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Strategic Plan for Groundwater Monitoring at the Waste Isolation Pilot Plant

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United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Field Office
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List of Acronyms

AEC	Atomic Energy Commission
AMSL	Above Mean Sea Level
ASER	Annual Site Environmental Report
ASME	American Society of Mechanical Engineers
BGS	Below Ground Surface
BLM	Bureau of Land Management
C&C	Consultation and Cooperation
CBFO/ORC	U. S. DOE, Carlsbad Field Office, Office of Regulatory Compliance
CCA	Compliance Certification Application
CFR	Code of Federal Regulation
CH	Contact-Handled
CI	Confidence Interval
CMP	Compliance Monitoring Program
COMP	Compliance Monitoring Parameter
CTAC	Carlsbad Field Office Technical Assistance Contractor
DMP	Detection Monitoring Program
DOE	U. S. Department of Energy
DMW	Detection Monitoring Well
DOI	U. S. Department of Interior
DRZ	Disturbed Rock Zone
EEG	Environmental Evaluation Group
EMP	Environmental Monitoring Plan
EPA	U. S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
ES&H	Environment, Safety and Health
FEP	Features, Events and Processes
GLMP	Groundwater Level Monitoring Program
GMP	Groundwater Monitoring Program
GSP	Groundwater Surveillance Program
GTMP	Geotechnical Monitoring Program
GWMP	Groundwater Monitoring Program
HWDU	Hazardous Waste Disposal Unit
HWFP	Hazardous Waste Facility Permit
LMP	Land Management Plan
LWA	Land Withdrawal Act
MIP	Management Implementation Plan or Monitoring Implementation Plan
MOC	Management and Operating Contractor
MOU	Memorandum of Understanding
NAS	National Academy of Sciences
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMHWA	New Mexico Hazardous Waste Act

NMOSE	New Mexico Office of the State Engineer
NMSA	New Mexico Statutes Annotated
NQA	Nuclear Quality Assurance
NRC	U. S. Nuclear Regulatory Commission
OCD	Oil Conservation Division
ORNL	Oak Ridge National Laboratory
PA	Performance Assessment
P&A	Plug & Abandonment (or Plugging and Abandoning)
PIP	Production-Injection Packer
PL	Public Law
QA	Quality Assurance
QAPD	Quality Assurance Program Document
RCRA	Resource Conservation and Recovery Act
RH	Remote-Handled
SA	Scientific Advisor
SCP	Site Characterization Plan
SNL	Sandia National Laboratories
SOP	Standard Operating Procedure
SPDV	Site Preliminary Design Validation
T	Transmissivity
TD	Total Depth
TDS	Total Dissolved Solids
TRU	Transuranic
TV	Trigger Value
USC	United States Code
USI	Ultrasonic Imaging
USGS	United States Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WIPP	Waste Isolation Pilot Plant
WLMP	Water Level Monitoring Program
WQSP	Water Quality Sampling Program

Executive Summary

Groundwater-monitoring activities at the Waste Isolation Pilot Plant (WIPP) are an integral part of the U. S. Department of Energy's (DOE) broader requirements to ensure protection of the environment, the health and safety of workers and the public, proper characterization of the disposal system, and compliance of the WIPP with applicable regulations. This commitment is not only for the current operational phase of the WIPP but extends through the post-closure phase to meet regulatory requirements. To meet these long-term needs, the DOE has developed a strategy for groundwater monitoring that addresses both regulatory and operational requirements (drivers). This DOE plan describes the long-term groundwater monitoring strategy and provides the process for its implementation.

The objectives of this strategic plan include:

- Identify all drivers (e.g., regulations, DOE commitments, operational plans) for groundwater monitoring at the WIPP site.
- Describe the elements of the current groundwater-monitoring program.
- Identify the relevant links between the drivers and the program elements.
- Describe the long-term groundwater strategy and the process for how the strategy will be implemented.
- Define the roles, responsibilities and standard operating procedures for plan participants.
- Integrate and optimize the activities currently being pursued as independent programs
- Address other operational requirements related to groundwater monitoring such as Quality Assurance (QA) and Environment, Safety and Health (ES&H).
- Define the life cycle of the plan and establish appropriate review and revision schedules.

The goal of this plan is to provide the framework for the strategy inclusive of all current and future groundwater-monitoring activities. Within this framework, detailed investigation plans will be prepared to provide specific scopes of work, milestones, schedules, and cost estimates. The development of the strategic plan is the responsibility of the DOE's CBFO, Office of Regulatory Compliance (CBFO/ORC), while the investigation plans will be developed by the WIPP supporting organizations as directed and authorized by the CBFO/ORC. Because of distinct and overlapping roles and responsibilities of all program participants, the development and implementation of this plan requires a high-degree of integration among project participations.

Groundwater-Monitoring Drivers

Groundwater monitoring at the WIPP is driven by regulatory requirements and commitments made by the DOE during the certification and permitting processes. These regulations and commitments for monitoring are termed "drivers" throughout this plan and are subdivided into

two categories: (1) upper-tier drivers and (2) implementing drivers. The upper-tier drivers provide the general framework and language describing the need for monitoring, while the implementing drivers provide details of how the monitoring will be conducted to meet the requirements.

Because the WIPP is accepting mixed waste, the upper-tier drivers are derived from two sets of governing laws and regulations, one set for radioactive components and one for hazardous components. Radioactive waste disposal regulations, promulgated by the U.S. Environmental Protection Agency (EPA) and found primarily in Title 40 of the Code of Federal Regulation Part 191 (40 CFR 191) and its implementing criteria 40 CFR 194, are the primary drivers for transuranic waste disposal. The New Mexico Hazardous Waste Act (NMHWA) l regulation, e.g., 40 CFR 264) and regulations promulgated by the New Mexico Environmental Improvement Board are the upper-tier drivers for hazardous waste disposal.

The implementing drivers are typically found in certification/permit applications and activity-specific program plans. A summary of these implementing drivers follows:

- DOE's Compliance Certification Application or CCA (including Chapter 7.0, Appendix MON and Attachment MONPAR) submitted to the EPA for certification of the WIPP as a radioactive waste disposal facility.
- DOE's Compliance Monitoring Implementation Plan (MIP) developed to identify appropriate compliance parameters to be monitored over the life-time of the WIPP.
- DOE's WIPP Environmental Monitoring Plan (EMP) and the WIPP Groundwater Monitoring Plan (GMP) submitted with the CCA.
- HWFP issued to the U. S. DOE and the WIPP Management and Operating Contractor (MOC), including Module V - Groundwater Detection Monitoring.

Current Groundwater-Monitoring Program

The current groundwater-monitoring program comprises three basic elements:

1. Groundwater measurements
2. Well maintenance and replacement
3. Investigative studies

As directed by the DOE, the WIPP MOC and Scientific Adviser (SA) have primary responsibility for the program elements. The three monitoring elements are briefly described below.

Groundwater Measurements

Groundwater measurements focus primarily on the Culebra member of the Rustler Formation because this geohydrologic unit is the most transmissive saturated unit of the stratigraphic sequence within which the WIPP is sited. Groundwater measurements include:

- Groundwater quality sampling
- Groundwater level monitoring
- Pressure-density surveys
- Injection well surveys

Sampling for groundwater quality in the Culebra is conducted semi-annually and is limited to six wells, three located up-gradient and three located down-gradient from the WIPP shaft area. Water quality in a seventh well completed to the Dewey Lake Formation (stratigraphically above the Culebra) is also monitored. Analysis of the groundwater includes quantification of the concentrations of all analytes called out in the WIPP HWFP requirements plus 20 other chemical and metal constituents.

Monthly groundwater level measurements are made in the seven water quality wells plus other wells completed in the Culebra (quarterly measurements are made in the case of redundant wells located on the same well pad where measurements are made monthly). In addition to measurements of the water levels in the Culebra, water levels in the Dewey Lake, Magenta, Rustler-Salado contact, Forty-Niner, and Bell Canyon are measured at a limited number of locations to aid in the characterization of site hydrology. Some wells have multiple completions so more than one hydrologic unit can be measured in the same well. Currently, seventy one wells are in the groundwater network and monitor 80 water-bearing intervals.

Water density in the Culebra varies across the site and must be characterized in concert with the water levels to determine accurately the potentiometric surface at the site. Water density is determined from annual pressure-density surveys. The water level and density data are used to calculate freshwater equivalent heads that are then used to assess groundwater flow quantity and direction as required by regulation.

Injection of brine into the Bell Canyon Formation by petroleum operations has raised concerns that the operations may impact WIPP groundwater through leaking casings or other hydraulic short-circuits. The injection pressure, temperature and injected brine volume are being monitored in six injection wells located near WIPP Well H-9 to determine injection effects on Culebra water levels at the H-9 well pad.

Well Maintenance and Replacement

With the exception of the seven RCRA wells, many of the other wells in the current groundwater-monitoring network were constructed more than 20 years ago. As such, the integrity of these older wells, as well as the reliability of the data acquired from the wells, is questionable in some cases. Regular well maintenance and replacement, as necessary, is important to ensure continued well integrity. The integrity of the existing wells is determined through well logging techniques (e.g., ultrasonic imaging). Maintenance plans are developed based on the logging information. In some cases, the well condition may be so degraded that maintenance is not feasible. In these cases, a plugging and abandonment (P&A) program is in place to permanently seal the well(s) and remove it (them) from the monitoring network. As more problems are encountered, wells will be replaced to maintain the regulatory requirements for determining groundwater flow and direction.

Investigative Studies

Groundwater investigative studies are derived both from monitoring requirements, operational concerns, and the need to respond to potential changes in site conditions and/or issues raised by regulators and stakeholders. Two investigative studies are currently on-going and include:

- Culebra water level rises
- Shallow water infiltration into the WIPP exhaust shaft

Rises in Culebra water levels across the WIPP site were identified as a potential problem in the most recent assessment of compliance-monitoring data. In response to this finding, the DOE has directed the MOC and SA to identify the reason(s) for the water level rises and to assess the impact of such rises on compliance. A study has been implemented to develop scenarios that explain the observed water level rises, test the scenarios using numerical modeling and field tests, and re-evaluate the Culebra groundwater conceptual model with consideration given to the results of the study. The scope of the Culebra investigations include: installation and testing of new wells, development of a Magenta flow model, geologic/geophysical testing, flow modeling, and re-assessment of Culebra transmissivity fields.

In September, 1996, the MOC observed water seeping into the WIPP exhaust shaft at a depth where no water was encountered when the shaft was originally constructed. The DOE directed the MOC to investigate the source and extent of the water. Four wells and twelve piezometers were installed near and around the exhaust shaft and identified a perched water table at the contact between the Santa Rosa and Dewey Lake Formations. Water quality sampling, well testing and flow modeling have been performed, but the data and results compiled to date have been insufficient and inconclusive, particularly regarding the extent of the perched water. Thus, the study will remain active with the installation of additional wells/piezometers, well testing, electromagnetic surveys, and flow modeling.

Strategic Objectives

The primary goal of the strategic groundwater-monitoring program is to maintain, by means of groundwater sampling and analysis, an accurate and representative groundwater database that is scientifically defensible and demonstrates continued regulatory compliance. A secondary goal is to improve efficiency and effectiveness of the groundwater program within the framework of regulatory compliance (i.e., implementing state-of-the-art innovative technologies, as appropriate). The groundwater program strategy is to use the current program elements to continue compliance with the governing regulations and to implement a new program element designed to systematically review the current program, available data, and other relevant information. Three basic issues of the groundwater strategy are:

1. Continued compliance
2. Effectiveness and efficiencies
3. Operational needs

The groundwater-monitoring program, as currently implemented, meets the regulatory drivers and other DOE commitments. Therefore, the basic strategy for continued compliance is to use proven elements of the current program. In addition, the program strategy must consider long-term monitoring compliance issues and, therefore, must address groundwater-related factors such as well degradation, unexpected groundwater data fluctuations or results, maintenance, manpower availability, budgets, new regulatory requirements and/or changes to existing regulatory requirements. These issues will be addressed in a formal review process and resolution of issues will be documented in reports.

