ISSUED

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WP 02-1
Revision 15

WIPP Groundwater Monitoring Program Plan

Cognizant Department: Environmental Monitoring and Hydrology

Approved by: Rick Salness

Nuclear Waste Partnership
An AECOM-led partnership with BWXT and AREVA

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CHANGE HISTORY SUMMARY

REVISION NUMBER	DATE ISSUED	DESCRIPTION OF CHANGES
14	03/30/16	• Throughout document the language was updated to differentiate between groundwater field parameter monitoring and final sampling. Titles of procedures were added after document numbers. • Updated Active Culebra Groundwater Wells table. • Changed language in 4.1.1 to clarify when the semiannual to annual reporting frequency occurred. • The word Unadjusted was removed from the inputs to determine freshwater head. • 4.6.1 replaced DOE/EH0173T with DOE-HDBK-1216-2015, Environmental Radiological Effluent Monitoring and Environmental Surveillance.
15	06/01/18	• Updated due to expiring. • Deleted Appendix A – *Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head.* • Deleted WP 02-EM1021, *Pressure Density Survey.*

ABBREVIATIONS AND ACRONYMS

a~~A~~msl	above mean sea level
ASER	Annual Site Environmental Report
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CofC/RFA	chain of custody/request for analysis
CRA	Compliance Recertification Application
Culebra	Culebra Member of the Rustler Formation
%C	percent completeness
DMP	Detection Monitoring Program
DMW	detection monitoring well
DOE	U.S. Department of Energy
DQO	data quality objectives
EM&H	Environmental Monitoring and Hydrology
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
ft	foot(feet)
GMP	Groundwater Monitoring Program
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LLC	Limited Liability Company
LWA	Land Withdrawal Act
m	meter
M&DC	monitoring and data collection instrument
MDL	method detection limit
MRL	method reporting limit
MS	matrix spike
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NWP	Nuclear Waste Partnership LLC
P&A	plugging and abandonment
PA	performance assessment
Permit	WIPP Hazardous Waste Facility Permit
pH	potential hydrogen (measure of acidity/alkalinity)
QA	quality assurance
QAO	quality assurance objective

QAPD	Quality Assurance Program Description
QC	quality control
RCRA	Resource Conservation and Recovery Act
RIDS	Records Inventory and Disposition Schedule
RPD	relative percent difference
ROR	RCRA Operating Record
SC	specific conductance
SG	specific gravity
SOP	standard operating procedure
STR	Subcontract Technical Representative
TDS	total dissolved solids
TOC	total organic carbon
TRU	transuranic
TSS	total suspended solids
UTLV	upper tolerance limit value
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant
WLMP	Water Level Monitoring Program
WQSP	Water Quality Sampling Program

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) Environmental Monitoring Plan (EMP), DOE/WIPP 99-2194, includes two important program elements: (1) radiological environmental monitoring and (2) non-radiological environmental monitoring. Monitoring conducted within the first element includes groundwater monitoring. Though listed under the radiological program, the groundwater monitoring program (GMP) also supports monitoring of non-radiological components. The two non-radiological components of the GMP required by the WIPP Hazardous Waste Facility Permit (Permit) include the Detection Monitoring Program (DMP) and the Water Level Monitoring Program (WLMP). These are implemented along with radiological monitoring requirements and plugging and abandonment (P&A) requirements in this GMP Plan.

This Plan is the implementing document for the GMP. The GMP complies with the following requirement drivers:

- WIPP Hazardous Waste Facility Permit (Permit) mandated by 20.4.1.500 NMAC (New Mexico Administrative Code) (incorporating applicable sections of Title 40 *Code of Federal Regulations* [CFR] Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"). This is the driver for non-radiological monitoring of groundwater.

- WIPP Compliance Recertification Application (CRA) (DOE, 2009) submitted to document compliance with the disposal standards of 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," in accordance with the criteria specified in 40 CFR Part 194, "Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with ~~the~~ 40 CFR Part 191 Disposal Regulations" (61 *Federal Register* 5224). This is a driver for radiological monitoring of groundwater.

- DOE Order 458.1, *Radiation Protection of the Public and the Environment*. This is a driver for radiological monitoring of groundwater.

The WIPP facility includes a mined geologic repository for the disposal of transuranic (TRU) waste. The disposal horizon is located approximately 2,150 feet (ft) (655 meters) below the land surface in the bedded salt of the Salado Formation. At the WIPP facility, water-bearing units occur both above and below the disposal horizon. Groundwater monitoring of water-bearing zones below the repository is not performed because the uppermost water-bearing unit (in the Bell Canyon Formation) is not considered a credible pathway for a release from the repository. This is because the repository horizon and water-bearing sandstones of the Bell Canyon Formation are separated by over 2,000 ft (610 meters) of very low-permeability evaporite sediments. No credible pathway has been established for contaminant transport to water-bearing zones below the repository horizon, as there is no hydrologic communication.

The U.S. Environmental Protection Agency (EPA) concluded in 1990 that natural vertical communication does not exist based on their review of numerous studies (EPA, 1990). Furthermore, drilling boreholes for groundwater monitoring through the Salado Formation and the Castile Formation into the Bell Canyon Formation would compromise the isolation properties of the repository medium.

Groundwater monitoring at the WIPP facility is focused on the nearest water-bearing unit above the repository in the Culebra Dolomite Member of the Rustler Formation (Culebra) because it represents the most significant hydrologic contaminant migration pathway to the accessible environment (EPA 1990).

The WIPP facility is located in Eddy County in southeastern New Mexico (figure 1) within the Pecos Valley section of the southern Great Plains physiographic province (Powers et al., 1978). The facility is 26 miles (42 kilometers) east of Carlsbad, New Mexico, in an area known as Los Medaños (the dunes). Los Medaños is a relatively flat, sparsely inhabited plateau with little surface water and limited land uses.

The WIPP facility consists of 16 sections of federal land in Township 22 south, Range 31 east. The 16 sections of federal land were withdrawn from the application of public land laws by the WIPP Land Withdrawal Act (LWA) (Public Law 102-579). The WIPP LWA transferred the responsibility for the administration of the 16 sections from the U.S. Department of the Interior, Bureau of Land Management, to the DOE. This law specified that mining and drilling for purposes other than support of the WIPP Project are prohibited within this 16-section area, with the exception of Section 31. Oil and gas drilling activities are restricted in Section 31 from the surface down to 6,000 ft. Addendum L1 of the WIPP Resource Conservation and Recovery Act (RCRA) Part B Permit Renewal Application (DOE, 2009) and appendix HYDRO of DOE/CAO-1996-2184, WIPP Compliance Certification Application (CCA), provide more detailed discussions of the local and regional hydrogeology.

This GMP Plan addresses requirements for sample collection and analysis, groundwater surface elevation monitoring, groundwater flow rate and direction determination, data management, and reporting of groundwater monitoring data. It also describes plugging and abandonment (P&A) of monitoring wells, and establishes personnel responsibilities for the WIPP GMP, as well as quality assurance/quality control (QA/QC) elements and associated data acceptance criteria.

Instructions for performing field activities that will be conducted in conjunction with this sampling and analysis plan are provided in standard operating procedures (SOPs). Procedures are required for groundwater surface elevation measurement, groundwater flow rate and direction determination, sampling equipment installation and operation, field groundwater stability measurements, final sample collection to determine groundwater quality, data verification and validation, and other aspects as needed. Activities under the GMP will be performed by qualified personnel, or personnel under the supervision and direction of qualified personnel.

2.0 GENERAL REGULATORY REQUIREMENTS

The WIPP facility is defined under RCRA as a miscellaneous unit, therefore, the applicable groundwater monitoring requirements are prescribed in 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart X) and 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F).

In 1992, the U.S. Congress passed the WIPP LWA which, among other things, mandated that the EPA certify the DOE's compliance with 40 CFR Part 191, Subparts B and C. The EPA issued criteria for certification as 40 CFR Part 194. An application, titled "Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant," was the DOE submittal to the EPA, requesting certification which was granted in 1998. The WIPP facility compliance to the disposal standards was recertified in 2005 and 2010. As part of the certification and recertification applications, the DOE committed to perform groundwater monitoring to meet the Assurance Requirements of 40 CFR Part 191 §191.14. The DOE has demonstrated that the WIPP facility can be operated and closed in a manner that complies with federal radiation protection standards prescribed in 40 CFR Part 191.

3.0 WIPP GROUNDWATER MONITORING PROGRAM OVERVIEW

The GMP contains several components which are described broadly here. These include the DMP, ~~the~~ WLMP, ~~the~~ P&A Program, and radiological monitoring program. Details regarding each component follow in subsequent sections of this plan.

3.1 DMP Scope

The DMP is stipulated in the Permit to satisfy the requirements of 40 CFR Part 264, Subpart F. The Permit requires that Nuclear Waste Partnership LLC (Permittees) sample groundwater to determine if there has been contamination of groundwater as the result of a potential release from TRU mixed waste managed at the WIPP facility. In addition, the Permit requires that the DMP detection monitoring wells (DMWs) be used in the determination of flow rate and direction of groundwater in the Culebra, as discussed in Section 3.2. The Permit specifies that the DMP include annual groundwater sampling and analysis conducted to meet the requirements of the Permit. The Permit also provides background water quality data that are used for comparison to ongoing sampling and analysis to determine if a release may have occurred.

In order to satisfy the requirements of 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F), the Permit stipulates that the DMP include six DMWs completed in the Culebra. Wells WQSP-1, WQSP-2, and WQSP-3 are Culebra DMWs that are located up gradient (north) of the WIPP shaft area. Wells WQSP-4, WQSP-5, and WQSP-6 are Culebra DMWs that are located down gradient (south) of the WIPP shaft area. The DMWs are the only Culebra wells that are sampled for chemical analysis to determine groundwater quality. Other wells may be identified by the program in the future for such sampling and analysis. In this case, the methods employed for the current DMWs can also be used for other wells.

