binocular microscope may be used for grain and fabric identification on some samples. The petrographic microscope will be used to identify mineralogy and rock fabric, estimate porosity, and understand diagenetic sequences using standard or polished thin sections. In addition to recorded observations about the individual sample, digital or film records (photomicrography) will be made of selected samples or portions of thin sections. Each such film or digital record will be catalogued on a photograph log. XRD will be used on powdered samples of bulk rock to identify minerals, and it may also be used on physical or chemical concentrations of minerals to identify them. Minerals will commonly be identified by comparing sample patterns with standard patterns; more specialized methods may be applied, such as the method of Bodine and Fernald (1973) for clay mineral concentration and identification. SEM methods provide high-magnification images of mineral and pore textures. These may be noted by recording general observations, and selected images may be saved digitally or as a print record for further use. In addition, the concentrations of selected elements (e.g., potassium or calcium) can be mapped over an image area to help identify mineral phases and their distributions. Selected images may be retained as printed or digital records for basic data and use in illustrating features. The SEM also has the capability of providing a spot analysis (an area a few microns in diameter) for a number of elements. These spot analyses can help identify the locations of minerals reported through XRD or below the level of detection for XRD.

Sample blocks will be sized for standard thin sections or will be marked to indicate the area for the thin section block. Samples will be impregnated with epoxy containing a blue fluorescing dye. The dye color helps to identify porosity during normal petrographic work; an ultraviolet light causes the dye to fluoresce, and this can be helpful in using computer software to estimate the porosity. A number of thin sections will be polished for SEM work. The sample must be coated before SEM analysis, and established laboratory procedures will govern the process. XRD analysis will require a small subsample be ground in a non-reactive mortar. More detailed XRD analysis of clays may require some concentration and analysis after various treatments such as heating or expanding the clay lattice with a chemical such as ethylene glycol. Established procedures, such as those in Millot (1970) or Bodine and Fernald (1973), will be used to prepare samples. Any other sample preparation will be documented and the method referenced.

4.1.4 Identification of Prerequisites or Special Controls

The drilling records and previous work on existing WIPP drillholes will be used to compile a listing of useful core intervals of the Dewey Lake and compare them with available natural gamma and resistivity logs. From this list, cores from several drillholes will be designated for sampling to provide evidence of cements and matrix representing differing resistivity zones across the WIPP Site and beyond, if possible. In addition, some samples will be selected to represent some of the sedimentary zones within the Dewey Lake having stratigraphic continuity across the area. An example would be the sandstone unit found in drillhole B-25 at a depth of about 57 m (~ 185 ft) (Figure 5). A preliminary estimate is that between 100 and 200 small samples will be taken for possible analysis. More samples will be acquired than are likely to be analyzed; given the current core inventory, it is more practical to select possible alternative or ancillary samples at the beginning than it is to make additional sampling expeditions. Where practical, samples will be quarter or half cores to preserve samples of the interval in the core inventory.

After core samples have been described and re-examined as appropriate in the laboratory (possibly using a binocular microscope), a table will be developed showing the analyses to be conducted on each sample. At this point, a number of samples may not be designated for initial sampling but they will be reserve samples that will be available to extend or narrow the stratigraphic coverage or to provide supplemental samples if there are unusual results requiring verification. If additional samples are analyzed, the table will be revised, and the table number or footnotes will indicate the revisions.

4.1.5 Known Sources of Error and Uncertainty

Mineral abundances estimated by XRD in polymineralic samples is semi-quantitative or relative; some minerals have overlapping diffraction peaks, and diffraction peak intensity depends on abundance and mineral structure.

Core sample depth may vary from depths recorded on geophysical logs. Larger errors or uncertainty have been reported in basic data reports for drillholes.

4.1.6 Compatibility of Data Processing with Conceptual or Mathematical Models

The data to be obtained on types and distribution of mineral cements and matrix minerals are compatible with developing a basic geohydrological conceptual model of the Dewey Lake incorporating a variety of data, including geophysical logs.

4.1.7 Documents to be Maintained as QA Records

A scientific notebook, electronic files and printouts supporting the notebook or summary report, and a report including relevant tables, charts, or figures of data will be prepared, submitted, reviewed, and archived.