Long-term programs, such as the groundwater-monitoring program, must be reassessed periodically to determine if the current programs are implemented in the most efficient and effective manner. Additionally, programs that may experience change as a result of changes in regulations or development of unforeseen issues must be assessed periodically to evaluate the complementary impacts of all changes. This groundwater program strategy includes elements that provide for periodic reassessment of the program and implementation of changes that improve efficiency as well as effectiveness. The efficiencies and effectiveness issues to be addressed by the program include:

- Improvements in well integrity/longevity
- Assurances of data relevance and quality
- Minimization of network requirements (optimize well locations based on data relevance/needs)
- Advancements in data collection techniques (e.g., automated remote monitoring)
- Improvements in well design, testing and data analysis
- Recognition and resolution of long-term issues

Operational concerns are issues that arise from the day-to-day operation of the site and are not generally tied to regulatory drivers. An example of an ongoing operational concern is the investigation of the nature and origin of water leaking into the WIPP exhaust shaft. The groundwater program strategy must be capable of addressing similar operational issues as well as current and unknown future concerns. To accomplish this within the groundwater program, the strategy must include an element that addresses operational issues. This program element must identify the data needs of operational concerns and then outline activities that provide the relevant information relating to the concerns. These issues will be addressed in a formal review process with resolution of issues documented in reports.

Implementation of Strategic Objectives

Implementation of the groundwater strategy includes continued use of the proven elements of the current groundwater-monitoring programs and the development, documentation and implementation of new program elements that address long-term monitoring requirements, efficiencies and operational issues. The groundwater-monitoring program, including any new program elements, will be the responsibility of an Integrated Groundwater Team (IGWT) staffed by members from the DOE, the MOC, and the SA to ensure integration of ideas, capabilities and communication. The IGWT shall ensure communication between the project participants and authorize all related groundwater activities. The IGWT shall be responsible for planning and documenting the results of all assessments that are used to justify changes to the groundwater program, monitoring and/or reporting functions. Furthermore, the IGWT shall communicate to DOE management recommendations for changes to the groundwater program including those that enhance effectiveness, implement efficiencies and address unplanned/out of scope issues.

Other Requirements

All activities conducted under this strategic plan shall meet the requirements put forth in the DOE/CBFO Quality Assurance Program Document (QAPD), individual project participant QA plans, standard operating procedures, and necessary ES&H procedures. Other requirements not directly related to groundwater monitoring but that may affect the operation of monitoring activities are also incorporated by reference.

Roles and Responsibilities

Implementation of this strategic groundwater-monitoring plan will require active integration among the DOE/CBFO, the MOC, the SA, and the CTAC. Although the IGWT will be given oversight over the monitoring programs and elements, specific roles and responsibilities for individual project participants still remain. Thus, this strategic plan outlines the roles and responsibilities of the groundwater monitoring project participants.

The IGWT, as directed by DOE/CBFO, will resolve differences in interpretation of the roles and responsibilities of project participants that may arise during the groundwater-monitoring period. Furthermore, the IGWT will provide appropriate checks and balances to ensure that the activities of one project participant do not adversely affect the activities of the other participants.

Plan Life Cycle of Project Participants

The life cycle of this strategic groundwater-monitoring plan covers both the operational and post-closure phases of the WIPP. Because of the long-term requirements for the plan, periodic reviews and updates shall be scheduled. The reviews/updates will be performed by the IGWT with the first scheduled completion due one year after the next revision of the EMP is approved (scheduled for 2003). Subsequent reviews/updates will follow every three years.

1. Introduction

1.1 Overview

Groundwater-monitoring activities at the Waste Isolation Pilot Plant (WIPP) are an integral part of the U. S. Department of Energy's (DOE) broader requirements to demonstrate WIPP operations are performed in a manner that ensures protection of the environment, the health and safety of workers and the public, proper characterization of the disposal system, and compliance of the WIPP with applicable regulations. This monitoring commitment is required not only for the current operational phase of the WIPP, but extends through the post-closure phase of the facility to meet regulations.

The DOE has developed a strategy for groundwater monitoring that addresses both regulatory and operational requirements (drivers). The DOE strategy, set forth in this planning document, also addresses both current and future needs of the groundwater-monitoring program and describes the processes and methods for implementing the strategy. The plan specifically covers the 5- to 7-year period commencing with the issuance of this plan, but also establishes a framework for extending the monitoring strategy to the end of the WIPP operational period and beyond.

A historical perspective of the groundwater monitoring resources (i.e., wells) and programs is provided below to establish the context of the current program and the need for a long-term strategy. This historical perspective is followed by a description of the scope of the strategy to be implemented, including a listing of major objectives, and a summary of how this document is organized in presenting the plan.

1.2 Historical Perspective

Since the inception of the WIPP, groundwater information has been derived from boreholes either drilled and completed under the direction of the DOE and its predecessor agencies, the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA), or acquired by the DOE through other entities such as petroleum companies. Although a relatively large number of boreholes were drilled and completed specifically for hydrologic investigation, many others were drilled to characterize the geology and stratigraphy at the site, evaluate potash reserves, and, in some cases, explore for hydrocarbons. It was only later that these "non-hydrologic" boreholes were converted to wells for groundwater testing and monitoring.

A total of 112 boreholes[1] have been drilled at the WIPP for geologic and hydrologic purposes. Appendix A provides a comprehensive listing of these boreholes and also gives drilling start/end dates, surface elevation, total depth (TD), formation encountered

[1] This total does not include more than 60 shallow holes drilled to investigate soil conditions for building foundations or the 12 piezometers used to monitor shallow water directly under the WIPP surface facilities.

at TD, completion interval(s), and current status (i.e., plugged and abandoned (P&A), in use, etc). Of this total, 71 are currently being used for groundwater monitoring, 38 have been P&A, and 3 have been turned over to local landowners for private use. The boreholes range in depth from approximately 17 meters (Santa Rosa/Dewey Lake Contact) to nearly 1,500 meters (Bell Canyon) depending on the geohydrologic unit targeted for study. Groundwater monitoring focuses primarily on the Culebra dolomite member of the Rustler Formation because it represents the most transmissive saturated geohydrologic unit at the site. However, other units, such as the Santa Rosa, Dewey Lake, Magenta, Rustler/Salado Contact and Bell Canyon, are important to WIPP groundwater issues and are also being monitored. Additional well details, including location maps and monitored intervals, are provided in Section 3.

The materials used in the installation of the 71 active wells depend on the age of the borehole (well) [Hill et al, 1997]. Prior to 1989, all wells were drilled and completed using standard oil field technology. With this technology, steel casing is set either to TD or just above the interval of interest and then the annulus between the casing and borehole wall is cemented back to surface. Hydrologic intervals are completed by perforating the steel casing and cement in the targeted interval or by deepening the borehole through the targeted interval leaving an open hole below the cemented casing. Wells constructed after 1989 typically used the U.S. Environmental Protection Agency (EPA) specifications provided in the Resource Conservation and Recovery Act (RCRA) groundwater monitoring guidance document [EPA, 1986]. Using these specifications, a borehole is drilled and then a slotted fiberglass screen set on a solid fiberglass casing is positioned in the targeted interval with the solid casing extending back to the surface. The annulus between the screen and borehole wall is filled with gravel and/or sand, which is then isolated from other units using bentonitic clay or cement. The EPA specifications were used in the newer wells at the WIPP to minimize changes in the composition of the water in and near the well resulting from chemical reactions between the well water and the (steel) casing.

For the most part, only a single hydrologic interval (e.g., Culebra, Magenta, etc) is monitored in an individual well. However, in some cases, a single well is completed to more than one hydrologic unit. Bridge plugs, packers and/or production-injection packers (PIPs) are installed in these multi-completion wells to prevent commingling of groundwater from different intervals. For example, when both the Culebra and Magenta members of the Rustler Formation are monitored in the same well, a PIP is installed between the Culebra and Magenta intervals (the Magenta is located stratigraphically above the Culebra) to allow monitoring of the Culebra through tubing connected to the PIP and monitoring of the Magenta in the annulus between the tubing and the casing. Over the course of several years, a well may be reconfigured to monitor other hydrologic units while retaining its original completion interval. In these cases, plugs and packers are also used to isolate hydrologic units even though a single interval is being monitored.

Several programs have been implemented to plan, schedule and execute the drilling and monitoring activities at the WIPP. These programs have focused on key aspects of the repository site selection process including: site selection, site characterization, pre-operational surveillance/monitoring, and operational and compliance monitoring. The evolution of these programs and the drilling activities directly related to groundwater monitoring are summarized below.

1.2.1 Evolution of the Groundwater-Monitoring Well Network

As early as 1957, the National Academy of Sciences (NAS) recommended natural rock salt as an appropriate medium for disposal of radioactive wastes [NAS, 1957]. Following this recommendation, the DOE through its predecessor agencies, the AEC and later ERDA, identified the Delaware Basin of southeastern New Mexico as a candidate site for disposal of radioactive wastes because of the presence of thick salt beds (Salado Formation) extending from approximately 250 to 850 meters below ground surface (bgs). In 1972 under the direction of the AEC, Oak Ridge National Laboratory (ORNL) and the U.S. Geological Survey (USGS) jointly selected a location northeast of the current WIPP site in the northern portion of the Delaware Basin. The USGS then conducted regional geologic investigations that included the drilling of two exploratory holes (AEC 7 and 8). Preliminary results suggested the ORNL/USGS site was acceptable for hosting a repository, but further investigations were suspended because of a change in the waste management policy of the AEC.

In 1975, Sandia National Laboratories (SNL) resumed scientific investigations at the ORNL/USGS site and directed the drilling of a third exploratory hole (ERDA 6) within two miles of AEC 7. ERDA 6 encountered unexpected geology (severe distortion and dipping of beds) and the ORNL/USGS site was abandoned in favor of another Delaware Basin site located approximately 5 miles southeast of the ORNL/USGS site [Powers et al, 1978]. In 1976, SNL directed the drilling of ERDA 9 at the approximate center of this new site (the current WIPP site). Data from ERDA 9, Cabin Baby #1 (a deep borehole acquired by DOE from a petroleum company) and D-268 (a borehole drilled by a potash mining company) confirmed the suitability of the new site, a finding that marked the end of the site selection program and launched the formal Site Characterization Program (SCP). At the same time, the project received the familiar name it carries today (i.e., WIPP).

From 1976 to 1979, the primary focus of the SCP was to evaluate potash resources and characterize site geology, stratigraphy and hydrology. Twenty-one potash resource boreholes (denoted “P” holes) were drilled under the management of Fenix & Scission, Inc. At the request of DOE/SNL, the USGS logged the boreholes and characterized the stratigraphy and cores to estimate the distribution, composition and tonnage of potash resources in the WIPP site area [Jones, 1978]. In addition, SNL directed the drilling of twenty geologic boreholes (denoted “WIPP” holes) and twenty-six hydrologic boreholes (denoted “H” holes) (multiple references, see Hill et al, 1997]. The geologic boreholes were used to characterize site geology/stratigraphy and to investigate the presence or absence of various geologic features or processes such as faulting, anticlinal structures, breccia pipes, and salt dissolution. The hydrologic boreholes were used primarily for well testing [e.g., Beauheim et al, 1991; Beauheim, 1989].

In 1979, Public Law (PL) 96-164 [PL, 1979] authorized the DOE to proceed with development of the WIPP facility. As a result, the DOE formally established the WIPP as a research and development facility for the purpose of demonstrating the safe geologic disposal of transuranic radioactive wastes resulting from the nation's defense activities. PL 96-164 also required that the DOE enter into an Agreement for Consultation and Cooperation (C&C) with the State of New Mexico to keep the State informed of all key events (including decisions to proceed with construction of the WIPP) and to solicit and comment on recommendations concerning public health and safety made by the State. The C&C agreement [DOE, 1981] named the Director of the State's Environmental Evaluation Group (EEG) as the State of New Mexico representative in matters relating to the WIPP and required that the DOE provide resources for EEG WIPP-related activities. The EEG, as part of the C&C agreement, made recommendations to DOE for additional investigations (primarily hydrologic studies), were given the task of providing independent technical oversight of the project, and also received full partnership with DOE to provide independent environmental monitoring of the site.