The DMP also serves to provide samples for radiological monitoring of the groundwater as required by DOE Order 458.1.

3.2 WLMP

The WLMP is stipulated in the Permit to satisfy requirements prescribed in 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subparts F and X). Monthly measurement of the water level in wells completed in the Culebra, coupled with annual determinations of water density, allow the reporting of equivalent freshwater heads over a broad network of monitoring wells. These data are used to determine if the general flow rate and direction of groundwater in the Culebra is not changing with time and to evaluate the efficacy of the location of the DMWs. The WLMP wells, as of February 17, 2015, used to measure the water level in the Culebra are presented in the table below. The list of wells is subject to change due to P&A and drilling of new wells. Water levels are also routinely measured for non-Culebra wells in the region separate from the WLMP requirements of the Permit.

Active Culebra Monitoring Wells as of February 15, 2016

AEC-7R	C-2737(PIP)	ERDA-9	H-02b2	H-03b2	H-04bR	H-05b
H-06bR	H-07b1	H-09bR	H-10cR	H-11b4R	H-12R	H-15R
H-16	H-17	H-19b0	H-19b2[1]	H-19b3[1]	H-19b4[1]	H-19b5[1]
H-19b6[1]	H-19b7[1]	I-461	SNL-01	SNL-02	SNL-03	SNL-05
SNL-06	SNL-08	SNL-09	SNL-10	SNL-12	SNL-13	SNL-14
SNL-15	SNL-16	SNL-17	SNL-18	SNL-19	WIPP-11	WIPP-13
WIPP-19	WQSP-1	WQSP-2	WQSP-3	WQSP-4	WQSP-5	WQSP-6
1: Redundant wells on H-19 pad, measured quarterly						

3.3 Well P&A

Federal and state permits to drill and operate groundwater wells include requirements to maintain the wells in a manner that protects groundwater and to plug and abandon the wells when they are no longer usable or needed. These P&A requirements are implemented at the WIPP facility. The objectives of the P&A Program include:

- Eliminate physical hazards
- Prevent groundwater contamination
- Conserve yield and hydrostatic head of groundwater
- Prevent intermixing of geologic formation waters
- Comply with state and federal P&A regulations

At the present time, the WIPP area-wide groundwater-monitoring network contains 84 accessible wells, the majority of which are completed in the Culebra. Most of these wells are in reasonably good operating condition. Wells are selected for P&A based on health and safety factors for the workers of P&A, condition of the well (i.e., casing, annular seal, and production interval), geographic location, and the ability of the well to yield useful data. The New Mexico Office of the State Engineer has regulatory authority over the~~,~~ plugging and abandoning of groundwater production and monitoring wells.

As described in Permit Part 5, condition 5.3.3, the Permittees may propose to plug and abandon a DMW by submitting a permit modification request (PMR) ~~to the Secretary~~ in compliance with 20.4.1.900 NMAC (incorporating 40 CFR Part 270, §270.42, "Permit Modification at the Request of the Permittee"). In this instance, the DMW must be plugged and abandoned in a manner which eliminates physical hazards, prevents groundwater contamination, conserves hydrostatic head, prevents intermixing of subsurface water, and complies with applicable regulations. The Permittees shall submit a report to the Secretary which summarizes and certifies DMW plugging and abandoning methods within 90 calendar days from the date a DMW is removed from the DMP.

4.0 GROUNDWATER MONITORING PROGRAM DESCRIPTION

The WIPP GMP has been designed to meet the groundwater monitoring requirements of the Permit, DOE Order 458.1, the CCA, and applicable state and federal P&A regulations. This section provides a description of the GMP in terms of monitoring frequency, parameters measured, sampling and analytical methods, field data collection requirements, sample control, and laboratory analysis for sampling and analysis components of the GMP. Subsequent sections address calibration, analysis of data, reporting, records management, organization and QC.

The DMP sampling and analysis component of the GMP consists of a network of six DMWs. The DMWs (WQSP 1-6) were constructed to be consistent with the specifications provided in the RCRA Groundwater Monitoring Technical Enforcement Guidance Document (EPA, 1986) and constitute the RCRA groundwater monitoring network specified in the DMP. The DMWs were used to establish background groundwater quality data in accordance with 20.4.1.500 NMAC (incorporating 40 CFR Part 264, §§ 264.97 and 264.98 (f)). Another sampling and analysis component of the GMP is the WLMP, which is used to determine groundwater surface elevation and flow direction in the Culebra.

4.1 Monitoring Frequency

4.1.1 Monitoring Frequency for the DMP

The Permit requires that the six DMWs be sampled on an annual basis. This sampling was completed biannually since 1994 until it was changed to annual sampling in 2012. The initial ten rounds of sampling were used to determine background groundwater quality. A statistical baseline for comparison of future sampling results is included in the Permit.

Detection monitoring started with the emplacement of waste and will continue for 30 years after closure as required by the Permit. During detection monitoring, samples and sample duplicates will be collected at the frequency specified in the PERMIT. As shown in Table 1, the DMP currently requires the collection of groundwater quality samples for all six wells on an annual basis. The characteristics of the DMP (frequency, location) will be evaluated if significant changes are observed in the groundwater flow rate or direction. If any change occurs which could affect the ability of the DMP to fulfill the requirements of 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F), the proper notifications and actions will be taken to comply with applicable permit requirements (Table 2).

4.1.2 Monitoring Frequency for the WLMP

Groundwater surface elevation measurements in the DMWs is to occur before each sampling round. In addition, WLMP wells (including DMWs) will be measured at the minimum frequency required by the Permit, although other drivers, such as the scientific program, may require more frequent measurements. These data will be used to supplement the groundwater surface elevation database for the area. Groundwater surface elevation measurements will be taken monthly in at least one accessible completed interval at each available well pad. In addition, ~~in accordance with the Permit,~~ density determinations will be made annually from each of the Culebra WLMP wells in accordance with the Permit. Density may be determined using transient pressure-density measurement methods or using installed pressure measurement devices.

4.2 Indicator Parameters and Hazardous Constituents

4.2.1 Indicator Parameters and Hazardous Constituents for the DMP

The DMP samples will be analyzed for the indicator parameters and hazardous constituents listed in Table 3. Indicator parameters to be measured in the field include pH (measure of acidity/alkalinity), specific conductance (SC), temperature, and specific gravity (SG). Indicator parameters to be analyzed by the analytical laboratory, include SC, total dissolved solids (TDS), total suspended solids (TSS), SG, pH, and total organic carbon (TOC). These indicator parameters are included because of their universal commonality to groundwater. Parameters such as chloride, calcium, magnesium, and potassium are included as matrix-specific general indicator parameters and support the CRA and associated performance assessment (PA)~~)~~. Organic and inorganic constituents were chosen because they are expected to occur in the waste to be disposed at the WIPP facility. Additional constituents may be identified and may be added to the DMP list in accordance with WP 02-PC3002, *WIPP Hazardous Waste Facility Permit Change Request and Modification Processing*.

4.2.2 Indicator Parameters and Constituents for the WLMP

Water samples are not obtained from ~~T~~the WLMP wells; therefore ~~does not use~~ indicator parameters or constituents are not measured.

4.3 Groundwater Sample Collection and Laboratory Analysis

4.3.1 Groundwater Sample Collection and Laboratory Analysis for the DMP

Groundwater samples will be collected using field parameter measurements and final sampling methods. Field parameter measurements are collected until water stabilization requirements in the Permit are met, after which the final sample for analysis will be collected. Final samples will be analyzed for the DMP analytical suite. Final and field parameter measurements are taken and analyzed in accordance with WP 02-EM1010, *Field Parameter Measurements and Final Sample Collection*.

4.3.2 Groundwater Sample Collection and Laboratory Analysis for the WLMP

Water samples are not collected from ~~T~~the WLMP wells.~~does not use the collection of samples.~~

4.4 Groundwater Surface Elevation and Density Monitoring Methodology

Freshwater heads are useful in identifying hydraulic gradients in water-bearing zones of variable density such as those existing in the vicinity of the WIPP facility. Freshwater head at a given point is defined as the height of a column of freshwater that will balance the existing pressure at that point. Measured groundwater surface elevation data will be converted to equivalent freshwater head from knowledge of the density of the borehole fluid.

Collection of groundwater surface elevation data is required by 20.4.1.500 NMAC (incorporating 40 CFR Part 264) and 40 CFR Part 191. Per the Permit, the equivalent freshwater head data are needed to determine groundwater flow direction and rate, which is used to determine that the DMWs are still appropriately placed. The density-adjusted water level data from the WLMP are used to extend the documented record of groundwater surface elevation fluctuations in the Culebra in the vicinity of the WIPP facility, beyond the DMWs. If a cumulative groundwater surface elevation change of more than two feet is detected in any DMW over the course of a calendar year that is not attributable to site tests or natural stabilization of the site hydrologic system, notification will be made to the New Mexico Environment Department (NMED) in writing and a discussion of the possible origin of the changes will be included in the Annual Culebra Groundwater Report for that year.

Relative to compliance with the disposal standards in 40 CFR Part 191 and the EPA CCA, the water level in the Culebra is a monitoring parameter that has related PA parameters. Changes in the groundwater flow, or water level, are related to several PA parameters, including Culebra transmissivity, fracture and matrix porosity, fracture spacing, dispersivity, and climate index. If significant changes in the water level in the Culebra occur, the cause must be investigated and potential impacts on the long-term performance of the repository must be assessed.

4.4.1 Groundwater Surface Elevation and Density Monitoring Methodology for the WLMP

Density for DMWs will be expressed as SG as measured in the field during sampling events using a hydrometer.