4.2 Sample Control

4.2.1 Sample Labeling or Identification

Core or rock samples will be collected and controlled in accordance with SNL NP 13-1 *Control of Samples and Chemical Standards*. The chain of custody for the samples when they are moved to the point of analysis (mainly SNL-Carlsbad) will be established in accordance with SNL SP 13-1 *Chain of Custody*. SNL SP 13-2 *Core Sample Logging and Management* applies to a limited degree to the existing core inventory managed by WTS; some basic sample controls are repeated here. Each will be uniquely marked, catalogued, and described as they are identified. Where practical, an arrow will be marked on the core pointing in the uphole direction. Each sample will be put in its own plastic bag for ease of identification and handling. Each bag will be marked to represent uniquely the sample. Identifying information on or in the bag will include: project name (SNL Dewey Lake Geohydrology); sample number (abbreviated well name-depth in feet; e.g., B25-186.4); well designation; sample location (core depth in ft); collector's name; and date of collection. Outcrop samples taken for comparison with core samples will be similarly marked, with location information as appropriate. Sample identification and description should be adequate for another investigator to relocate the sampling point.

4.2.2 Sample Handling or Nonconforming Requirements

The samples require no special disposal or handling.

4.2.3 Sample Storage and Environmental Controls

The main sources of samples for this study are cores currently held in storage facilities by WTS. There may be some supplemental sampling of outcrops in the field. These samples will have a varying history of drilling and storage (or exposure) periods and conditions. They are acceptable for this project as long as the source (e.g., drillhole and depth) can be determined. The natural cements within these rocks develop and change over geological time in response to pressure, temperature, and the volume and solute concentrations of water as it moves through the sediment or rock. During storage at WIPP, cores experience varying degrees of diurnal and seasonal changes in temperature. Air flow and changes in relative humidity are moderated by the storage facility, boxes, and sleeving. Pressure changes are insignificant while in storage. The silicate, carbonate, and sulfate minerals that are part of matrix materials and natural cements of most interest in determining natural cements in the Dewey Lake are considered stable to metastable for most local surface conditions.

For this study, drilling, recovery, and storage conditions are insignificant compared to geological processes.

4.2.4 Sample Disposal

Large remains of samples can be returned to the source.

4.3 Data Quality Control

4.3.1 Measuring and Test Equipment

Standard measuring and test equipment for purposes of calibrating pressure measurements or similar quantitative variable are not used for this study. Equipment such as the XRD and SEM are maintained to provide data for a variety of studies. As described in section 2.3.4, common minerals such as quartz provide internal controls on the consistency and accuracy of the equipment for this study.

4.3.2 Data Acquisition System

Data acquisition systems are built-in to equipment such as the X-ray diffraction and SEM units and are not maintained separately.

4.3.3 Methods for Justification, Evaluation, Approval, and Documentation of Deviations from Test Standards or Use of Specially Prepared Test Procedures

There are no typical test standards (e.g., sampling rate to obtain a level of statistical confidence) applied to this study except those built-in to the operation of XRD and SEM. No special test procedures are being developed; references to test procedures (e.g. Bodine and Fernald, 1973) will be included in notes if the tests are applied.

4.3.4 Controls or Reference Samples Used

Dewey Lake samples include well-known minerals (e.g., quartz) with standard responses to analyses such as X-ray diffraction. The mineral quartz is not an object of this study, and it serves as an internal control on such procedures. If significant uncertainty develops over such a procedure, a standard material can be obtained as an external reference.

4.3.5 Control and Characterization of Test Media

There are no test media identified for this study.

4.4 Data Identification and Use

4.4.1 Methods of Recording Data

Electronic records, photographs, or written records must be clearly identified with the investigation, investigator's name, date, description of record content, scales, or other necessary

information to understand the record and associate it correctly with the study and individual sample. A scientific notebook is appropriate for recording information and data (NP 20-2, *Scientific Notebooks*) but is not required.

Observations or data collected for a sample must refer to the sample identification and must also record the conditions under which the observations were made or data collected. The criterion for this is that an auditor or independent investigator can associate the observation or datum with the correct interval within a core or outcrop and can associate proper scales and other conditions for the observation or datum.

4.4.2 Data Transfer and Reduction Controls

Selections or copies of data obtained during this investigation will be transferred, as needed, by memo or letter with attachments in appropriate formats. A copy of the memo will be sent for archiving; data will not be archived unless they differ from data prepared for a record package.