The SCP was continued after PL 96-164 was enacted, but the primary emphasis shifted from geologic to hydrologic characterization. During the period from 1979 to 1992, fifteen additional hydrologic boreholes (denoted "H" holes, as described above) and three more geologic boreholes (i.e., WIPP 14, DOE-1 and DOE-2) were drilled [Hill et al, 1997]. Furthermore, many of the geologic boreholes (including those from the site selection program) and a few of the potash resource evaluation boreholes drilled earlier were converted to hydrologic boreholes. These newly drilled and converted hydrologic boreholes were used to evaluate important hydrologic properties as was the case for the earlier hydrologic holes. As well testing activities were completed, most of the wells (hydrologic boreholes) were kept in service under a surveillance program designed to collect representative and reproducible water quality samples and water levels that provided defensible groundwater data for use, initially, in site characterization and performance assessment and, later, in permitting and regulatory compliance.

Site preparation and construction activities were also initiated in 1979 with the drilling by Bechtel National Inc. of more than 60 shallow holes (denoted "B" holes) to evaluate building foundation conditions and one deep hole (i.e., B-25) to determine lithology and stratigraphy for use in shaft design [Bechtel, 1979a, 1979b]. From 1981 through 1984, three shafts were constructed in succession including the Salt Handling Shaft (or Exploratory Shaft), the Waste Shaft, and the Exhaust Shaft. Construction of the fourth and final shaft, the Air Intake Shaft, was completed in 1988. The shafts provided access to the planned repository horizon (approximately 655 meters bgs) and marked the beginning of the Site and Preliminary Design Validation (SPDV) phase of the project. The SPDV phase was conducted to validate the preliminary repository design and comprised a large number of full-scale experiments conducted in the WIPP underground to verify site geology and to confirm geomechanical and hydrological conceptual models for the host rock.

Based in large part on the confirmatory results obtained from the SCP and SPDV, the U.S. Congress enacted the WIPP Land Withdrawal Act (LWA) [PL 102-579, 1992] in 1992, which transferred jurisdiction of the WIPP site from the U.S. Department of Interior (DOI), Bureau of Land Management (BLM), to the DOE. Through the LWA, the role of the WIPP changed from a research and development facility to, potentially, a fully operational disposal facility. Thus, DOE's focus was on construction, operation, disposal, monitoring and, ultimately, decommissioning of the facility and how these activities could be performed within the regulatory environment. Owing to the fact that the defense-related wastes destined for the WIPP were mixed wastes (contained both transuranic and hazardous constituents), the DOE was required to obtain from the EPA and the New Mexico Environment Department (NMED), respectively: (a) certification under Title 40 Code of Federal Regulation (CFR) Parts 191 and 194 for the disposal of transuranics and (b) a hazardous waste facility permit (HWFP) under the New Mexico Hazardous Waste Act (NMHWA) for the disposal of hazardous waste. In this context, site characterization and validation studies were suspended in favor of surveillance monitoring to establish appropriate background or baseline conditions in anticipation of receiving certification/permit approval.

In 1994, the DOE decided to install six new Culebra wells dedicated primarily to water quality sampling. The wells were used to establish baseline or background concentrations of important chemical constituents. Three of the wells (WQSP 1 through 3) were located hydrologically up-gradient from and north of the WIPP shaft area, while the other three (WQSP 4 through 6) were located down-gradient from and south of the shaft area. When water was encountered in the Dewey Lake Formation in WQSP 6, a seventh well (WQSP 6a) was drilled and completed in the Dewey Lake. The wells were constructed and completed according to the specifications provided in the RCRA Groundwater Monitoring Technical Enforcement Guidance Document [EPA, 1986] to reduce chemical reactions between the groundwater and the well materials that were expected to bias the results of the measured baseline concentrations.

In the early 1990s, regulators and independent reviewers of the WIPP project raised concerns about conceptual models proposed for transport processes occurring in the Culebra dolomite and questioned the interpretation of tracer tests conducted in several of the earlier hydrologic boreholes. In response to these concerns, SNL directed the drilling of seven wells at a newly constructed well pad (H-19 located about one mile southeast of the WIPP surface facility) to obtain detailed and accurate data from carefully controlled tracer tests performed in the Culebra. These tracer tests were completed in 1996 [Meigs et al, 2000]. The seven wells used in the tests were then added to the groundwater surveillance monitoring network.

In May 1995, a scheduled inspection of the Exhaust Shaft revealed a thin stream of water emerging from cracks in the shaft liner located approximately 80 feet below the shaft collar. Since no water was encountered at this location when the shaft was originally constructed in 1984-85, an Exhaust Shaft Hydraulic Assessment Program was initiated in 1996 by the WIPP MOC [DOE, 1997a, 1997b, 2000]. Under this assessment program, four shallow wells (C-2505, C-2506, C-2507 and C-2811) and twelve piezometers (PZ-1 through PZ-12) that penetrated the upper Dewey Lake Formation were installed within and near the fenced area containing the WIPP surface facilities. Perched groundwater was intercepted at a depth of approximately 10 to 20 meters in most of these wells/piezometers. Since installation, the wells/piezometers have been used to monitor water levels and water quality on a regular basis, but have not been considered a traditional part of the overall groundwater-monitoring program because the perched water entering the exhaust shaft was considered an operational rather than hydrologic issue.

Following submission of separate certification and permit applications, the DOE received certification from EPA in 1998 [EPA, 1998] and a hazardous waste facility permit from NMED in 1999 [NMED, 1999] to dispose of transuranic and hazardous wastes, respectively, in the WIPP. These two milestones represented the beginning of the compliance-monitoring phase for the WIPP, which will remain in effect through the planned 35-year operational period and is expected to continue for 30 years and perhaps as long as 100 years following closure of the facility. With the exception of the drilling of Well C-2737 in 2001 to replace the hydrologic borehole H-1[2] [Powers, 2002], no new drilling related to the WIPP project has occurred since 1999 when receipt of waste was initiated.

Full details of the current groundwater-monitoring network are provided in Section 3 of this plan.

1.2.2 Groundwater-Monitoring Plans

Groundwater monitoring at the WIPP dates back to 1972 when ORNL and the USGS initiated the first site selection investigations in the Delaware Basin. From 1972 to 1975, the monitoring activity was a component of the site selection process focusing first on the ORNL/USGS site and later on the present WIPP site. Monitoring at both candidate sites was limited to static water level measurements and groundwater quality determinations including characterization of radionuclide levels in groundwater of the Rustler Formation (located stratigraphically above the Salado Formation).

With the launching of the SCP in 1976, a significant number of new hydrologic boreholes were drilled over the next decade, while geologic and potash resource evaluation boreholes were also being drilled and then, in many instances, converted to hydrologic holes. With the access provided by the hydrologic boreholes, an extensive well testing program was initiated to acquire data needed to evaluate important hydrologic (e.g., transmissivity, storativity, porosity, etc), geochemical and transport properties of the Magenta and Culebra dolomite members of the Rustler Formation. Hydrologic testing was also performed in the Dewey Lake and Bell Canyon Formations and the contact zone between the Rustler and Salado Formations. At some locations, more than one well was completed to the same test interval to have both a test well and an observation well(s) on the same well pad. The well testing and the construction of the four WIPP access shafts significantly altered the natural hydraulic heads and gradients in various hydrologic units comprising the WIPP site.

Groundwater-monitoring activities from 1972 through 1985 were controlled primarily by test plans developed under the larger site selection and site characterization programs directed by the DOE and implemented by the USGS, SNL and various subcontractors. In

[2] H-1 was P&A in 2001 because of erratic water level measurements and the discovery of holes in the casing at depths of approximately 12 meters.

1985 however, the first formal Groundwater Surveillance Program (GSP) was developed and consisted of two plan activities: (1) the Water Quality Sampling Plan (WQSP) and (2) the Water Level Monitoring Plan (WLMP). The objective of the WQSP was to collect representative and reproducible groundwater samples from water-bearing zones in the area of the WIPP site to characterize their physical and chemical composition. The objective of the WLMP was to collect water level measurements both during well testing and during subsequent well recovery and surveillance periods to fully characterize WIPP hydrologic properties and static groundwater conditions. Ultimately, the WQSP and WLMP were used to obtain defensible data for meeting the requirements of site characterization, performance assessment, regulatory compliance and permitting.

In 1988, the MOC assumed responsibility for the GSP including the WQSP and WLMP. At the same time, the DOE directed the MOC to develop an Environmental Monitoring Program (EMP), as called for in various DOE Orders (e.g., DOE 5400.1 and DOE/EH 0173T). Although the EMP is customized to meet the needs of each DOE facility, its basic features include an evaluation of background environmental conditions at the facility and on-going monitoring to assess how the environmental conditions change with time in response to the construction and operation of the facility. The WIPP-specific EMP required the compiling of pre-operational and operational radiological and non-radiological environmental data through an on-going monitoring program [DOE, 1996b]. One element of the WIPP EMP was groundwater monitoring. Thus, the GSP (including the WQSP and WLMP) was incorporated into the EMP as a subprogram.

As discussed previously, seven wells (i.e., WQSP 1 through 6 and 6a) were drilled and completed in 1994 using special groundwater monitoring techniques and materials specified in EPA's guidance document [EPA, 1996]. In anticipation of obtaining WIPP certification and a HWFP, the water quality in these seven wells was monitored semi-annually to establish background or baseline information that could then be used for comparison with water quality information obtained from the same wells during operation. In consecutive order, the WQSP, GSP and EMP were all updated to incorporate these changes by dropping the water quality monitoring requirements for all wells constructed during the SCP and making the seven wells drilled in 1994 the sole water quality sampling locations at the WIPP. During the same period, the WLMP was updated to include the seven new wells in the water level monitoring network; but unlike the WQSP, the WLMP retained all of the SCP wells.

With the certification of the WIPP by EPA in 1998 [EPA, 1998] and issuance of a HWFP by NMED in 1999 [NMED, 1999], the groundwater-monitoring program was again updated. Given that the EMP and GSP were included in the CCA, the elements of both programs were adopted directly by the Compliance-Monitoring Program (CMP). The only change was the renaming of the GSP to the Groundwater Monitoring Program (or GMP). The GMP retained the WQSP and the WLMP as defined in the older GSP. Following a parallel path, the HWFP required the development of a Detection-Monitoring Program (DMP). As with the EPA certification, the DMP approved by NMED in the HWFP adopted both the WQSP and the WLMP activities of the GMP and the EMP. In addition, the DMP called out requirements for point of compliance, well maintenance and P&A, and data evaluation and reporting. Although separate compliance monitoring programs are called for in the EPA certification and HWFP, both programs derive their groundwater data from the same monitoring activities (the WQSP and the WLMP). The most significant differences in the two groundwater-monitoring programs are the methods used to assess the monitoring data against expected repository performance and the schedules and format for reporting the data and assessments to the two regulators. These differences are further described in Section 2.

1.3 Scope

This strategic plan for groundwater monitoring at the WIPP has several objectives as follows:

- Identify all drivers (e.g., regulations, DOE commitments, operational plans) for groundwater monitoring at the WIPP site
- Describe the various elements of the current groundwater-monitoring program
- Identify the relevant links between the drivers and the program elements
- Describe the groundwater strategy and the process for how the strategy will be implemented
- Define the roles, responsibilities, and standard operating procedures for plan participants
- Integrate and optimize the activities currently being pursued as independent programs
- Address other operational requirements related to groundwater monitoring such as QA and ES&H
- Define the life cycle of the plan and establish appropriate review and revision schedules

The goal of this plan is to provide a framework inclusive of all current and future groundwater-monitoring activities. Within this framework, detailed investigation plans will be prepared to provide specific scopes of work, milestones, schedules, and cost estimates. The development of the strategic plan is the responsibility of the Carlsbad Field Office, Office of Regulatory Compliance (CBFO/ORC), while the investigation plans will be developed, as directed and authorized by the CBFO/ORC, by DOE's supporting organizations including the MOC, the WIPP SA, and/or the DOE CBFO Technical Assistance Contractor (CTAC). Because of distinct and overlapping roles and responsibilities for all program participants, the development and implementation of the plan will necessarily require a high-degree of integration among the DOE, MOC, SA and CTAC.