Groundwater surface elevation measurements will be collected in accordance with WP 02-EM1014, *Groundwater Level Measurement.* Elevation data are adjusted to equivalent freshwater head data calculated annually by Sandia National Laboratories via data obtained from pressure transducers installed in each well.~~in accordance with WP 02-EM1021, *Pressure Density Survey*.~~

The inputs to determining freshwater heads from groundwater density measurements are:

- Pressure exerted on a transducer by a water column
- Height of the water column
- Culebra mid-member depth
- Hydrometer (DMWs)
- Temperature (DMWs)
- Water level below reference point
- Reference point elevation
- Groundwater density as calculated from pressure of the water column

Freshwater head data are used to determine the flow rate and direction of the groundwater in the Culebra. Evaluation of head data for construction of the potentiometric surface map is in accordance with WP 02-EM1025,~~ *Construction of the Potentiometric Surface Map for the Annual Culebra Groundwater Report*.~~ Data Review for the Annual Culebra Groundwater Report. Water level data are managed in accordance with WP 02-EM1026, *Water Level Data Handling and Reporting*.

4.5 Field Methods and Data Collection Requirements

4.5.1 Field Methods and Data Collection Requirements for the DMP

4.5.1.1 DMP Pumping and Sampling Systems

The groundwater pumping and sampling systems used to collect a groundwater sample from the six DMWs provide continuous and adequate production of water so that a representative groundwater sample can be obtained. The wells used for groundwater quality sampling vary in yield, depth, and pumping lift. These factors affect the duration of pumping as well as the equipment required at each well.

The type of pumping and sampling system to be used in a well depends primarily on the water-bearing characteristics of the Culebra at the well location and well construction. The DMWs are individually equipped with dedicated submersible pumping assemblies. Each well has a specific type of submersible pump, matched to the ability of the well to yield water during pumping. The down-hole submersible pumps are controlled by a variable electronic flow controller to match the production capacity of each well.

As required by the Permit, the wells will be purged no more than three well bore volumes or until field parameters have stabilized, whichever occurs first. WP 02-EM1002, *Electric Submersible Pump Monitoring System Installation and Operation,* specifies the methods used for controlling flow rates and monitoring water levels. Well purging requirements will be used in conjunction with field measurements to determine when the groundwater chemistry stabilizes, and is therefore representative of undisturbed groundwater.

4.5.1.2 Water Level Monitoring System

Water levels during sampling will be monitored using down-hole water level probes.

4.5.1.3 Groundwater Sampling Overview

Field parameter monitoring is the sequential collection of measurements for the purpose of determining when the groundwater chemistry stabilizes and is therefore representative of undisturbed groundwater. The SOP for field parameter monitoring provides criteria for determining when a final sample should be taken. Each DMW will be purged to no more than three well bore volumes, or until field parameters stabilize, whichever occurs first. Well stabilization occurs when the field-analyzed parameters are within ± 5% ~~of~~ for three consecutive measurements, which is determined by field parameter monitoring. A well bore volume is defined as the volume of water from static water level to the bottom of the well sump.

An explanation will be provided of why the final samples were collected when field monitoring parameters were not stabilized, and that explanation will be placed in the WIPP Facility Operating Record.

Field measurements are analyzed to detect and monitor the chemical variation of the groundwater as a function of the volume of water pumped. Once field measurements begin, the frequency at which field serial samples measurements are taken will be left to the discretion of the samplers, but will be performed a minimum of three times to determine stability.

Final samples will be collected when the field monitoring parameters have stabilized and are, therefore, representative of undisturbed groundwater, or when three well-bore volumes have been pumped, whichever is first.

Field Monitoring and final samples are collected and analyzed in accordance with WP 02-~~-~~EM1010. Final samples will be analyzed for the DMP parameters and constituents indicated in Table 3. Duplicates of the final sample will be provided to WIPP oversight agencies as requested by the Carlsbad Field Office or the NMED. During DMP sample collection, samples are also collected for submittal to WIPP Labs for radiological analysis. ~~by WIPP Laboratories.~~

Wastes that are generated by the sampling activities are disposed of in accordance with WP 02-RC.01, *Hazardous and Universal Waste Management Plan*.

4.5.1.4 Sample Preservation, Tracking, Packaging, and Transportation

Many of the chemical constituents measured by the DMP are not chemically stable, and thus the water samples require preservation and special handling techniques. Some ~~S~~samples requir~~e~~e~~ing~~ acidification as prescribed ~~will be treated as requested~~ by the analytical laboratory's and described in standard operating procedures (SOPs) and ~~-~~WP 02-EM1010, *Field Parameter Measurements and Final Sample Collection*. ~~specifies sample preservation requirements.~~

The sample tracking system at the WIPP facility uses chain-of-custody/request for analysis ~~(~~CofC/RFA~~)~~ forms. The primary consideration for storage or transportation is that samples shall be analyzed within the prescribed holding times for the analytes of interest. WP 02-EM1010 provides instructions to ensure proper sample tracking and shipment protocol.

4.5.1.5 Sample Documentation and Custody

Chain of custody, as described in WP-02-EM1010 and laboratory SOPs, will be used to document the integrity of the samples from the time of sample collection through data reporting.

~~To ensure the integrity of samples from the time of collection through reporting date, sample collection, handling, and custody shall be documented. Sample custody and documentation for hydrology sampling and analysis activities are detailed in WP 02-EM1010.~~Standardized forms used to document samples will include sample identification numbers, sample labels, the sample tracking data, and the CofC/RFA forms.

4.5.2 Field Methods and Data Collection Requirements for the WLMP

Sandia National Laboratories obtains high frequency fluid pressure data in all Culebra wells through installed pressure transducers.WP 02-EM1021 specifies a method for obtaining density data (expressed as SG). When portable instruments are used, pressure measurements are taken in wells completed in the Culebra at mid-member depth to assess fluid density. Fluid density values are calculated annually by Sandia National Laboratories using the measured mid-member pressure from the transducers. If dedicated transducers are used, fFluid density is also derived from submergence height and the pressure measured from the transducers.

4.5.2.1 Methods

To obtain an accurate groundwater surface elevation measurement, a calibrated water level measuring device will be used and the depth to water recorded from a known reference point. WP 02-EM1014 specifies the methods to be used in obtaining groundwater-level measurements.

4.5.2.2 Records and Document Control

Groundwater surface elevation measurement data are collected in accordance with WP 02-EM1014 and managed in accordance with that procedure as well as WP 02-EM1026. These procedures include requirements for verification of field data, preparation of reports and records management.

4.6 Laboratory Analysis

4.6.1 Laboratory Analysis for the GMP

Methods for analysis of samples for hazardous constituents and indicator parameters will be selected to be consistent with EPA-recommended procedures in *Test Methods for Evaluating Solid Waste* (SW 846, EPA, 1996). Methods for analysis of indicator parameters are taken from SW 846, *Standard Methods for the Examination of Water and Wastewater and Methods for Chemical Analysis of Water and Wastes* (EPA, 1983). Methods for analysis of radionuclides are consistent with regulatory guidance provided in DOE-HDBK-1216-2015, Environmental Radiological Effluent Monitoring and Environmental Surveillance.. Additional detail on analytical techniques and methods will be given in laboratory SOPs. Table 3 presents the target constituents and parameters analytical parameters and constituents for the WIPP DMP. The CCA identifies the radionuclides that are most significant to PA.

If a commercial laboratory is used, Nuclear Waste Partnership LLC (NWP) has established criteria for laboratory selection. The analytical laboratory shall demonstrate, through QA manual and laboratory SOPs, that it will follow appropriate analytical method requirements. The laboratory shall also provide annual method detection limits documenting documentation describing the sensitivity of laboratory instrumentation.

This documentation will be retained in the facility operating record ROR as required by the Permit.

The SOPs for the laboratory will also be maintained in the ROR.a file in the operating record. An initial set of SOPs was provided to the NMED, and . SOP updates along with a description of the changes will be provided to the NMED on an annual basis.

Data validation for Permit parameters and constituents will be performed by Environmental Monitoring and Hydrology (EM&H) in accordance with WP 02-EM3003, *Data Validation and Verification of RCRA Constituents*. Data validation of radionuclide data will be performed in accordance with WP 02-EM3004, *Radiological Data Verification and Validation*. Copies of the RCRA data validation report will be distributed in accordance with WP 02-EM3003, *Data Validation and Verification of RCRA Constituents* and will be kept on file in RORthe operating record as required by the Permit.

4.6.2 Laboratory Analysis for the WLMP

The WLMP does not use laboratory analysis of samples except for density determinations made in the field laboratory, as discussed above.

5.0 CALIBRATION

Monitoring and data collection equipment used for the GMP will be calibrated in accordance with WP 10-AD3029, *Calibration and Control of Monitoring and Data Collection Equipment.* EM&H will be responsible for assuring that necessary equipment is submitted for calibration on schedule. EM&H will also be responsible for maintaining current calibration records for each piece of equipment.

6.0 STATISTICAL ANALYSIS OF LABORATORY DATA

6.1 Statistical and Temporal Analysis of Laboratory Data for the GMP

The GMP prescribes the collection and analysis of groundwater samples for the chemical analysis of parameters, constituents, and radionuclides as follows:

- Parameters (general chemistry indicator parameters) are the major components contributing to the water chemistry and physical properties. Changes in the concentrations of the parameters may impact the predictions of the PA supporting the certification.

- Hazardous constituents are the target RCRA regulated organic and metal analytes defined in the WIPP Permit. The hazardous constituent concentrations are measured during each annual sampling round and compared with the background values listed in the Permit to determine if there have been any changes that represent statistically significant contamination.

- Selected radionuclides are identified from the WIPP Waste Acceptance Criteria and are monitored in accordance with DOE-HDBK-1216-2015.

The 20.4.1.500 NMAC (incorporating 40 CFR Part 264, §§264.97 and 264.98) requires evaluation using statistical analysis in accordance with EPA guidance in *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (EPA, 2009). DOE-HDBK-1216-2015 provides guidance for evaluatingon of radionuclide data. The procedures for the statistical analysis of laboratory data for groundwater monitoring are summarized in this section.