4.4.3 Control of Erroneous or Inadequate Data

If erroneous data are generated during this study, records will be examined to determine which are erroneous or inadequate. Scientific notebook entries regarding the erroneous or inadequate data will be annotated, initialed, and dated to indicate clearly which data are erroneous or inadequate. If these data have not entered an analysis phase, they may be discarded and the annotation should so indicate. If the data have been included in an analysis, those who are known to have received, used, and archived the erroneous or inadequate data will be informed in writing of the erroneous or inadequate data, and any records package including the data will include such information.

4.4.4 Data Conversion Controls

Data obtained during standard laboratory investigations (e.g., X-ray diffraction) are converted into useful information, such as relative peak height and diffracting angle, during operation of the equipment and attendant computers. Malfunctions of such conversion are determined by inspection; an example would be the lack of a diagnostic peak for a mineral such as quartz that is known to be present in the samples.

Other data, such as depth of a core sample from a particular drillhole, may be converted from English (e.g., feet) to metric (e.g., meters) for presentation or publication. These conversions are carried out using standard hand calculators or commercial spreadsheets such as Excel. The conversion standard commonly used is $1 \text{ ft} = 0.3048 \text{ m}$, and spreadsheet equations can be checked.

5 BROAD FRAMEWORK FOR ESTABLISHING AND EXTENDING A GEOHYDROLOGIC CONCEPTUAL MODEL OF DEWEY LAKE

A broad framework for Dewey Lake studies is helpful for understanding how different project efforts can contribute to establishing and extending a geohydrology conceptual model for the Dewey Lake. As stated earlier, this framework is not intended to replace or override other SNL efforts or other organization's efforts to understand or investigate aspects of the Dewey Lake geology or hydrology. It provides a general framework for developing the conceptual model, and it places the study of sample mineralogy and natural cementation in that framework (Section 3.2).

5.1 Interpret Architecture of Apparent Hydraulic Properties

There is only one reported test yielding a value for transmissivity of the Dewey Lake (Beauheim and Ruskauff, 1998), and therefore there is no direct basis for establishing the architecture of hydraulic properties for the Dewey Lake. There is, however, information on formation resistivities from holes drilled for the WIPP, and these resistivities can be used to establish porosity zonation, a general three-dimensional framework or architecture for that zonation, and an estimate of the relative hydraulic properties of the zones.

The initial work for this part has been done, and the resistivity logs show vertical zonation (Figure 5) and evidence of areal variation. It is likely that this work will be completed outside of this test plan, under the direction of WTS. This work should be incorporated in a Dewey Lake geohydrological conceptual model as developed by WTS or SNL.

As new wells are drilled in the vicinity of the WIPP for groundwater monitoring, some will have geophysical logs that can be used to extend the resistivity zonation, and by proxy the hydraulic architecture of the Dewey Lake and related units. Saturated zones in the Dewey Lake encountered in these wells may be tested, providing more direct evidence of the hydraulic properties and some degree of correlation of measured formation resistivity to hydraulic properties.

Anthropogenic or recent groundwater at shallow depths in the vicinity of WIPP facilities will be further investigated by WTS. Although most of the groundwater has been found in the basal Santa Rosa, recent drilling at C-2737 and C-2811 shows the groundwater in the upper Dewey Lake south of the site facilities (Powers, 2002). Past testing of the saturated zone under the facility area provides some hydraulic properties of the Santa Rosa, which can be compared to the resistivity logs of this formation. Additional testing of this saturated zone, especially in the upper Dewey Lake, will contribute to our knowledge of Dewey Lake (and Santa Rosa) hydraulic architecture.

5.2 Relate Hydraulic Architecture to Geological Factors

This part of developing a geohydrologic conceptual model for the Dewey Lake is the focus of this TP. Likely factors affecting hydraulic properties and their distribution in the Dewey Lake include depositional bedding, matrix minerals and distribution, and natural cements in the porosity. Work to date (Powers, 1997, 2002) suggests that a major change in formation resistivity is related to the change in natural cement from sulfate (below) to carbonate (above). The resistivity zonation of much of the formation is also closely related to depositional units as well. The program of study covered in this TP will help to define the spatial relationships of cements, matrix, and other lithological factors across the WIPP Site and immediate surroundings.