1.4 Plan Organization

The regulatory and operational requirements or drivers for groundwater monitoring are discussed in Section 2.0. Current groundwater program elements are identified and described in Section 3.0. Section 4.0 provides the linkage between drivers and program elements. The strategic objectives of groundwater monitoring and methods used to implement these objectives are described in Sections 5.0 and 6.0, respectively. The roles, responsibilities and standard operation procedures (SOPs) for the various program participants are summarized in Section 7.0. Other operational requirements such as QA and ES&H are described in Section 8.0. The plan life cycle, including review and revision schedules, is given in Section 9.0. Section 10 provides a list of references cited throughout this plan.

2. Drivers for Groundwater Monitoring

The current groundwater-monitoring program at the WIPP is being driven by two upper-tier regulatory requirements: (1) 40 CFR 191 and 40 CFR 194 promulgated by the U.S. EPA to establish standards for governing the management and disposal of all spent nuclear fuel and high-level and transuranic radioactive wastes and (2) the NMHWA and governing regulations for hazardous waste disposal promulgated by the New Mexico Environmental Improvement Board and enforced by the NMED. The general requirements provided in these upper-tier documents often require a response (e.g., programs plans) from the disposal facility owner/operator that provides details on methods and processes that will be used to implement the requirements. Throughout this plan, the upper-tier requirements and implementing documents are termed drivers. Other requirements relating to operational aspects of the groundwater-monitoring program also apply, but are not included in the definition for drivers. Examples of these other requirements are found in the New Mexico Statutes Annotated (NMSA), which address underground water use and well construction in the State of New Mexico. A summary of the upper-tier and implementing drivers for groundwater monitoring, as well as other relevant requirements, are presented below.

2.1 Upper-Tier Drivers

2.1.1 40 CFR Part 191 and 40 CFR Part 194

The EPA standards governing the management and disposal of all spent nuclear fuel, high-level and transuranic radioactive wastes are codified in 40 CFR Part 191 [EPA, 1985; 1993]. The WIPP must satisfy these standards because it currently accepts Contact-Handled (CH) TRU waste and could eventually accept Remotely-Handled (RH) TRU waste. The portion of the law that is applicable to groundwater monitoring can be found in Subpart B of 40 CFR §191.14(b) *Assurance Requirements*, namely:

(b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring.

Under the WIPP LWA of 1992 [PL 102-0579, 1992; as amended, 1996], the EPA was required to issue, by rule, the criteria for the WIPP certification and subsequent recertifications of compliance with final disposal regulations. The EPA issued these required criteria as 40 CFR Part 194 [EPA, 1996]. The portions of 40 CFR 194 applicable to groundwater monitoring are presented below (paraphrased) and can be found in Subpart B *Compliance Certification and Re-Certification Applications* and Subpart C *Compliance Certification and Re-Certification General Requirements*.

Subpart B §194.15 Content of Compliance Re-Certification Application(s)

(a) Requires that any previous compliance application be updated to provide EPA with sufficient information to determine whether or not the WIPP continues to be in compliance with the regulations. Updated documentation shall specifically include: all additional geologic, geophysical, geochemical, hydrologic, and meteorologic information; all additional monitoring data, analyses and results; and any additional information requested by the EPA.

Subpart C §194.42 Monitoring

(a) Requires that DOE conduct an analysis of the effects of disposal system parameters on the containment of waste in the disposal system, include analysis results in any compliance application and use analysis results in developing plans for pre-closure and post-closure monitoring. The analysis shall include groundwater flow, effects of human intrusion in the vicinity of the disposal system and brine quantity, flux, composition, and spatial distribution, among other parameters.
(b) Requires that DOE document and substantiate the decision not to monitor a particular disposal system parameter.
(c) Requires, to the extent practicable, that DOE conduct pre-closure monitoring of significant disposal system parameters where significance is defined as the system's ability to contain waste or the ability to verify predictions about the future performance of the disposal system. Such monitoring shall begin before waste emplacement is initiation and shall end at the time at which the shafts of the disposal system are backfilled and sealed.
(d) Requires, to the extent practicable, that DOE conduct post-closure monitoring (commencing when shaft backfilling and sealing has been completed) to detect substantial and detrimental deviations from expected performance. Post-closure monitoring shall be complementary to hazardous waste regulations using techniques that do not jeopardize waste containment and may be terminated when DOE can demonstrate to EPA that there are no significant concerns to be addressed by further monitoring.
(e) Requires that any compliance application submitted by DOE shall include detailed pre-closure and post-closure monitoring plans. Such plans shall identify the parameters that will be monitored and how baseline values will be determined, indicate how each parameter will be used to evaluate any deviations from the expected performance of the disposal system; and discuss the length of time over which each parameter will be monitored to detect deviations from expected performance.

In addition to these groundwater-specific monitoring requirements, 40 CFR 194 requires Performance Assessments (Pas) to demonstrate that the WIPP complies with all regulations. Groundwater-related inputs to these PAs need to be integrated with future monitoring requirements. Subpart A of 40 CFR 194 incorporates, by reference, relevant U. S. Nuclear Regulatory Commission (NRC) and American Society of Mechanical Engineers (ASME) publications including NUREG-1297, *Peer Review for High-Level Nuclear Waste Repositories* [Altman, et al., 1988] and ASME Nuclear Quality Assurance (NQA) Standards NQA-1 [ASME, 1989a], NQA-2a [ASME, 1989b] and NQA-3 [ASME, 1989c].

2.1.2 New Mexico Hazardous Waste Act (NMWHA)

Waste disposed at the WIPP is termed "mixed" waste because it contains both radioactive and hazardous constituents. Disposal of radioactive constituents is regulated by EPA, as described above. Disposal of hazardous constituents is regulated under the RCRA [United States Code (USC), 1976].

The RCRA is a statute designed to provide "cradle-to-grave" control of hazardous waste by imposing management requirements on generators and transporters of hazardous wastes and on owners and operators of treatment/storage/disposal facilities. The RCRA requirements are implemented primarily through the 40 CFR Part 260-280 series of regulations with Parts 260-270 consisting of requirements and standards pertaining to solid waste, particularly hazardous waste, and Parts 280-281 pertaining to the management of underground storage tanks (USTs) containing petroleum products or hazardous chemicals.

The EPA has delegated authority to the State of New Mexico such that the state hazardous waste management program has been approved to operate in lieu of the federal RCRA program. Consequently, it is the NMED that has authority over hazardous waste management at the WIPP. The NMHWA, and regulations promulgated thereunder, form the legal basis for the WIPP HWFP. Applicable New Mexico Administrative Code (NMAC) [NMED, 2000] requirements for groundwater monitoring include:

20.4.1.500 NMAC (incorporating 40 CFR §§264.97 and 264.98)

> Specifies the requirements for a Detection Monitoring Program (DMP) to establish background groundwater quality and monitor indicator parameters and waste constituents that provide a reliable indication of the presence of hazardous constituents in the groundwater.

20.4.1.500 NMAC (incorporating 40 CFR §264.601(a))

> Specifies the need for the DMP to demonstrate compliance with the environmental performance standard for the Underground Hazardous Waste Disposal Units (HWDUs). This standard requires prevention of any releases

that may have adverse effects on human health or the environment due to migration of waste constituents in the groundwater or subsurface environment.

20.4.1.500 NMAC (incorporating 40 CFR §§264.95, 264.98, 264.601, and 264.602)

Specifies the need to identify the point of compliance relative to the groundwater flow direction and the need for detection monitoring wells.

20.4.1.500 NMAC and 20.4.1.900 NMAC (incorporating 40 CFR §§264.97(a) and (c), 264.98(b), 270.42)

Describes requirements for well location, maintenance, and plugging and sealing.

20.4.1.500 NMAC (incorporating 40 CFR §264.98(a))

Specifies the parameters and constituents to be monitored in the DMP.

20.4.1.500 NMAC (incorporating 40 CFR §264.97(f))

Specifies the need for determination of groundwater surface elevations at monitoring wells and throughout the region.

20.4.1.500 NMAC (incorporating 40 CFR §264.98(e))

Specifies the need for the determination of groundwater flow rate and direction using groundwater surface elevations.

2.2 Implementing Drivers

2.2.1 Compliance Certification Application

Using the criteria established by the EPA in 40 CFR Part 194, the DOE prepared a Compliance Certification Application (CCA) to demonstrate compliance of the WIPP with the requirements put forth in 40 CFR Part 191. In 1996, this CCA, entitled *Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant* [DOE, 1996a], was formally submitted to the EPA for a certification decision ruling. As required by 40 CFR Subpart C §194.42(a), the CCA contained, in part, the results of an analysis conducted to determine the effects of disposal system parameters on the containment of waste in the disposal system. These results were the basis for the development of a Compliance Monitoring Program (CMP) for pre- and post-closure monitoring activities required under 40 CFR Subpart C §194.42(c) and §194.42(d), respectively. Based on the final rule-making that certified the WIPP's compliance with the radioactive waste disposal regulations [EPA, 1998], the EPA implicitly accepted the results of the 40 CFR Subpart C §194.42(a) analysis as well as the pre- and post-closure monitoring plans prepared by the DOE.

The monitoring parameter analysis conducted by the DOE for the CCA was guided by several general principles and/or screening criteria (e.g., 50 FR 38081 and 40 CFR 194.42) including:

- Monitoring should address significant concerns associated with the performance of the isolation system and should provide meaningful data in a relatively short period of time (i.e., the time corresponding to the operational phase and the active institutional control phase of the facility).
- Monitoring should not become a reason to relax the degree of care for which the compliance determination is made.
- Monitoring must not jeopardize the integrity of the disposal system.
- Monitoring should address significant disposal system parameters and important disposal system concerns.
- Monitoring to assess compliance with radioactive waste disposal regulations should complement monitoring required for the hazardous waste disposal programs.

When these guiding principles/criteria were applied to the disposal system parameters specifically identified in 40 CFR Subpart C §194.42(a) as well as other parameters known to be important to system performance, only ten parameters were formally adopted by the CMP that was included in the CCA (see Chapter 7.0, Appendix MON, and Attachment to Appendix MON (MONPAR)). These compliance-monitoring parameters, or COMPs, include:

1. Culebra Groundwater Composition
2. Change in Culebra Groundwater Flow (as manifested through Culebra water levels)
3. Probability of Encountering a Castile Brine Reservoir
4. Drilling Rate Within the Delaware Basin
5. Surface Subsidence Measurements
6. Waste Activity
7. Creep Closure and Stresses
8. Extent of Brittle Deformation
9. Initiation of Brittle Deformation
10. Displacement of Deformation Features

Only the first two COMPs are relevant to this plan.

The CCA examined other groundwater monitoring and hydrologic parameters, but excluded them from the monitoring program because (1) changes in the parameters were not significant or only moderately significant to system performance, (2) changes during the regulatory period will be so slow that their measurement during the regulatory periods is impractical, and because (3) monitoring, in and of itself, could jeopardize the integrity of the disposal system. Specific groundwater and hydrologic parameters excluded from monitoring include Salado hydrology and brine composition, Castile hydrology and brine composition, and disturbed rock zone (DRZ) hydrology.

The CCA also addresses long-term operational issues related to groundwater monitoring. For example, the monitoring plans recognize that technology, regulations, site management, safety requirements, and public opinion will likely change with time and that these changes will need to be incorporated in the future, particularly during the transition from the pre-closure to post-closure phases. Furthermore, the plans recognize the need for maintenance of the well network. In particular, the DOE will be required to perform maintenance on the wells used for groundwater composition measurements (i.e., WQSP 1 through 6), replacing casing as required or every 25 years until monitoring ceases [CCA, Appendix MON, 1996]. Although not stated specifically, maintenance on the other wells in the network will also be performed as needed.

Monitoring of Culebra groundwater composition, change in flow, and well water levels are to be conducted both during the pre-closure and post-closure (i.e., 30 years after closure and/or as required by RCRA) phases of the repository. CCA Appendices EMP and GWMP provide details of the groundwater-monitoring program including specifications for measurement frequency, sampling locations, and reporting responsibilities.