6.1.1 Temporal and Spatial Analysis

Temporal and spatial analyses of the data were completed as part of establishing the RCRA baseline. The recommendation carried forward to the operations period was to evaluate changes relative to background on an individual location basis and to report the concentrations of parameters, constituents, and radionuclides as a time series, either in tabular form or as time plots.

The analytical results for constituents will be reported as time series, either in tabular form or as time plots or both, and compared to the 95th UTLVs, 95th percentile values or method reporting limits(MRLs) identified in Permit Part 5, Table 5.6.

6.1.2 Action Levels

Action levels concentrations are based on the 95th upper tolerance limit value (UTLV), or 95th percentile; two or three standard deviations; or the arithmetic mean of the concentrations from the baseline study. If the groundwater concentration of a RCRA constituent is determined to exceed an action level prescribed in the Permit, a series of events is set in motion including further evaluation of the data, notification of the client, a test for outliers [see Permit Attachment L, Section L-4e(3)], and resampling and analysis of the affected groundwater as described in WP 02-EM3003, *Data Verification and Validation of RCRA Constituents*.

Radionuclide concentrations are examined to determine whether they fall within the 99 percent confidence interval range of the concentrations reported in DOE/WIPP-92-037. Evaluation of radionuclide results is described in WP 02-EM3004. Radionuclide results are reported as described in section 7.2.2.

6.1.3 Tests for Outliers

A test for outliers is performed in accordance with the methodologies specified in “Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities” (EPA, 2009). If an outside source of variation is not identified to account for an outlier, notification, further evaluation including re-sampling and reporting are implemented consistent with WP 02-EM3003 and WP 02-EM3004.

6.2 Statistical and Temporal Analysis of Laboratory Data for the WLMP

The WLMP does not use the statistical analysis of laboratory data.

7.0 REPORTING

Actions, reporting, and notifications required for the GMP are defined in Table 2. The primary reports associated with groundwater data are summarized in this section. The data for the indicator parameters associated with the PA are also reviewed by another contractor and included in their reports.

7.1 Reporting for the DMP

7.1.1 Laboratory Data Reports

Laboratory data will be provided in electronic and hard copy reports. Laboratory data reports are submitted to the Subcontract Technical Representative (STR) and will contain the following information:

- A brief narrative summarizing laboratory analyses performed, date of issue, deviations from the analytical method, technical problems affecting data quality, laboratory QC checks, corrective actions (if any), and the ~~labs~~ laboratory's project manager's signature approving issuance of the data report.
- Header information for each analytical data summary sheet, including sample number and corresponding laboratory identification number; sample matrix; date of collection, receipt, sample preparation and analysis; and analyst's name.
- Parameter and hazardous constituent, analytical results, reporting units, MRL, analytical method used.
- Results of QC sample analyses.
- Cation-anion balance sheet showing the concentrations of each cation and each anion along with a comparison of the total milliequivalents of all the cations and the total milliequivalents of all the anions as a measure of the analytical accuracy.

7.1.2 Analytical and Statistical Analysis Results

Analytical results for parameters and hazardous constituents from groundwater sampling activities will be compared and interpreted through generation of statistical analyses as specified in the Permit. Results of the statistical analyses will be included in the Annual Culebra Groundwater Report in summary form.

The Annual Culebra Groundwater Report, containing the chemical and statistical analysis results is submitted to the NMED Secretary by November 30 of each year after the final sample is collected. If the statistical analysis shows a significant increase in one or more RCRA constituents at the DMWs, the well shall be resampled immediately and no later than one month after the reported contamination. The remaining DMWs shall also be re-sampled within two months of the reported contamination. Notifications and further actions are listed in Table 3.

7.1.3 Other Reporting

Several DMP data results are reported in the Semi-Annual Groundwater Surface Elevation Report and Annual Culebra Groundwater Report as discussed below.

7.2 Reporting for the WLMP

7.2.1 Groundwater Surface Elevation Results

Water level data are to be submitted to the NMED Secretary semiannually by May 31 and November 30 of each year. The November groundwater surface elevation report shall be combined with the Annual Culebra Groundwater Report.

7.2.2 Annual Site Environmental Report

Data collected from the DMP and the WLMP are reported in the Annual Culebra Groundwater Report and Semi-Annual Groundwater Surface Elevation Report to the NMED as specified in the Permit. In addition to Permit reporting requirements, environmental monitoring data, including radiological analytical measurements and data analysis, are also reported in the Annual Site Environmental Report (ASER) including applicable information that may affect the comparison of background groundwater quality and groundwater surface elevation data through time.

Information required in the Permit reporting includes but is not limited to:

- WLMP well configuration changes that may have occurred from the time of the last report (e.g., plug installation and removal, packer removal and reinstallation, or both).
- Pumping activities that may have taken place since publication of the last annual report (e.g., related to groundwater quality sampling, hydraulic testing, etc.).
- A discussion of the origins of abnormal unexpected changes in the groundwater surface elevation, which is not attributable to site tests or natural stabilization of the site hydrologic system that exceeds two feet in a DMP well over the course of the period covered by the Annual Culebra Groundwater Report (this may indicate changes in recharge/discharge which would affect the assumptions regarding DMP well placement and constitute new information as specified in 20.4.1.900 NMAC (incorporating 40 CFR Part 270, §270.41(a)(2)).
- The results of the annual measurements of densities.
- Annotated hydrographs.

- Groundwater flow rate and direction.

- Potentiometric surface map generation using specifications in the Permit

The DMP and WLMP data used in generating the Annual Culebra Groundwater Report and Semi-Annual Groundwater Surface Elevation Report will be maintained as part of the WIPP facility Operating Record.

8.0 RECORDS MANAGEMENT

Records generated during groundwater sampling and groundwater surface elevation monitoring events will be maintained in accordance with the applicable portions of the Permit and WP 15-RM, *Records Management Program,* in the EM&H project files (operating record). Project records include, but are not limited to:

- Sampling and analysis plans
- SOPs
- Sample tracking logbooks
- CofC/RFA forms
- Analytical laboratory data reports
- Variance logs and nonconformance reports
- Corrective action reports
- Verification and validation reports
- Monthly groundwater surface elevation measurements
- Semiannual WLMP reports
- Annual GMP Reporting

Detection Monitoring Program sampling, testing, and analytical data and WLMP data will be maintained in the WIPP Facility Operating Record and in accordance with WP 15-RM, the Permit, and the EM&H Records Inventory and Disposition Schedule (RIDS) and will be made available for inspection upon request. The following records will be transmitted to the Project Records Services for long-term storage in accordance with the RIDS:

- Instrument maintenance and calibration records
- QC sample data
- Control charts and calculation
- Sample tracking and control documentation
- Raw analytical results

9.0 QUALITY ASSURANCE REQUIREMENTS

Specific QA requirements for activities conducted at or on behalf of the WIPP facility are defined in the NWP Quality Assurance Program Description (QAPD) (WP 13-1, *Nuclear Waste Partnership LLC Quality Assurance Program Description*). Requirements specific to the DMP and the GMP are presented in this section.

9.1 Data Quality Objectives and Quality Assurance Objectives

Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality of data required to support project decisions. DQOs have been established to ensure that the data collected will be of a sufficient and known quality for their intended uses. For the purpose of the GMP, quality assurance objectives (QAOs) for measurement data are specified in terms of accuracy, precision, completeness, representativeness, and comparability. Appropriate QC procedures are used so that known and acceptable levels of accuracy and precision will be maintained for each data set. The following subsections define the DQOs for the DMP and the WLMP.

9.1.1 DMP

The overall DQO for the DMP is to collect accurate and defensible data of known quality that will be sufficient to assess changes in the concentrations of constituents in the groundwater underlying the WIPP area. The QAOs for the analytical portions of the DMP are described below.

9.1.2 WLMP

The DQO for the WLMP is to collect accurate and defensible data of known quality that will be sufficient to assess the groundwater flow direction and rate at the facility.

The QAOs for measurement data have been specified in terms of accuracy, contamination, precision, completeness, representativeness, and comparability.

A. Accuracy

Accuracy is the closeness of agreement between a measurement and an accepted reference value. When applied to a set of observed values, accuracy is a combination of a random component and a common systematic error (bias) component. Measurements for accuracy will include analysis of calibration check standards, method blanks; laboratory control samples (LCSs), matrix spike samples, and monitoring surrogate spike recoveries. The bias component of accuracy is expressed as percent recovery. Percent recovery is expressed as follows:

$$\%R = \frac{(measured\ sample\ concentration)}{true\ concentration}\ x\ 100$$

1. Accuracy Objectives for Field Measurements

Field measurements include pH, SC, temperature, SG, and static groundwater surface elevation. Field measurement accuracy is determined using calibration standards. Thermometers used for field measurements are calibrated to a National Institute for Standards and Technology traceable standard on an annual basis to ensure accuracy. Accuracy of groundwater surface elevation measurements is checked before each measurement period by verifying calibration of the device within the specified schedule.

The QAPD, Section 2.5, Monitoring, Measuring, Testing and Data Collection Equipment, outlines the basic requirements for field equipment use and calibration.

2. Accuracy Objectives for Laboratory Measurements

Analytical system accuracy is quantified using the following laboratory accuracy QC checks: calibration standards, LCSs, method blanks, matrix spikes (MS) and surrogate spike recoveries. The accuracy of an LCS, MS, and the surrogate spike compounds is expressed as percent recovery. Laboratory analytical accuracy is parameter dependent and is prescribed in the laboratory SOP consistent with applicable industry standard analytical procedures. Alternatively, the recovery acceptance criteria may be determined using the laboratory's historical control chart limits based on experience with the analytical method and the sample matrix. The recovery objectives may range from 80-120 percent, 70-130 percent, or 60-140 percent, depending on the method. The laboratory's historical control chart limits may be lower for some organic compounds that are difficult to extract or whose recovery is adversely affected by the high-brine groundwater.