The information about the lithological factors will be directly related through the log information (Section 3.1) to the resistivity structure, and, by inference, to the hydraulic architecture. Maps and cross-sections will be created to illustrate the spatial relationships. [These graphic illustrations may be produced as part of the work identified under other sections.]

5.3 Relate Known Occurrences of Water in the Dewey Lake to Apparent Hydraulic Conductivity and Geological Factors

Beauheim and Ruskauff (1998) and Powers (1997) summarized known occurrences of water in the Dewey Lake in the vicinity of the WIPP Site. The geophysical logs of H-11b4, for example, indicate that a significant change in resistivity (Figure 4) occurs at the depth where water was encountered in nearby drillhole P-9 (Jones, 1978).

Maps of the elevations of resistivity changes or lithologic factors may be used to interpolate the elevation of groundwater encounters in drillholes without resistivity logs. As noted in Section 3.1, future drilling and testing programs can provide data for confirming or refining these relationships.

WTS is considering a program to explore the distribution of anthropogenic or recent groundwater near the center of the WIPP Site, and this program may contribute significantly to the broader understanding of Dewey Lake (and Santa Rosa) geohydrology. Surface-based geophysical techniques may be found useful in delineating shallow to deeper zones of saturation prior to drilling and testing. In addition, some samples may be tested to determine the degree of saturation of shallow units; this could contribute to our understanding of how saturated zones develop.

5.4 Develop and Test a Conceptual Model of Dewey Lake Geohydrology

The laboratory work covered by this TP can be coupled with resistivity zones and known groundwater occurrences to develop a conceptual model of Dewey Lake geohydrology. Preliminary work suggests that natural groundwater occurs above the contact between sulfate cements (below) and carbonate cements (above). Saturated zones created in the basal Santa Rosa and uppermost Dewey Lake near the center of the WIPP Site since WIPP construction began,

however, are still above this cement change, and a different explanation is necessary. It isn't known yet whether the upper Dewey Lake will retard infiltration to the cement change for a short period or for a time approaching 10,000 years.

Two general kinds of tests of a conceptual model can be applied. Future wells for monitoring groundwater will be drilled into or through the Dewey Lake, and the record of cores, geophysical logs, or saturated zones will provide a direct test. The second kind of test may be to consider the effects of hydraulic zonation predicted by the conceptual model on models of infiltration and recharge of units at the WIPP. These effects can be compared to previous models considering the Dewey Lake to be a homogenous hydraulic unit.

6 QUALITY ASSURANCE

The data developed through laboratory studies undertaken for this TP are not to be used directly in setting parameters for performance assessment or for re-evaluating FEPs. The data will be useful in developing and refining a geohydrologic conceptual model of the Dewey Lake Formation, and that geohydrologic conceptual model will be useful in evaluating the existing understanding of the hydrologic system at WIPP. The principal elements of QA that will apply to this activity therefore reflect the need for traceability of samples and results to sample, and accurate record-keeping.

7 TRAINING

Investigations under this test plan may affect the SNL WIPP Performance Assessment calculations. Therefore, all activities performed under this test plan will be performed under quality assurance (QA) procedures which are consistent with the requirements specified in the Carlsbad Field Office (CBFO) Quality Assurance Program Document (QAPD). All personnel associated with this test plan will be qualified in accordance with all applicable QA requirements prior to performing any quality-affecting work.

The qualifications of Sandia participants will be documented on Nuclear Waste Management Program (NP) Form NP 2-1-1, *Qualification and Training Form* as per NP 2-1, Qualification and Training. The existence of these forms will be verified in the WIPP Records Center. Sandia participants receive QA program and NP training via Annual Refresher QA Training, either by attendance at training seminars or by viewing a training video. Training for Sandia participants will also be verified.

Non-Sandia participants under contract to Sandia will follow the same training and qualification processes as Sandia participants.

8 HEALTH AND SAFETY

The work described in this Test Plan is principally undertaken within the laboratory area of SNL-Carlsbad, and ES&H training associated with such laboratory work will be provided. General Employee Training is required for unescorted on-site visits at WIPP, and general fieldwork requires normal precautions.

Activities, such as core examination and selection, conducted in areas controlled by WTS will follow applicable safety practices and policies.

9 PERMITTING/LICENSING

Not applicable.

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