Before WIPP received certification from the EPA, the EMP was developed in response to various DOE Orders (e.g., DOE Order 5400.1 [DOE, 1990a], DOE Order 5400.5 [DOE, 1990b], and DOE/EH-0173T [DOE, 1991]) specifically written to prevent environmental contamination at a DOE site during its pre-operational and operational life. An EMP for the WIPP was prepared [DOE, 1994] in response to these requirements, was later submitted along with the CCA, and has now become an integral part of WIPP's certification. Implementation of the EMP, including plan review and revision as required, is the responsibility of the MOC. Changes to the plan are intended to allow the use of advanced technology and new data collection techniques as they arise. Monitoring data collected under the EMP are reported in the Annual Site Environmental Report (ASER).

The EMP includes two important program elements: (1) Radiological environmental monitoring and (2) Nonradiological environmental monitoring. Monitoring conducted within the first element comprises sampling of effluent (liquid and air), groundwater, surface water, soil samples, sediments and biota. Within the nonradiological element, monitoring comprises sampling of meteorological conditions, volatile organic compounds (VOCs), groundwater, and wildlife conditions as well as activities related to land management (disturbance, reclamation and restoration), oil and gas surveillances and population changes. Pre-operational baseline conditions for the program elements have been established and are used to compare and contrast with data acquired during the operational phase of the WIPP. As appropriate, sample splits from the monitoring program are made available to the EEG for independent verification of WIPP's environmental monitoring results.

As noted, the EMP requires monitoring of groundwater, which is addressed in the WIPP GMP Plan (CCA Appendix GWMP), a companion plan to the EMP. Implementation of the GMP Plan, including review and revision as required, is the responsibility of the MOC. The objectives of the GMP (formerly known as the GSP) are to:

- Determine the physical and chemical characteristics of WIPP groundwater
- Maintain surveillance of groundwater levels surrounding the WIPP facility, both before and throughout the operational lifetime of the facility
- Document and identify effects, if any, of WIPP operations on groundwater parameters
- Fulfill the requirements of the EPA Compliance Certification, DOE Orders and, as described later, the HWFP.

The WIPP GMP consists of two subprograms including the Water Quality Sampling Program (WQSP) and the Water Level Monitoring Program (WLMP). Each of these programs has been implemented through appropriate program plans that are summarized below.

<u>Water Quality Sampling Plan (WQSP).</u> The WQSP was initiated before the WIPP was certified and included groundwater quality sampling and surveillance of most of the wells constructed during site characterization. In anticipation of EPA certification (and also the HWFP), seven new wells were drilled including, six (WQSP 1 through 6) completed to the Culebra and one (WQSP 6a) completed to the Dewey Lake. These wells were used to established background (or baseline) water quality and now, after certification, represent the sole locations for water quality compliance monitoring. Samples are recovered from the seven wells twice per year, i.e., from March through May and again from September through November. The samples are analyzed for chemical and physical parameters, as well as specific radionuclides. A complete list of analytes is provided in the EMP.

<u>Water Level Monitoring Plan (WLMP).</u> The WLMP was also initiated before WIPP was certified by EPA and included groundwater-level measurements in all completed hydrologic units of the wells constructed during site characterization and surveillance. The water level data, along with the hydrologic properties, were used during site characterization to establish flow rate and direction within the various hydrologic units. After certification, most of these wells (number and locations provided in Section 3) have remained in the compliance-monitoring network to acquire data to assess changes in flow rate and direction with time. The WLMP provides the data for these assessments by measuring water levels either on a monthly or quarterly basis. Monthly measurements are taken at locations containing a single well or multiple wells completed to different hydrologic units, while quarterly measurements are taken in any redundant wells. The primary focus of the WLMP is the Culebra member of the Rustler Formation. However, the WLMP also collects water-level data in wells completed to other hydrologic units including the Magenta, Forty-niner, and Los Medanos members of the Rustler; the Rustler-Salado contact; the Dewey Lake; and the Bell Canyon.

2.2.2 Compliance Monitoring Implementation Plan (MIP)

In the CMP developed for the CCA, the DOE made commitments to conduct a number of monitoring activities to comply with the criteria at 40 CFR §194.42 and to ensure that important deviations from the expected long-term performance of the repository are identified at the earliest possible time. To implement the CMP, the DOE developed the *40 CFR Parts 191 and 194 Compliance Monitoring Implementation Plan* [DOE, 1999c]. This plan identifies the activities needed to comply with the relevant regulatory monitoring requirements and the organizations responsible for the various monitoring activities. In addition, it establishes the compliance monitoring and reporting schedules and defines the processes for assessing compliance against the CCA baseline and for reviewing and modifying the monitoring program to ensure that appropriate and useful parameters are included in the CMP.

The CMP described in the CCA identified ten COMPs to be monitored. The EPA has accepted these ten parameters through its certification of the WIPP. As such, the DOE directed the SA to develop a plan for annually deriving the COMPs and assessing these derived values against the CCA baseline expectations. In response to this direction, the SA issued a COMPs assessment plan [Sandia National Laboratories, 2000a] which recommended that trigger values (TVs) be established for each COMP, as appropriate, and be used in the annual assessment as indicators of conditions that may affect continued compliance of the WIPP. The TVs assigned by the SA [Sandia National Laboratories, 2002] were based not only on compliance issues, but also on the effect changes in a COMP could have on operations and safety of the facility and on assumptions used in the features, events and processes (FEPs) analysis conducted for the CCA. The exceedance of a TV during the annual assessment does not mean that continued compliance is in jeopardy, but that further action, such as additional investigative studies, must to be taken.

The TVs established for the Culebra groundwater composition COMP make use of statistical quantities (means and confidence intervals, C.I.) derived from concentrations of major ions determined during the background or baseline water quality sampling conducted for WQSP Wells 1 through 6. Specifically, the trigger values are defined as conditions in which Culebra groundwater composition (including both duplicate analyses from a given round of sampling) for a major ion falls outside the 95% C.I. for three consecutive sampling periods (or rounds).

The TVs established for the Culebra groundwater-level COMP incorporate historical water level measurements (and their errors) taken in the 32 wells used to calibrate the Culebra transmissivity fields (T-fields) that defined, in part, the flow and transport conceptual models used in the CCA PA. The 32 wells represented all the wells in the modeling domain with the exception of those that were sufficiently close to other wells to be considered redundant. The T-fields were interpolated from iterative simulations using the "point" values of transmissivity measured from welling test at individual locations and water-level measurements made at all well locations within the modeling domain. In this process, the simulated T-fields were adjusted from model run to model run until the simulated heads fell within error ranges of heads estimated for each well in the model domain. The error ranges in heads are now being used as the TVs for the annual COMPs assessment.

Various outcomes from the compliance assessment can occur. One outcome is that the COMPs are consistent with the expectations within the CCA baseline. In this case, the SA informs the DOE and then awaits the next assessment cycle. Another outcome is that the COMPs are not consistent with these expectations. In this case, the SA again informs the DOE of the results, but in addition, performs an evaluation to assess the significance of the observed condition and provides recommendations to assure resolution. Resolution of unexpected results may require modification of the monitoring program(s) and CMP processes. Regardless of the outcome, the DOE provides the results of the COMPs assessment to the EPA for review.

2.2.3 Hazardous Waste Facility Permit

In 1999, the NMED issued a hazardous waste facility permit (HWFP) to the DOE and the MOC to operate a hazardous waste storage and disposal facility at the WIPP [NMED, 1999]. Among other terms and conditions of the permit, the NMED required the implementation of a Detection-Monitoring Program (DMP), Site Closure Plan and Site Post-Closure Plan, each of which contained requirements pertaining to groundwater monitoring. These requirements are summarized below.

<u>Detection Monitoring Program (DMP).</u> The DMP is included as part of the HWFP to establish background groundwater quality and to monitor indicator parameters and waste constituents that provide a reliable indication of the presence of hazardous constituents in the groundwater. Components of the DMP related to groundwater monitoring include:

- Point of compliance
- Well maintenance and plugging and abandonment
- Water quality sampling
- Groundwater level monitoring
- Data evaluation and reporting

The HWFP defines the point of compliance as the vertical surface located perpendicular to the groundwater flow direction at the detection monitoring wells (DMWs) that extends to the Culebra member of the Rustler Formation. The DMWs are specified to be the WQSP Wells 1 through 6 (completed to the Culebra) and WQSP Well 6a (completed to the Dewey Lake). The locations of these wells are shown in Section 3.

Maintenance of the seven DMWs is to be performed according to the requirements of 20 NMAC 4.1.500 (see earlier discussion). The DMWs may be P&A by submitting a permit modification request to NMED. P&A is to be performed in such a manner as to eliminate physical hazards, prevent groundwater contamination, conserve hydrostatic head and prevent commingling of subsurface water. A P&A report needs to be submitted to NMED 90 days from the date the DMW is removed from the DMP.

Groundwater quality sampling from WQSP Wells 1 through 6 and 6a is required under the DMP to establish an accurate and representative groundwater database that is scientifically defensible and demonstrates regulatory compliance. Two separate phases of sampling are identified under the DMP. During the first phase, groundwater sampling and analyses are performed to determine background or existing conditions of groundwater quality. This phase must be completed before any hazardous waste is disposed in the WIPP and must contain four sampling rounds performed over a two-year period[3]. In the second phase, groundwater sampling must be performed semi-annually (March through May and September through November of each year) to determine if groundwater composition is changing or being affected by WIPP activities. The parameters and chemical constituents to be monitored in both phases are listed in Module V of the HWFP.

The DMP also requires groundwater level measurements in wells located across the site. Water level measurements of particular interest are those taken in the Culebra and Magenta members of the Rustler Formation. However, water level measurements are also to be made in monitoring wells completed in other water-bearing zones overlying and underlying the WIPP repository horizon when access to those zones is possible. These zones include, but are not limited to, the Bell Canyon, the Forty-niner, the Rustler-Salado contact and the Dewey Lake. Under the DMP, water level measurements are taken in the seven water quality wells (WQSP Wells 1 through 6 and Well 6a) and in older wells located at 26 other locations as called out in Attachment L, HWFP. Measurements are to be made monthly in at least one accessible completion interval at each available location. At locations with two or more wells completed in the same interval, quarterly measurements are to be taken in the redundant wells. Water levels in the new water quality wells are to be determined monthly and, in addition, before each water-quality sampling event.

The WIPP MOC is responsible for implementing, maintaining and revising the DMP. As such, they are also required to evaluate data acquired under the DMP and report the data and results of the evaluations to the NMED. Water quality evaluations are to be performed and reported following each sampling round (i.e., semi-annually) using statistical analysis methods to determine if current conditions are different from the established background conditions. Groundwater level measurements, in terms of field surface elevations and freshwater equivalent elevations, are to be determined and reported monthly. In addition, all groundwater-monitoring activities are to be reported in the ASER delivered to the NMED by October 1 of each year. The ASER also needs to document flow rate and flow direction in the Culebra.

<u>Site Closure Plan.</u> The Site Closure Plan describes the activities necessary to close the WIPP individual units and facility and includes plans for underground panel closure, surface storage unit closures, shaft sealing, and activities related to groundwater. The operational phase of the facility will be followed by a decontamination and

[3] The water quality baseline for the WIPP has been established and is based on 10 rounds of sampling conducted over a five-year period.

decommissioning phase and final closure. Closure will likely occur approximately 35 years after the date waste was first received. During the closure phase, monitoring wells no longer in use will be P&A according to applicable regulations as provided for in the Closure Plan. Those wells remaining in the network during the closure phase (i.e., those not P&A) will be monitored at the same frequency and level of effort described in the DMP for the operational phase.

Site Post-Closure Plan. The Site Post-Closure Plan describes the activities required to maintain the WIPP after completion of facility closure and to implement institutional controls to limit access. Post-closure groundwater monitoring will continue in accordance with the DMP. The sampling frequency may be changed to biannually after the final facility closure is completed. The final target analyte list specified in the HWFP for water quality sampling may also be changed based on the final composition of the waste. The changes would require a modification of the current HWFP approved by the Secretary of the NMED.