3. Contamination

Contamination is an accuracy consideration. Contamination is measured in various QC samples including method blanks, trip blanks, and field blanks. Samples are analyzed to measure and document any contamination attributable to sample collection equipment, sample handling and shipping, and laboratory reagents and glassware.

Laboratory Mmethod blanks are used to assess contamination resulting from the analytical process and are analyzed at a minimum frequency of one sample per 20 samples, or 5 percent of the samples collected. Evaluation of sample blanks is performed following the *National Functional Guidelines for Superfund Organic Methods Data Review* (EPA, 2008) and *National Functional Guidelines for Inorganic Data Review* (EPA, 2004). The criterion for evaluating method blanks is established as follows: if any method blank analyte concentrations results are higher than the exceed MRLs, the concentration in the method blank will become the MDL for the sample batch.

Trip blanks are used to assess any volatile organic compound (VOC) sample contamination acquired during shipment and handling and are collected and analyzed at a frequency of one sample per sample shipment.Trip blank samples are provided by the laboratory to assess whether any of the samples were contaminated by volatile organic compounds (VOCs) during shipment and handling of the samples. Trip blank samples are provided in replicate as backup samples and are analyzed at a frequency of one per batch of samples.

Field blanks samples are collected in the field used to assess whether any samples were contaminated during the sample collection process. Field blank samples field sample collection methods and are collected for VOCs during all sampling events and in preserved and unpreserved samples for metals analysis during selected sampling events and analyzed at a minimum frequency of one sample per batch.and analyzed at a minimum frequency of one sample per batch for VOCs and selected batches of samples for metals analysis.

Detection of analytes of interest in method blank and field blank samples may disqualify the usability of some samples data. This could result in the need for resampling and additional analyses and will be determined on a case-by-case basis. The quality objective for contamination is to not detect any of the target analytes, but certainly to keep their concentrations below the MRL and below the MDL if possible. Blank contamination has not been an issue for the DMP.

B. Precision

Precision is the agreement among a set of replicate measurements without assumption or knowledge of the true value. Precision data are derived from duplicate field and laboratory measurements. Precision is expressed as relative percent difference (RPD), which is calculated as follows (smaller RPD represents better precision), vertical lines indicate calculation based on absolute value of a number.

$$RPD = \frac{|(measured\ value\ sample\ 1 - measured\ value\ sample\ 2)|}{average\ of\ measured\ samples\ 1+2}\ x\ 100$$

1. Precision Objectives for Laboratory Measurements

Precision of laboratory analyses will be determined by analyzing a LCS and a laboratory control sample duplicate (LCSD), by analyzing a matrix spike (MS) and matrix spike duplicate (MSD), or by analyzing one of the field samples in duplicate depending on the requirements of the particular standard analytical method. The precision is measured as the RPD of the concentrationrecoveries for the spiked LCS/LCSD pair, for the spiked MS/MSD pair, or the RPD of the laboratory duplicate sample analysis results. Laboratory analytical precision is also parameter dependent and will be prescribed in laboratory SOPs. Generally the laboratory duplicate precision objective is a RPD less than or equal to 20. The precision objective does not necessarily apply to field duplicate samples where duplicate samples are collected, but for DMP aqueous samples, the field duplicate precision is expected to be as good as for laboratory duplicate samples.

2. Precision Objectives for Field Measurements

Specific conductance, pH, temperature, and SG will be measured during well purging and after sampling. SC measurements will be precise to ±10%; pH to 0.10 standard unit, SG to 0.01 by hydrometer, and temperature to 0.10 degrees Celsius (°C)., Water-level measurement will be precise to ±0.01 ft. The precision of water density measurements, when measured in the field using down hole instrumentation, will be determined on a well-by-well basis and will result in no more than ±2 ft of error in the derived fresh-water head.

C. Completeness

Completeness is a measure of the amount of usable valid data resulting from a data collection activity, given the sample design and analysis. Completeness may be affected by unexpected conditions occurring during the data collection process. Occurrences that reduce the amount of data collected include sample container breakage during sample shipment or in the laboratory and data generated while the laboratory was operating outside prescribed QC limits. All attempts will be made to minimize data loss and to recover lost data whenever possible. The completeness objective is equal to or greater than 90 percent for general indicator parameters ~~is ≥ 90 percent~~ and 100 percent for hazardous constituents. If the completeness objective is not met, a decision will be made to determine the need for resampling on a case-by-case basis.

The numerical expression for percent completeness (%C) of the data is as follows:

$$\%C = \frac{number\ of\ accepted\ samples}{total\ number\ of\ samples\ collected}\ x\,100$$

D. Representativeness

Representativeness is the degree to which sample analyses accurately and precisely represent the media they are intended to represent. The goal of generating representative data is accomplished by applying approved sampling procedures and using validated analytical methods. Sampling procedures are designed to minimize factors affecting the integrity of the samples. Groundwater samples will only be collected after well purging criteria have been met. The analytical methods selected are those that will most accurately and precisely represent the true concentration of analytes of interest.

For water levels and density, representativeness is a qualitative term that describes the extent to which a sampling design adequately reflects the environmental conditions of a site. The SOP~~s~~ for sample collection~~measurement~~ helps ensure that samples are representative of site conditions.

E. Comparability

Comparability is the extent to which one data set can be compared to another. Comparability is achieved through reporting data in consistent units and collection and analysis of samples using consistent methodology. Aqueous samples are consistently reported in units of measures dictated by the analytical method. Units of measure include:

- Milligrams per liter for general chemistry parameters and metals
- Micrograms per liter for volatile~~VOCs~~ and semi volatile organic compounds.

9.1.3 WLMP

The QAOs for the WLMP are as follows:

A. Accuracy

Accuracy is the extent of agreement between an observed value (sample result) and the accepted, or true, value of the parameter being measured. Accuracy is frequently used synonymously with bias. Specifically, the term "bias" describes the systematic or persistent error associated with a measurement process.

For field measurements, accuracy is defined by the manufactures' manual and verified through calibration. WP 10-AD.01, *Metrology Program,* contains instructions that outline protocols for maintaining current calibration of groundwater surface elevation measurement instrumentation. Table 4 provides the accuracy objectives for each parameter measurement.

B. Precision

Precision is the degree of agreement among repeated measurements of the same characteristic (depth, water density, pressure etc.) under the same or similar conditions. Precision data indicate how consistent and reproducible the field sampling has been. Field measurement precision is measured making replicate measurements, either using the same instrument or using co-located instruments. The precision objective for water level and pressure density measurements is a ≤~~10~~ RPD less than or equal to 10.

C. Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that could be expected to be obtained under "normal" conditions. Completeness is calculated as the number of valid (i.e., nonrejected) data points divided by the total number of data points requested. Completeness is addressed by measuring density in Culebra wells in the WLMP that are unobstructed to a pressure transducer. The completeness objective is 100 percent for critical data.

D. Representativeness

Representativeness is a qualitative term that describes the extent to which a sampling design adequately reflects the environmental conditions of a site. It takes into consideration the magnitude of the site area represented by one sample and assesses the feasibility/reasonableness of that design rationale. Representativeness also reflects the ability of the sample team to collect samples in such a manner that the data generated accurately and precisely reflects the conditions at the site. A discrete measurement is representative when it is made in accordance with some predefined protocol to assure the measurement represents the conditions at the site. The use of SOPs for measurement helps to ensure that samples are representative of site conditions.

E. Comparability

Comparability is an expression of the confidence with which one data set can be compared to another. SOPs provide for measurements that are consistent and representative of the media and conditions measured and will be consistent to provide comparability of measurement. Data collected are calculated, qualified, and reported in consistent units to provide for comparability of the data with previously generated relevant site data.

- Water level is measured in feet.
- Density is reported as SG and is unitless.

9.1.4 Performance and Acceptance Criteria

Performance and acceptance criteria include using calibrated equipment and taking measurements in accordance with approved procedures, and are included in Table 4.

Acceptance criteria are specifications intended to evaluate the adequacy of one or more existing sources of information or data as being acceptable to support the project's intended use. Performance and acceptance criteria are used to control the quality of the data collected.

Freshwater heads are reported in the Semi-Annual Groundwater Surface Elevation Report, and used to construct a potentiometric map using WP 02-EM1025. The density-adjusted water level values in the Culebra wells, along with their inherent uncertainties in Table 4 will generate uncertainty in the adjusted freshwater head of about ± 1.5 ft (see Appendix A).
The Culebra transmissivity fields used in the CCA and CRA-2009 modeling were considered to be acceptably calibrated with heads within 2 m (6 ft) of the calculated freshwater heads. Hence, uncertainties of the calculated freshwater heads of ± 1.5 ft are the range determined acceptable for modeling. The potentiometric surface at WIPP has approximately 70 ft of total elevation difference and a consistent north to south gradient. Uncertainties of the calculated freshwater heads of ± 1.5 ft represent approximately 2 percent of the total difference and are also acceptable in this context.

9.2 Design Control

The groundwater monitoring system was designed and will be maintained to meet requirements established in 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subparts F and X).

9.3 Instructions, Procedures, and Drawings

The preparation and use of instructions and procedures at the WIPP facility are outlined in WIPP Document WP 13-1, *Nuclear Waste Partnership LLC Quality Assurance Program Description*, are consistent with the requirements of the Permit Activities performed for groundwater monitoring, and will be performed in accordance with documented and approved procedures which comply with the Permit.

Technical procedures, as specified in this GMP Plan, have been developed for each quality-affecting function performed for groundwater monitoring. The procedures are sufficiently detailed and include, when applicable, quantitative or qualitative acceptance criteria.

9.4 Document Control

Document controls will ensure that the latest approved versions of procedures are used in performing groundwater monitoring functions and that obsolete materials are adequately identified and removed from work areas.