2.3 Other Related Requirements

2.3.1 U.S. Bureau of Land Management

Many of the wells used to monitor groundwater at the WIPP are located outside of the WIPP LWA boundary on land under the jurisdiction of the U.S. Bureau of Land Management (BLM). Under the provisions found in 43 CFR 2801.1 and 2801.2, the BLM has authority to require any well on public lands to be configured in a manner that would provide for the protection of resource values (e.g., potash, hydrocarbons, etc). An example of the type of protection the BLM may impose is the use of cemented steel casing in the construction of wells that penetrate any water-soluble geologic units (e.g. salt or potash). In addition, access to BLM lands requires submittal and approval of right-of-way waivers, which may be subject to stipulations that could affect other groundwater activities (e.g., new well and/or road construction). Other related issues have been addressed through a Memorandum of Understanding (MOU) between BLM and DOE and the Land Management Plan (LMP) [DOE, 1993].

2.3.2 Other WIPP LWA Requirements

In addition to transferring control of the WIPP site from the DOI to the DOE and the invoking of the requirements under 40 CFR 191 and 194, the WIPP LWA also required that the WIPP comply with all applicable Federal, State and local regulations. Many of these regulations contain requirements relevant to activities supporting groundwater monitoring and are included in Appendix B for reference.

2.3.3 New Mexico Statutes Annotated (NMSA) and Office of the State Engineer

Underground waters in New Mexico are declared to be public waters and, therefore, subject to the jurisdiction of the New Mexico Office of the State Engineer (NMOSE). Two NMSA apply to the groundwater activities of the WIPP: (1) 72 NMSA 12-1-28 entitled *Underground Waters* and (2) 72 NMSA 13-1-12 entitled *Artesian Wells* (latter applies to WIPP wells even if the heads measured in the wells are not expected to extend above the elevation of the local ground surface). The NMOSE has defined artesian wells as those wells completed in hydraulically confined (pressurized) stratigraphic units in which the head levels exceed the head levels of local potable aquifers regardless of whether the head levels exceed the elevation of the ground surface. Important groundwater requirements found in these two articles include:

- Any entity planning to drill a well(s) to appropriate use of underground waters must apply to the NMOSE. Among other requirements, the application must describe the use of the waters, location of the proposed well, name of the landowner, and amount of water to be appropriated.
- A change in location of a well or change of water use requires an application to the NMOSE.
- Well drillers must be licensed by the NMOSE and landowners must use licensed drillers.
- The owner of a previous water right may drill replacement and/or supplemental wells provided the wells are drilled into the same underground basin and appropriate no more water than under the previous water right. The requirements for replacement wells depend on whether the well is under or over 100 feet from the original well. The NMOSE must be notified of the drilling of replacement and supplemental wells.
- The NMOSE must be notified before a new well is drilled or when an existing well is re-completed. The public must also be notified.
- A permit must be obtained from the NMOSE to drill, repair, plug or abandon any artesian well.
- A drilling log of an artesian well must be kept and must include (1) recording the depth, thickness and character of different strata penetrated, (2) the dates when the work was begun and completed, (3) the amount, weight and size of casing set, and (4) the number of inches of flow from such well above the casing.

2.3.4 New Mexico Oil Conservation Division

The Oil Conservation Division (OCD) of New Mexico's Energy, Mineral and Natural Resources Department has jurisdiction over any well drilled as an oil exploration well. Because WIPP has inherited wells from the petroleum industry, groundwater-monitoring activities conducted on such inherited wells are subject to the requirements of the OCD. Similar to the BLM requirements, OCD is required to protect hydrocarbon resources and, thus, has adopted procedures and methods for well completion that must be considered by the WIPP monitoring programs.

3. Current Groundwater Program Elements

3.1 Groundwater Monitoring Network

As described in Section 1, a total of 112 boreholes have been drilled at the WIPP since 1972 when the site selection process was initiated. These boreholes were drilled for a variety of reasons including geologic and hydrologic site characterization, potash resource evaluation, and hydrocarbon exploration. Many of the "non-hydrologic" boreholes were later converted to hydrologic boreholes for use in well testing and groundwater-monitoring surveillance. Those not converted were P&A.

Appendix A provides a comprehensive listing of all boreholes and pertinent information including drilling start/end dates, surface elevations, TDs, formations encountered at TD, completion intervals, and current status. The ground surface elevation in the vicinity of WIPP ranges from approximately 950 to 1,125 meters above mean sea level (amsl). The ground surface elevation is higher to the east and north of the LWA boundary and lower to the west and south of the LWA boundary, particularly in Nash Draw. Borehole depths range from about 17 to more than 1,500 meters bgs depending on the geohydrologic unit targeted in the various investigations. Most of the boreholes were terminated in the upper Salado Formation or shallower units such as the Rustler or Dewey Lake Formations; however several extended below the current repository level of 655 meters bgs with some of these extending into the Castile and Bell Canyon Formations located below the Salado. Figure 3.1 provides a generalized cross-section through the WIPP site with key stratigraphic units identified for reference.

The current status of all WIPP boreholes is shown in Table 3-1. Of the 112 boreholes originally drilled at the site, 71 are currently being used as wells for groundwater monitoring (water quality, water level elevations, and/or water density), 38 have been P&A, and 3 have been turned over to local landowners. The 71 wells are located on 45 well pads (including the 4 locations containing the shallow wells used to monitored water leaking into the exhaust shaft)

Prior to 1989, all wells were drilled and completed using standard oil field technology. That is, steel casing set either to TD or just above the interval of interest and the annulus between the casing and borehole wall cemented back to surface. Hydrologic intervals were then completed by perforating the steel casing and cement in the targeted interval or by deepening the borehole through the targeted interval leaving an open hole below the cemented casing. Wells constructed after 1989 typically use slotted fiberglass screen set on a solid fiberglass casing with gravel and/or sand placed in the screened interval and bentonitic clay or cement placed above the screened interval to isolate it from other water-bearing intervals.

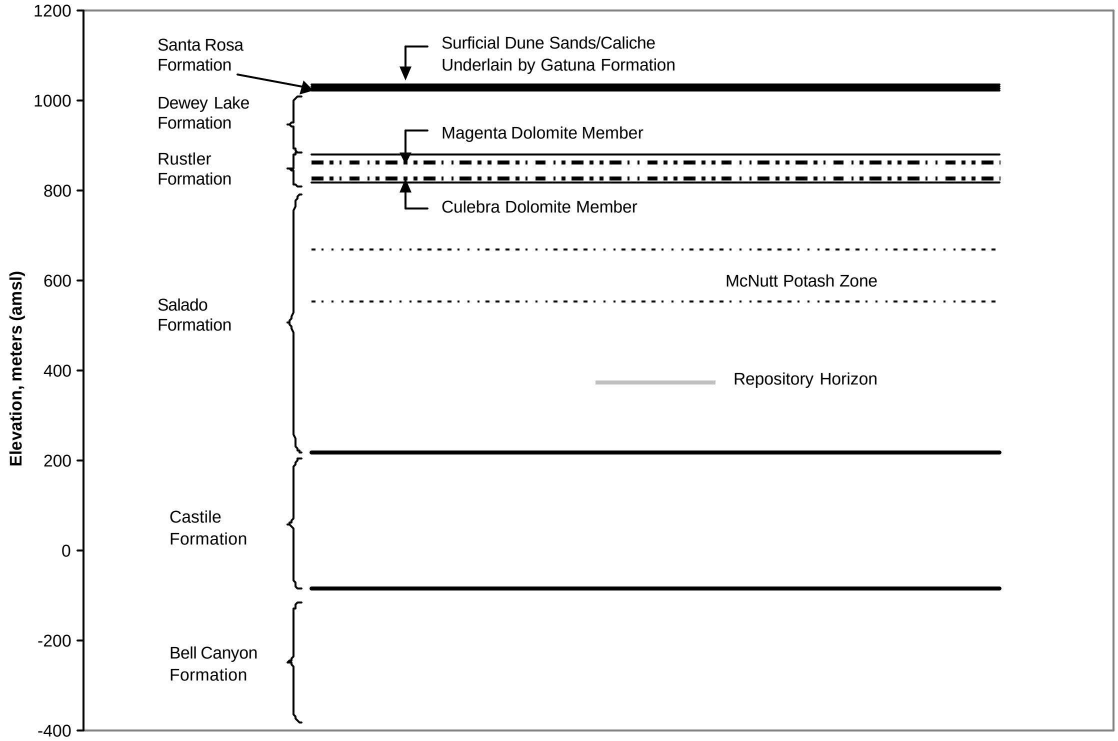

Figure 3.1 Generalized WIPP stratigraphy.

For the most part, only a single hydrologic interval or zone (e.g., Culebra, Magenta, etc) is monitored in an individual well. However, in some cases, a single well is completed to more than one hydrologic interval. Multiple completion intervals in the same well are isolated from one another using bridge plugs, packers and/or PIPs to prevent commingling of groundwater. Over the course of the different monitoring programs, a well may be reconfigured to monitor other hydrologic units while retaining its original completion interval. In these cases, plugs and packers are also used to isolate hydrologic units even though a single interval is being monitored. As shown in Table 3-2, eighty individual water-bearing zones are currently being monitored. Most of the monitoring emphasis is place on the Culebra member of the Rustler Formation because this hydrologic unit is the focal point of the EPA certification and the NMED HWFP and is also the most transmissive, saturated water-bearing zone at the WIPP.

Figures 3.2 and 3.3 show, respectively, the Culebra groundwater-monitoring locations both outside and within the WIPP LWA boundary. The Magenta groundwater-monitoring locations, as well as the monitoring locations of other water-bearing units, are shown in Figures 3.4 and 3.5, respectively. Well-location surveys make use of the State Plane Coordinates, which are on file with the NMOSE.

Table 3.1 Status of Boreholes Drilled at the WIPP

Borehole/Well Status	**Number of Boreholes/Wells**
Plugged and Abandoned (Total)	**38**
Potash Resource Evaluation	17
Geologic	8
Hydrologic	7
Converted Hydrologic[a]	6
Ownership Transferred	**3**
Groundwater Monitoring (Total)	**71[b]**
Single Interval Monitoring	
Santa Rosa/Dewey Lake Contact	4
Dewey Lake	1
Magenta	14
Culebra	44
Rustler/Salado Contact	1
Bell Canyon	1
Multiple Interval Monitoring	
Rustler Magenta and Culebra	3
Dewey Lake and Rustler Forty-niner	1
Rustler Forty-niner, Magenta, Tamarisk, Culebra and Los Medanos	1
Bell Canyon and Rustler Culebra	1
Total Boreholes/Wells	**112**

(a) Includes potash and geologic boreholes that were converted to hydrologic boreholes, and then later P&A.

(b) Located on 45 different well pads.

Table 3.2 Hydrologic Zones Monitored in the Current Groundwater Monitoring Network

Hydrologic Zone	Number of Measurement Zones[(a)]
Rustler Culebra	49
Rustler Magenta	18
Dewey Lake/Santa Rosa Contact	4
Dewey Lake	2
Bell Canyon	2
Rustler Forty-Niner	2
Rustler Tamarisk	1
Rustler Los Medanos	1
Rustler/Salado Contact	1
Total Number of Measurement Zones	**80**

(a) Zones completed in 71 wells located on 45 separate well pads.

3.2 Groundwater Measurements

Measurements of water quality, elevation, and density taken in wells comprising the groundwater-monitoring network described above are incorporated into two compliance-monitoring programs developed to meet the regulatory requirements of the EPA certification and the NMED HWFP found in 40 CFR 191/194 and the NMHWA, respectively. As described in Section 2, the two monitoring programs include the CMP and the DMP. The CMP is implemented through commitments in the CCA, the MIP and various analysis plans and reports, while the DMP is implemented through the DMP Plan included as Module V, Attachment L of the HWFP.

Both the CMP and DMP extract relevant groundwater data from the GMP. The GMP contains two subprograms, the WQSP and WLMP, and was originally developed under the EMP as the Groundwater Surveillance Program (GSP). Water quality, elevation and density measurement practices, defined under the current GMP, are summarized below.