9.5 Control of Work Processes

Process control requirements, defined in the QAPD Section 2.1, Work Processes; and Section 4, Sample Control and Quality Assurance Requirements, are consistent with the requirements of the Permit, and are met, and will continue to be met, for the GMP.

9.6 Inspection and Surveillance

Inspection and surveillance activities will be conducted as outlined in Section 2.4, Inspection and Testing; and Section 3.2, Independent Assessment, of the QAPD. The QA Department will be responsible for performing the applicable inspections and surveillance on the scope of work. EM&H personnel will be responsible for performance checks as defined in applicable procedures and determined by NWP metrology laboratory personnel. Performance checks for the GMP will determine the acceptability of purchased items and assess degradation that occurs during use.

9.7 Control of Monitoring and Data Collection Equipment

QAPD Section 2.5, Monitoring, Measuring, Testing, and Data Collection Equipment, outlines the basic requirements for control and calibrating monitoring and data collection (M&DC equipment) and are consistent with the requirements of the Permit. M&DC equipment shall be properly controlled, calibrated, and maintained according to WIPP procedures to ensure continued accuracy of groundwater monitoring data. Results of calibrations, maintenance, and repair will be documented. Calibration records will identify the reference standard and the relationship to national standards or nationally accepted measurement systems. Records will be maintained to track uses of M&DC equipment. If M&DC equipment is found to be out of tolerance, the equipment will be tagged and taken out of service until corrections are made.

9.8 Control of Nonconforming Conditions

Section 1.3, Quality Improvement; and Section 4.4, Disposition of Nonconforming Samples, of the QAPD specify the system used at WIPP for ensuring that appropriate measures are established to control nonconforming conditions and consistent with the requirements of the Permit. Nonconforming conditions connected to the GMP will be identified in and controlled by documented procedures. Equipment that does not conform to specified requirements will be controlled to prevent use. The disposition of defective items will be documented on records traceable to the affected items. Prior to final disposition, faulty items will be tagged and segregated. Repaired equipment will be subject to the original acceptance inspections and tests prior to use.

9.9 Corrective Action

Requirements for the development and implementation of a system to determine, document, and initiate appropriate corrective actions after encountering conditions adverse to quality at WIPP are outlined in Section 1.3, Quality Improvement, of the QAPD and are consistent with the requirements of the Permit. Conditions adverse to acceptable quality will be documented and reported in accordance with corrective action procedures and corrected as soon as practical. Immediate action will be taken to control work performed under conditions adverse to acceptable quality and its results to prevent quality degradation.

9.10 Quality Assurance Records

Section 1.5, Records, of the QAPD outlines the policy that will be used at WIPP regarding identification, preparation, collection, storage, maintenance, disposition, and permanent storage of QA records and are consistent with the requirements of the Permit.

Records to be generated in the GMP will be specified by procedure. QA and RCRA operating records will be identified. This will be the basis for the labeling of records as "QA" or "RCRA operating" on the EM&H RIDS.

QA records will document the results of the GMP implementing procedures and will be sufficient to demonstrate that all quality-related aspects are valid. The records will be identifiable, legible, reproducible, and retrievable.

REFERENCES
DOCUMENT NUMBER AND TITLE
40 CFR Part 191, *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*
40 CFR Part 194, *Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations* (61 *Federal Register* 5224)
40 CFR Part 264, *Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*
40 CFR Part 270 EPA Administered Permit Programs: the Hazardous Waste Permit Program. *Code of Federal Regulations*. Office of the Federal Register, National Archives and Records Administration, Washington, D.C.
20.4.1.500 NMAC, *Adoption of 40 CFR Part 264*, Title 20, New Mexico Administrative Code. Santa Fe, NM.
20.4.1.900 NMAC, *Adoption of 40 CFR Part 270*, Title 20, New Mexico Administrative Code. Santa Fe, NM.
DOE Order 458.1, *Radiation Protection of the Public and the Environment*
DOE/CAO-1996-2184, *United States Department of Energy Waste Isolation Pilot Plant Compliance Certification Application*
DOE-HDBK-1216-2015v2, *DOE Handbook, Environmental Radiological Effluent Monitoring and Environmental Surveillance*
DOE/WIPP-~~-~~92-037, *Statistical Summary of the Radiological Baseline Program for the Waste Isolation Pilot Plan*
DOE/WIPP-99-2194.~~2015~~, *Waste Isolation Pilot Plant Environmental Monitoring Plan.* Waste Isolation Pilot Plant, Carlsbad, NM.
Hazardous Waste Facility Permit, No. NM4890139088-TSDF
Powers, D. W.; S. J. Lambert; S. E. Shaffer; L. R. Hill; and W. D. Weart, eds., 1978. *Geologic Characterization Report for the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico*, SAND78-1596, Sandia National Laboratories, Albuquerque, NM.
Public Law 102-579. *Waste Isolation Pilot Plant Land Withdrawal Act. October 1992, as amended October 1996 by Public Law 104-201*.
Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005.
U.S. Environmental Protection Agency, 1996, SW-846, *Test Methods for Evaluating Solid Waste*
U.S. Environmental Protection Agency, 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance*
U.S. Department of Energy (DOE), 2009, Resource Conservation and Recovery Act Part B Permit Renewal Application, Addendum L1, Waste Isolation Pilot Plant, Carlsbad, NM, Rev. 6.4.
U.S. Environmental Protection Agency, 2008. *National Functional Guidelines for Superfund Organic Methods Data Review*
U.S. Environmental Protection Agency, 1990. *Background Documentation for the U.S. Environmental Protection Agency's Proposed Decision on the No-Migration Variance for*

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DOCUMENT NUMBER AND TITLE
U.S. Department of Energy's Waste Isolation Pilot Plant
U.S. Environmental Protection Agency, 2004. *National Functional Guidelines for Inorganic Data Review*
U.S. Environmental Protection Agency, 1986. *RCRA Groundwater Monitoring Technical Enforcement Guidance Document*
U.S. Environmental Protection Agency, 1983. *Methods for Chemical Analysis of Water and Wastes*
WP 02-EM1002, *Electric Submersible Pump Monitoring System Installation and Operation*
WP 02-EM1010, *Field Parameter Measurements and Final Sample Collection*
WP 02-EM1014, *Groundwater Level Measurement*
~~WP 02-EM1021, *Pressure Density Survey*~~
WP 02-EM1025, ~~*Construction of the Potentiometric Surface Map for the Annual Culebra Groundwater Report*~~*Data Review for the Annual Culebra Groundwater Report*
WP 02-EM1026, *Water Level Data Handling and Reporting*
WP 02-EM3003, *Data Validation and Verification of RCRA Constituents*
WP 02-EM3004, *Radiological Data Verification and Validation*
WP 02-PC3002, *WIPP Hazardous Waste Facility Permit Change Request and Modification Processing*
WP 02-PC.03, *WIPP Hazardous Waste Facility Permit Reporting and Notifications Compliance Plan*
WP 02-RC.01, *Hazardous and Universal Waste Management Plan*
WP 10-AD.01, *Metrology Program*
WP 10-AD3029, Calibration and Control of Monitoring and Data Collection Equipment
WP 13-1, *Nuclear Waste Partnership LLC Quality Assurance Program Description*
WP 15-RM, *Records Management Program*

Table 1 – WIPP Groundwater Detection Monitoring Program Sample Collection and Groundwater Surface Elevation Measurement Frequency	
Installation	**Frequency**
Groundwater Quality Sampling	
DMWs	Annually
Groundwater Surface Elevation Monitoring	
WLMP wells	DMWs – Monthly and prior to sampling events All other Culebra wells – Monthly

Table 2 – Stipulations Requiring Actions, Reporting, or Notifications

Permit Stipulation	Action, Report or Notification Due date	Permit or 40 CFR Citation
Determination of statistically significant contamination of parameters or constituents in Table 5.4.a and Table 5.4.b.	Seven calendar days from determination.	5.10.3.1, 5.10.4.1, L-4e(4)
If the Permittees determine, pursuant to permit condition 5.9, that there is a statistically significant difference for parameters or constituents specified in Table 5.4a and 5.4.b at any detection monitoring well (DMW) at the Compliance point, they may demonstrate that a source other than a regulated unit caused the increase or that the detection is an artifact caused by an error in sampling, analysis, statistical evaluation, or natural variation in the groundwater.	Submittal of modification request-the permittees shall, within 90 calendar days, submit to the Secretary an application for a permit modification to make any appropriate changes to the DMP, as required by 20.4.1.500 NMAC.	5.10.4.3
Changes that occur that could affect the DMP's ability to fulfill the requirements of 20.4.1.500 NMAC.	Permit modification request. No time specified.	L-4a
Background Water quality data report.	Prior to waste receipt.	L-4e(4)
Semi-Annual Groundwater Surface Elevation Report.	(Semiannually by May 31 and November 30)	5.10.2.2, L-4c(1)ii
DMP Statistical Comparison Report.	Annually in the Annual ~~Site Environmental Report~~ Culebra Groundwater Report.	L-4e(4)
The Permittees shall determine the groundwater flow rate and direction in the Culebra Member of the Rustler Formation at least annually.	Determine groundwater flow rate and direction annually.	5.8, 5.10.2.3
Evidence that a source other than a regulated unit caused groundwater contamination, or that contamination resulted from error in sampling, analysis, or evaluation.	Ninety calendar days from determination.	5.10.4.2
DMW Plugging and Abandoning Certification Reports.	Within ninety calendar days from the date a DMW is removed from the DMP.	5.3.3
The Permittees shall collect one (1) DMP sample and (1) DMP sample duplicate annually from each DMW using the procedure specified in Permit Attachment L section, L-4c, as required by 20.4.1.500 NMAC (incorporating 40 CFR Part 264, §§264.97[g][2], 264.98[d], and 264.601[a]).	Annually in the Annual Culebra Groundwater Report	5.5.1
DMP Data Evaluation Results Report.	Annually in the Annual Culebra Groundwater Report	5.10.2.1
Cumulative groundwater surface elevation changes more than 2 ft in any DMW during one year which is not attributable to site tests or natural stabilization.	Notification in writing (time not specified). Report in the Annual Culebra Groundwater Report.	L-4c(1), 5.10.2.3
The permittees shall immediately, but no later than one (1) month, sample the groundwater in all DMWs specified in Table 5.3.1 for which there was statistically significant evidence of contamination. The remaining DMWs shall be sampled within two (2) months after statistically significant evidence of contamination is determined in any DMW. All DMWs shall be sampled to determine the concentration of all substances identified in 20.4.1.500 NMAC (incorporating 40 CFR Part 264 Appendix IX), as required by 20.4.1.500 NMAC (incorporating 40 CFR Part 264, §264.98[g][2]).	Contaminated well within 1 month All other DMWs within 2 months.	5.10.3.2