3.2.1 Water Quality Sampling Plan (WQSP)

The current WQSP calls for water quality sampling in only seven wells, three (WQSP-1 through WQSP-3) located north and up-gradient from the WIPP shaft area and four (WQSP-4 through WQSP-6 and WQSP-6a) located south and down-gradient from the shaft area. With the exception of WQSP-6a, all wells identified in the WQSP are completed to the Culebra member of the Rustler Formation. WQSP-6a was completed to the Dewey Lake Formation when a saturated, water-bearing zone was discovered in the Dewey Lake during drilling of WQSP-6.

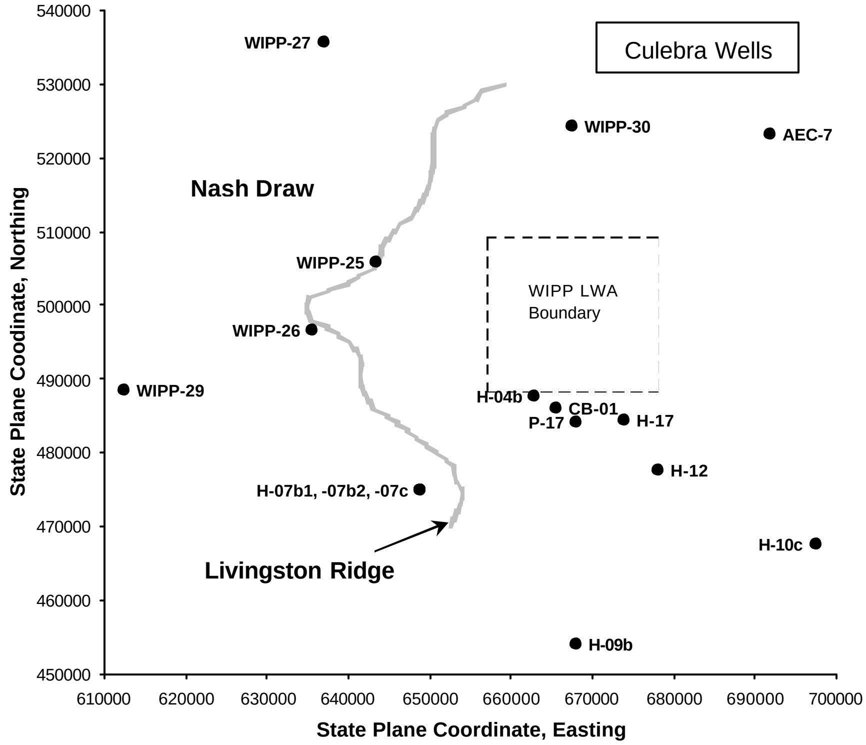

Figure 3.2 Culebra monitoring wells outside the LWA boundary.

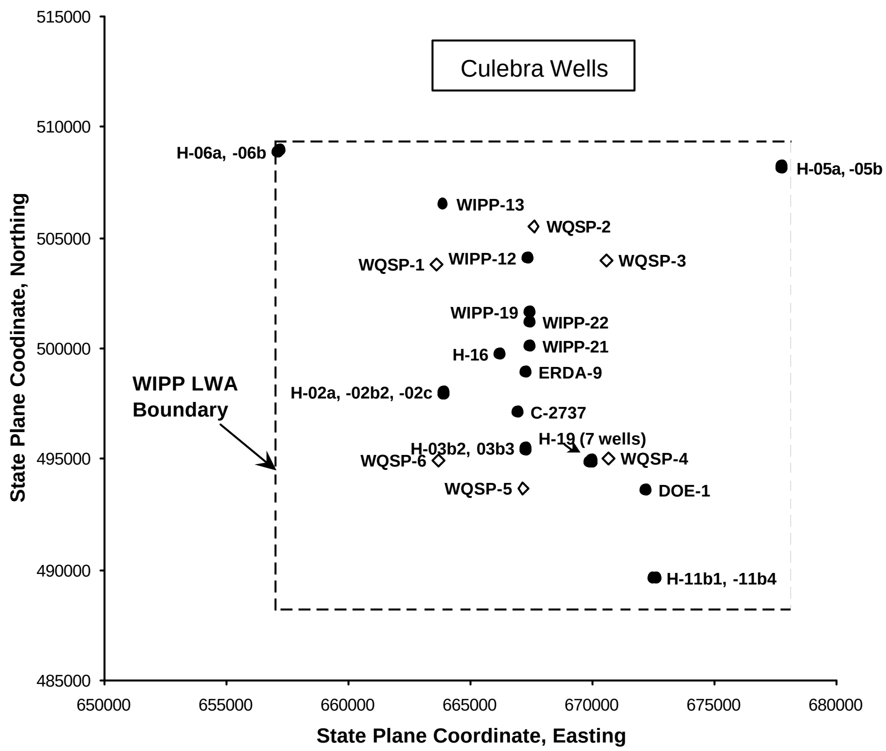

Figure 3.3 Culebra monitoring wells within the LWA boundary.

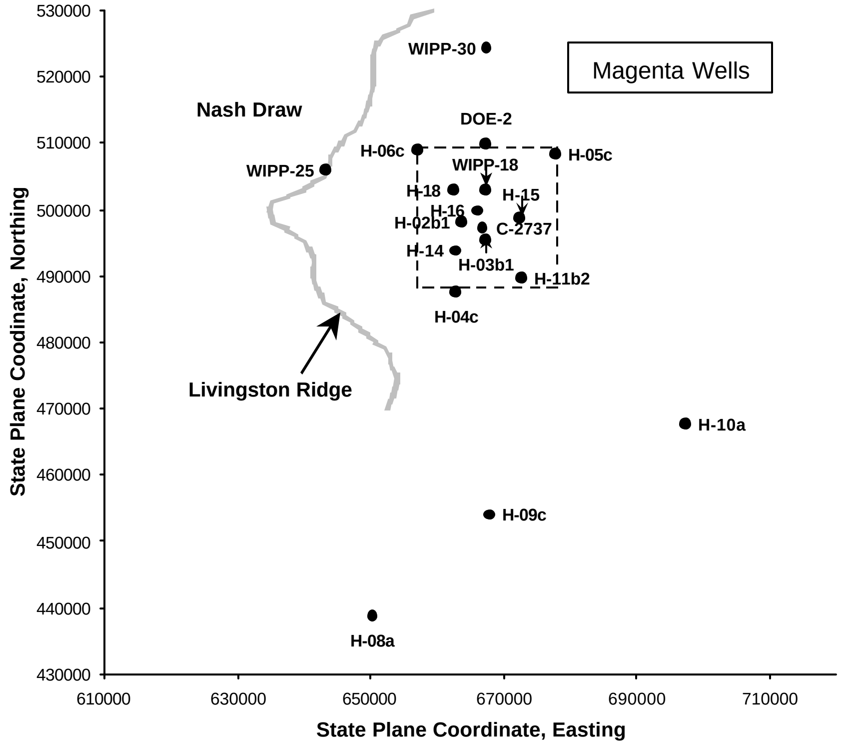

Figure 3.4 Magenta monitoring wells at the WIPP.

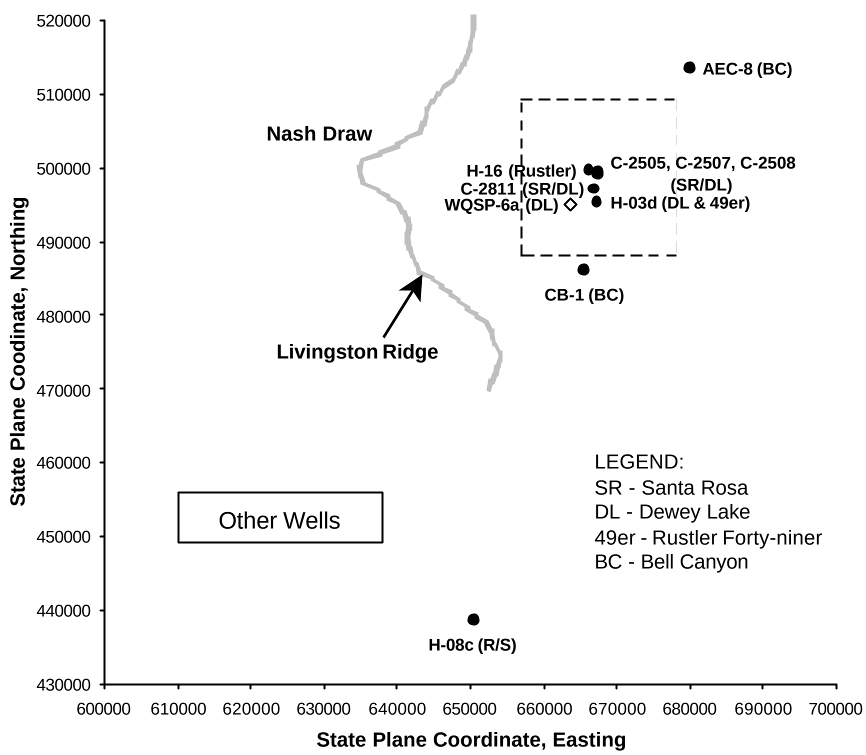

Figure 3.5 Other monitoring wells at the WIPP.

The locations of the seven WQSP wells are shown in Figures 3.3 and 3.5 and were selected to intercept flow vectors entering the WIPP shaft area from the north and exiting the shaft area to the south based on measured potentiometric surfaces and flow model simulations [Mercer, 1983; Davies, 1989]. All seven wells are inside the WIPP LWA boundary. In addition, WQSP-4 was specifically positioned to monitor the zone of higher transmissivity around wells DOE-1 and H-11, which may represent a faster flow path away from the WIPP shaft area to the LWA boundary.

One primary sample and one duplicate sample are collected semi-annually (usually in the Spring and Fall of each calendar year) from each of the seven WQSP wells and analyzed to quantify the current water quality parameters (e.g., pH, density, etc) and chemical constituent concentrations (defined in Module V of the HWFP). The collection of the primary and duplicate samples is termed a "sampling round." The same process was used in the five-year period preceding waste receipt to establish a defensible and accurate background or baseline database [DOE, 1998; IT 2000] consisting of 10 rounds of sampling (20 individual values for each parameter and chemical constituent considering the primary and duplicate samples). Water quality samples are collected using submersible pumps specifically dedicated to the individual wells. The pumps are sized according to expected yield and construction characteristics of the wells.

Two types of sampling, serial and final, are performed during each round. Serial samples are taken at regular intervals of time while a well is being pumped and then analyzed in a mobile field laboratory to determine when the water chemistry has stabilized. Indicator parameters used during serial sampling include temperature, Eh and pH. When the water quality has stabilized to within ± 5 percent of the average of the field indicator parameter measurements, final samples (primary and duplicate) are collected and shipped to an analytical laboratory where the values/concentrations of relevant analytes are determined. Sample collection and analysis are the responsibility of the MOC.

The data collected under the WQSP are evaluated to assess if current water quality is significantly different from the baseline conditions. This assessment requires the use of statistical analysis techniques. The MOC conducts the data assessment required under the HWFP, while the SA conducts similar compliance assessments required under the EPA certification. Water quality data are reported to the DOE/CBFO in the ASER prepared by the MOC. The DOE/CBFO submits the data and the results of the data assessments to the NMED semi-annually (within 60 days of each round of sampling) and to the EPA annually within 30 days of the issuance of the ASER.

3.2.2 Water Level Monitoring Plan (WLMP)

The current WLMP calls for water level measurements in the seven WQSP wells and all of the other wells in the monitoring network shown in Figures 3.2 through 3.5. The WLMP wells are located both within the LWA boundary (DOE jurisdiction) and outside the boundary (BLM jurisdiction). The primary focus of the WLMP is the Culebra member of the Rustler Formation, but water levels are also measured in wells completed to other hydrologic units when access to these units is available[4]. Other units currently monitored include the Santa Rosa/Dewey Lake Contact; Dewey Lake; Forty-niner, Magenta, Tamarisk, and Los Medanos members of the Rustler; Rustler/Salado Contact and the Bell Canyon.