Table 2 – Stipulations Requiring Actions, Reporting, or Notifications

Permit Stipulation	Action, Report or Notification Due date	Permit or 40 CFR Citation
Permittees may resample within one (1) month and repeat the analysis for those compounds detected. If the results of the second analysis confirm the initial analysis, these substances shall form the basis for compliance monitoring specified in Permit condition 5.10.3.4. If the permittees do not resample, the substances found during the initial analysis specified in Permit condition 5.10.3.2 shall form the basis for compliance monitoring specified in Permit condition 5.10.3.4.	Resample within (1) month.	5.10.3.3
If the Permittees determine, pursuant to Permit condition 5.9"... that there is statistically significant evidence of contamination for any parameter or constituent specified in Table 5.4.a and 5.4.b, the permittees shall comply with the following: ... The permittees shall within ninety (90) calendar days, submit to the secretary an application for a permit modification to establish a compliance monitoring program . . ."	Submit an application for permit modification accompanied by a compliance monitoring program plan within 90 days.	5.10.3.4
If the Permittees determine, pursuant to Permit condition 5.9 ... that there is statistically significant evidence of contamination for any parameter or constituent specified in Table 5.4.a and 5.4.b, the Permittees shall comply with the following: (I) All data necessary to justify an alternate concentration limit proposed in compliance with Permit condition 5.10.3.4.iv. (ii) An engineering feasibility plan for corrective action required by 20.4.1.500 NMAC (incorporating 40 CFR Part 264, §264.100), if necessary.	Submit plan for corrective action within 180 calendar days accompanied by an engineering feasibility study if necessary.	5.10.3.5
The Permittees shall submit a report to the Secretary which summarizes and certifies DMW plugging and abandoning methods . . .	Within ninety (90) calendar days from the date the DMW is removed from the DMP.	5.3.3
If the Permittees determine, pursuant to Permit condition 5.9 that there is significant evidence of contamination for any parameter or constituents specified in Table 5.4.a and 5.4.b. . .	Submittal of compliance monitoring program within 90 calendar days with an application for a permit modification to establish a compliance monitoring program.	5.10.3.4
If the Permittees determine wells ERDA-9, H-16, WIPP-19 are to be plugged do to deteriorating condition, NMED shall be contacted prior to plugging.	Discus with NMED prior to well plugging activities.	Appendix G, Table G-3
Releases have caused, or are expected to cause, concentrations of radionuclides or estimated doses due to radionuclides in underground sources of drinking water in the accessible environment to exceed the limits established pursuant to Part 191, Subpart C, or this chapter.	Report to EPA, within 24 hours, in writing.	40 CFR Part 194, §194.4(b)ii[c] 40 CFR Part 194, §194.4(b)iii

Note: Notifications to the NMED as specified in this table will be transmitted by the Environmental -Permit Compliance Team.

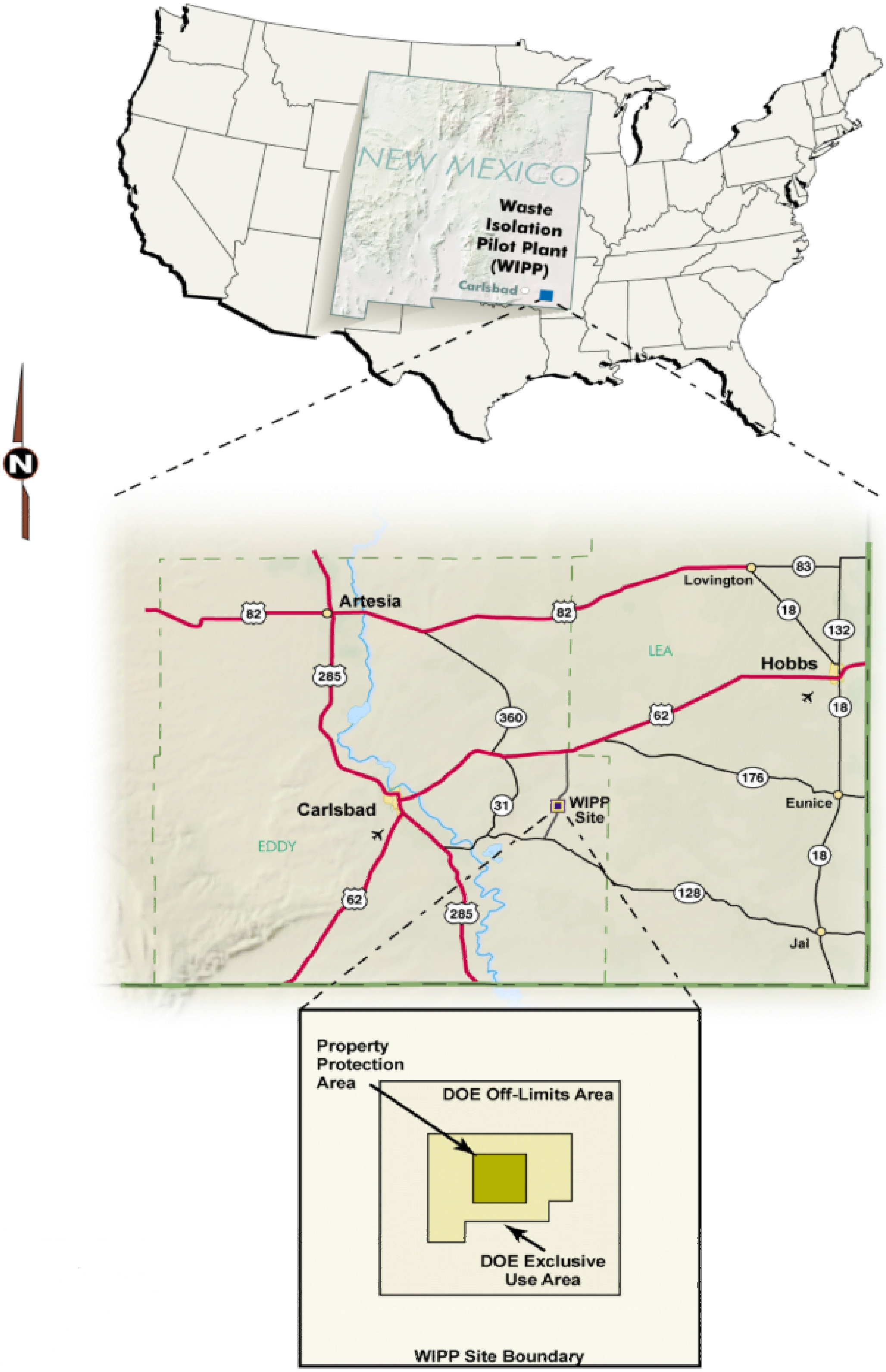
Table 3 – Indicator Parameters and Hazardous Constituents List for the WIPP Detection Monitoring Program		
Indicator Parameters	Hazardous Constituents	
pH	Chloroform	Barium
Specific conductance (**SC**)	1,2-dichloroethane	Cadmium
Total organic carbon (**TOC**)	Carbon tetrachloride	Chromium
Total dissolved solids (**TDS**)	Chlorobenzene	Lead
Total suspended solids (**TSS**)	1,1-dichloroethylene	Mercury
Specific Gravity (**SG**)	Methylene chloride	Selenium
Calcium	1,1,2,2-tetrachloroethane	Silver
Magnesium	Toluene	Antimony
Potassium	1,1,1-trichloroethane	Beryllium
Chloride	Cresols	Nickel
	1,4-dichlorobenzene	Thallium
	1,2-dichlorobenzene	Vanadium
	trans-1,2-dichloroethylene	1,1-dichloroethane
	2,4-dinitrophenol	Methyl ethyl ketone
	2,4-dinitrotoluene	Tetrachloroethylene
	Hexachloroethane	
	Hexachlorobenzene	
	Isobutanol	
	Pentachlorophenol	
	Pyridine	
	1,1,2-Trichloroethane	
	Trichloroethylene	
	Trichlorofluoromethane	
	Xylenes	
	Nitrobenzene	
	Vinyl chloride	
	Arsenic	

Table 4 – Data Quality Indicators for Water Level Monitoringand Pressure Density Measurement Program

PARAMETER	MEASUREMENT METHOD	UNITS	PRECISION	ACCURACY (as allowed error)	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY
Conductivity in DMW Sample	Probe	uS	<5 PRD	+ 10% of certified concentrations	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units
Depth to Water	Probe	FEET	≤10 RPD.	*±0.01 ft.* Verify that calibration of instrument is current prior to each use.	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units - equivalent freshwater head elevation in feet above mean sea level (amsl).
Depth of Submergence*	Pressure Transducer Cable	FEET	≤10 RPD.	*±1 ft.* Verify cable markings prior to survey.	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units
Pressure in Well	Pressure Transducer	PSI	≤10 RPD.	*±0.2 psi.* < 0.04% of range = < 0.46 feet (0.2 psi)	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units
Density Specific Gravity in DMW Sample	Hydrometer	SG	<5 RPD≤10 RPD.	*±0.002 SG units*	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units
pH in DMW Sample	Probe	SU	<5 RPD	+ 0.2 SU units	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units
Temperature in DMW Sample	Thermometer	Degrees Celsius	<5 RPD≤10 RPD.	0.10 degrees Celsius	Assured by use of approved SOPs and trained personnel	100%	Assured by reporting data in consistent units

*As close to mid-depth of the Culebra as possible

Appendix A – Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head



Appendix A – Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head

Figure 1 – WIPP Facility Location

Appendix A – Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head

INTRODUCTION

This report discusses the accuracy of groundwater density measurements made on aqueous samples collected at WIPP using the pressure density survey and resulting error on freshwater head, considering the accuracy of three measurements that are its components:

The elevation of the water in the well,
The pressure measurement as recorded by the transducer in use, and
The depth measurement of the transducer

Transducer submergence is calculated as the transducer depth less depth to water. Transducer depth and water level measurement are both from the top of casing. The water level measurement is accurate to one hundredth of a foot. The accuracy that is possible with the transducer depth is on the order of ±1.0 foot. It is shown that the overall density measurement error decreases with increased transducer submergence. That is, this error becomes less significant the deeper (in water) the transducer is.

The pressure density technique only measures the density of a water column above the transducer. All computations of error assume that the water column is homogeneous. Adjusted freshwater head is further dependent on casing survey elevation, actual Culebra midpoint elevation, and deviation of the well. However, density is the predominant source of uncertainty.

ACKNOWLEDGMENT OF INHOMOGENEOUS WATER COLUMNS

Water density is known to vary both laterally between boreholes and vertically within a borehole. Because of this, it is extremely important to place the transducer at the Culebra midpoint each time to assure a consistent set of measurements. The error that might be introduced by vertical variability has not been considered at this time, but the effect of the error can be mitigated by placing transducers at mid-member depth and converting directly from pressure to freshwater head (i.e., the measurement of density becomes representative). If this is not possible due to cable length or obstructions, then the deeper the transducer can be set (greater submergence), the more representative and accurate the density measurement.

DENSITY MEASUREMENT ERROR DETERMINATION

Relationship between Density Measurement Error and Accuracy of Depth Measurement

The pressure measured by the transducer is directly related to the depth of submergence (i.e., the height of the column of water over the transducer). If the error in measuring the depth of submergence is taken to be one foot[1], regardless of the depth of submergence, then the greater the column of water, the less significant the error.

This inverse relationship is shown as a function of depth of submergence in Table 1 and is shown as the measurement error in terms of the change in apparent density due to one foot of depth measurement inaccuracy.

Table 1
Density Error Due to Submergence, Specific Gravity Units

Submergence (feet)	Error in apparent density for 1 foot depth inaccuracy, SG units (dimensionless)
75	-0.0133
100	-0.0100
150	-0.0067
200	-0.0050
300	-0.0033
350	-0.0028
400	-0.0025
500	-0.0020

[1] One foot is believed to be a conservative estimate for error. On one hand, cable stretch is negligible and should not exceed this value. On the other hand, depth measurement can probably be made to the nearest half foot.

Appendix A – Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head

From the above analysis it can be seen that:

For a given depth measurement error, the effect on calculated densities increases as submergence decreases.

Below about 150 ft on down to 500 ft of submergence, the error of the pressure-density survey is ±0.007 to 0.002 SG units if the depth measurement is accurate to ±1 foot.

Density Accuracy Due to the Transducer

The WIPP groundwater monitoring staff used an In Situ, Inc. PXD-461, 500 psi pressure transducer from 2000 – 2008. Knowing the accuracy of the transducer, one can calculate the accuracy of apparent density due to pressure error. The stated accuracy is 0.04 percent of range.

In 2009 the groundwater monitoring staff used an In Situ, Inc. Level Troll 500 psi pressure transducer. Knowing the accuracy of the transducer, one can calculate the accuracy of apparent density due to pressure error. The stated accuracy for this transducer is 0.05%

The accuracy of the 500 psi transducers are therefore:

2000-2008: Accuracy = 500 psi * 0.0004 = ± 0.20 psi
2009-present: Accuracy = 500 psi * 0.0005 = ± 0.25 psi

at all depths submerged. Note that the specification sheet gives the accuracy as 5.54 inches of water for the transducer used during 2000-2009. For the period of 2009-present the accuracy is 6.93. These are derived by:

2000-2008: Error in inches = [0.2 psi accuracy / 0.433 psi/ft (pure water)] * 12 inches / ft = 5.54 inches.
2009-present: Error in inches = [0.25 psi accuracy / 0.433 psi/ft (pure water)] * 12 inches/ft = 6.93 inches.

The transducer error thus has a 0.46 footage equivalent for the time period of 2000-2008 and 0.58 footage equivalent for the period of 2009 – present, applicable at all depths of submergence. The corresponding error can be calculated as a function of depth as shown in Table 2.

Table 2
Density Error Due to Transducer, Specific Gravity Units

Submergence (feet)	Density Error, SG units, assuming water density is 1.000 for a constant transducer error of 0.46 feet equivalent from 2000-2008 (dimensionless)
75	0.0061
100	0.0046
150	0.0031
200	0.0023
300	0.0015
350	0.0013
400	0.0011
500	0.0009
Submergence (feet)	**Density Error, SG units, assuming water density is 1.000 for a constant transducer error of 0.46 feet equivalent from 2009-present (dimensionless)**
75	0.0077
100	0.0058
150	0.0039
200	0.0029
300	0.0019
350	0.0017
400	0.0015

Appendix A – Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head

500	0.0012

Total Error on Density

Table 3 gives the total error in density as a function of submergence depth. It is constructed from the data in Tables 1 and 2, recognizing that error is an absolute value and that, in the worst case, component errors are additive. Greater submergence reduces the error due to inaccuracy of both the transducer depth measurement and the transducer. For transducer submergence greater than approximately 150 ft, total density error should be less than 0.01 SG units if submergence is accurate to ±1 foot.

Table 3
Total Density Error of Pressure Density Survey, Specific Gravity Units

Error for time period of 2000-2008			
Submergence (feet)	**Density Error for one foot of cable inaccuracy (dimensionless)**	**Density Error due to Transducer, SG Units (dimensionless)**	**Total Density Error, Absolute Value, SG Units (dimensionless)**
75	0.0133	0.0061	0.019
100	0.0100	0.0046	0.015
150	0.0067	0.0031	0.010
200	0.0050	0.0023	0.007
300	0.0033	0.0015	0.005
350	0.0028	0.0013	0.004
400	0.0025	0.0011	0.004
500	0.0020	0.0009	0.003
Error for time period of 2009-present			
Submergence (feet)	**Density Error for one foot of cable inaccuracy (dimensionless)**	**Density Error due to Transducer, SG Units (dimensionless)**	**Total Density Error, Absolute Value, SG Units (dimensionless)**
75	0.0133	0.0077	0.021
100	0.0100	0.0058	0.016
150	0.0067	0.0039	0.010
200	0.0050	0.0029	0.008
300	0.0033	0.0019	0.005
350	0.0028	0.0017	0.005
400	0.0025	0.0015	0.004
500	0.0020	0.0012	0.003

EFFECT ON ADJUSTED FRESHWATER HEAD

The foregoing analysis leads to an important conclusion: provided the transducer is placed at the Culebra midpoint elevation, the error of adjusted freshwater head is approximately 1.5 ft and is constant for every well in the network where density has been measured that way. In such cases, density would not even have to be calculated because the pressure converts directly to a freshwater height. The sum of the pressure error (0.46 foot) and water column height error (1 foot) is, very simply, the freshwater head error.

Table 4 does show the results of the density error analysis and how it translates to a smaller percent error in resulting freshwater head in terms of the water column height of the Culebra wells. For convenience, wells are grouped into common heights of water columns (i.e., typical Culebra midpoint to top of the water column). Each well group with progressively greater column height propagates the density error more, but the error itself gets smaller.

Table 4
Percentage Elevation Error on WIPP Wells' Adjusted Freshwater Heads

Appendix A – Accuracy of the WIPP Pressure Density Survey and Effect on Culebra Freshwater Head

Water Column Height for Culebra Wells, June 2006 and June 2007 (used to adjust to freshwater head)		**Wells Included**	**Percent Error in Freshwater Elevation (2000-2008)**	**Percent Error in Freshwater Elevation (2009-present)**
From (feet)	**To (feet)**			
75	100	H-07B1	1.9-1.5	2.1-1.6
100	150	SNL-17, SNL-13, I-461	1.5-1.0	1.6-1.0
150	200	H-04B, SNL-1,	1.0-0.7	1.0-0.8
200	300	SNL-19, SNL-2, SNL-15, SNL-12, H-09C, SNL-18, SNL-9, SNL-10, WIPP-30	0.7-0.5	0.8-0.5
300	350	H-17, H-02B2, H-03B2, C-2737, H-11b4, ERDA-9, H-19B0, SNL-5	0.5-0.4	0.5
350	400	SNL-3, WIPP-13, H-12, WIPP-19, H-15	0.4	0.5-0.4
400	500	SNL-8, H-05B, AEC-7, WIPP-11	0.4-0.3	0.4-0.3
>500		H-10C	<0.3	<0.3

CONCLUSIONS

The significance of total accuracy of density measurements is submergence-dependent for a homogeneous water column. Greater submergence reduces the percent error due to both the transducer depth measurement and the transducer's accuracy.

Submergence to mid-depth of the Culebra is optimal and will reduce error because the Culebra water column is not homogeneous. The mid-point is assumed to give the average for the Culebra.

The error associated with WIPP's pressure density survey propagates to an error of approximately 1.5 ft in all wells.