The MOC determines water levels monthly in at least one accessible completed interval at each available well pad and quarterly in redundant wells at well pads with two or more wells completed in the same interval. The monthly and quarterly measurements make use of manually-operated water level sounders. The water level measurements are converted to freshwater equivalent elevations using the density of the water standing in the well. In addition to the manual water level measurements, the SA makes continuous water level measurements to document naturally-occurring and/or artificially high frequency perturbations that are believed to be impacting water levels in some wells. Continuous measurements are made using a Troll (electronic pressure transducer) that is set at a specified depth below the water level in a well. The Troll measures the fluid pressure represented by the hydraulic head of the column of water above the transducer. Changes in water level are manifested in changes in fluid pressure. Measured pressures are subsequently converted to freshwater equivalent elevations using the well-specific fluid density.

Groundwater level measurements are made primarily to examine changes in flow rate and direction across the WIPP for use in assessing compliance with relevant regulatory requirements. The measurements also extend the historical record of groundwater surface elevation fluctuations documented for various water-bearing zones and provide:

- Means to comply with future groundwater monitoring regulations.
- Input for making land use decisions, (i.e., designing long-term active and passive institutional controls for the site).
- Understanding of changes to readings from the water-pressure transducers installed in each of the shafts to monitor water conditions behind the liners.
- Understanding of whether or not the horizontal and vertical gradients of flow are changing over time.

Groundwater surface elevation monitoring will continue through the operational phase of WIPP and is also required during the post-closure period following operation.

The data collected under the WLMP are reported by the MOC in the ASER and also in monthly status reports. Included with the ASER is a determination of flow rate and direction for groundwater moving through the Culebra. The SA uses the water level data collected and reported by the MOC to conduct an annual COMPs assessment as described in Section 2. This assessment fulfills the requirements of the EPA certification and compares current water level measurements with defined trigger values to determine if water levels are consistent with performance expectations documented in the CCA baseline.

[4] The term access is not defined in the upper-tier or implementing drivers but is assumed to mean where wells and completion intervals are available.

3.2.3 Pressure-Density Surveys

Naturally occurring groundwater in the Culebra Member of the Rustler Formation (as well as other water-bearing units) exhibits highly variable total dissolved solids (TDS) concentrations across the WIPP site area. The localized-area changes in TDS concentration are reflected in a commensurate variability in formation fluid density. At WIPP, groundwater levels are typically expressed as equivalent freshwater head values. These values are calculated using the actual measured water level, adjusted for the specific formation fluid density defined at the particular monitoring well location. These adjusted water levels allow more accurate determination of groundwater-flow directions and gradients.

Many of the WIPP water-level-monitoring wells were constructed with open-hole completion intervals or were drilled through the Culebra into the Los Medanos Member of the Rustler Formation. Also, many wells have been pumped, reconditioned, or have been reconfigured at some point in their existence. These various activities have often resulted in the density of well-bore fluids not being representative of or equal to that found in the surrounding water-bearing formation. Therefore, fluid densities defined from past sampling activities may not be representative of what exists in the well-bore today.

The Pressure-Density (P-D) Survey was developed to accurately measure the density of the fluid now standing in the WLMP wells. As discussed above, determining well-bore fluid density is necessary to correct water level measurements so groundwater flow directions and gradients can be accurately defined. Regulatory requirements dictate that the P-D Survey be conducted at least once each year.

These surveys are conducted using a trailer-mounted cable-reel assembly, containing 335 meters of digital insulated cable. A highly accurate pressure-transducer probe is attached to the cable and lowered into the well. Pressure measurements are made at several different levels between the standing water level and the mid-formation depth to assess fluid density stratification should it exist. Fluid density values are calculated for each interval using the measured pressure that was exerted by the water standing above the probe at each measuring point. These individual density values are then combined to determine an average density for the fluid standing in the well-bore.

Some wells are completed in more than one hydrologic interval (e.g., Culebra and Magenta). In these wells, the completion intervals are isolated from one another using bridge plugs and/or PIPs to prevent commingling of formation waters from the different units. Depending on the configuration of the well, the P-D surveys are then performed either in the tubing that is connected directly to a down-hole PIP or in the annulus between the tubing and the well casing.

MOC staff routinely performs P-D surveys on approximately 35 wells per year. Thus, all 71 wells can be surveyed over the course of a two-year period unless the P-D equipment cannot physically be installed in a well because of space limitations or obstructions.

Additional wells may be incorporated into the program by request or as needed for special programs and research activities.

3.2.4 Injection Well Monitoring

Several petroleum companies have drilled and completed deep brine injection wells into the Bell Canyon Formation near the WIPP site. These wells are used both for brine disposal and for secondary recovery of hydrocarbons. WIPP stakeholders have suggested that these brine injection wells are hydraulically connected to Culebra groundwater, particularly south of the WIPP LWA boundary near the H-9 well pad, causing water levels to fluctuate erratically. The hydraulic connection could be occurring directly through leaking injection wells or indirectly through other production wells completed to the Bell Canyon in this area.

Because of the potential for a hydraulic connection between the injection wells and the Culebra, the DOE directed the MOC to initiate monitoring of injection wells near the WIPP. Wells selected for monitoring included 6 wells located south of the WIPP site near the H-9 well pad and other injection wells located northeast of the WIPP site. Currently, only the six wells near the H-9 hydropad are being monitoring. As shown in Figure 3.6, the six injection wells are located approximately 1.5 to 3 miles north and east of the H-9 well pad. In five of the injection wells (i.e., Cal Mon #5, Sand Dunes 28 #1, Todd 26 Federal #2, Todd 26 Federal #3, and Todd 27 Federal #16), the Bell Canyon injection interval lies between 1,300 and 1,850 meters bgs, while in the sixth well (Pure Gold B Federal #20) the injection interval lies between 2,360 and 2,370 meters bgs. The MOC collects data from the six wells approximately daily except for weekends and holidays. The data include total cumulative injection volume as read on the injection meter for each well, well injection pressure, and the date and time each meter was read.

The DOE has directed the SA to evaluate the injection data and to assess the potential for hydraulic connection between the Culebra groundwater and the injection wells. This evaluation/assessment process is on-going and is expected to continue for at least 3 to 5 years.

3.3 Well Maintenance and Replacement

3.3.1 Well Logging and Integrity Testing

Many of the wells in the WIPP monitoring network are more than 20 years old and have received only routine maintenance (e.g. scraping and cleaning) over the years. As discussed in Section 1, the wells constructed before 1989 used technology and materials available at the time of completion (i.e., carbon steel casing cemented directly into the well bore). This type of well configuration is expected to corrode and deteriorate when continuously exposed to the harsh brine waters indicative of WIPP well bores. Evidence of such corrosion and deterioration was acquired during recent re-entry of several of the oldest WIPP wells. The conditions of these older wells raise at least two concerns:

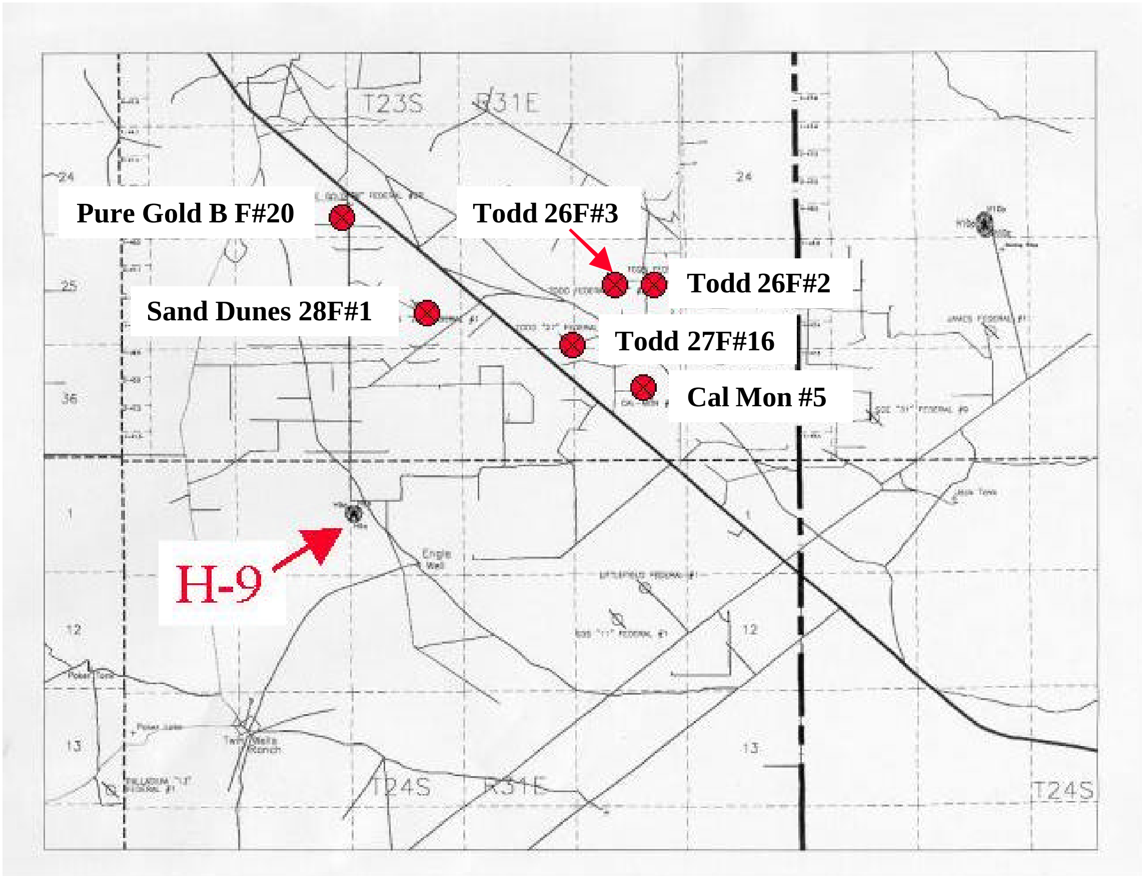

Figure 3.6 Brine injection monitoring wells located near the H-9 well pad.

1. Well casings that leak because of structural problems or corrosion could allow commingling of waters from different formations or infiltration of rainfall traveling along and through the casing, which is a violation of 72 NMSA 13-1-12 adjudicated by the NMOSE.
2. Commingling of formation waters creates the impression of water-level changes that are interpreted as altered flow rates and flow directions.

Based on the evidence gathered to date, the DOE has directed and the MOC is implementing a systematic well logging and integrity-testing program. Testing directed by the MOC has been initiated for all of the wells in the network to assess the condition of each well and to determine if data acquired from individual wells are useful and representative of actual conditions of the groundwater. Current plans are to test approximately 20 wells per year.

The integrity testing makes use of various wireline technologies and ultrasonic imaging USI) tools to accurately determine both casing and cement quality in the wells. The USI tool employs a rotating sub that allows full 360-degree coverage of the casing being inspected. The rotating sub uses an ultrasonic transducer that acts as both a transmitter and a receiver. This transducer produces a short pulse of acoustic energy and receives an echo from the casing, cement and geologic formation adjacent to the well. By analyzing the echo, the quality of the cement behind the casing and the internal and external corrosion of the casing can be determined.

3.3.2 Well Plugging and Abandonment Program

Of the 112 boreholes drilled at the WIPP site to date, 38 have been P&A including several used as wells for hydrologic monitoring. Eventually, all wells in the current (or any future) monitoring network will need to be plugged sometime during the pre- or post-closure phases of the WIPP. Current plans call for the P&A of 8 shallow wells and 1 deep well per year until all of the steel-cased wells have been P&A. Shallow wells are defined as wells that have a TD that extends to the top of the Salado or shallower, while deep wells are those that have a TD that extends below the repository horizon.

A plan for the P&A of all steel-cased wells has been developed using a priority system [Richardson and Crawley, 1999]. The plan groups the wells into three categories based on various criteria including health and safety factors, the need for the well in the monitoring network, the age and condition of the well, regulatory concerns, and availability of resources. Wells in the first group will receive the highest priority for P&A because they represent deteriorating well conditions or data redundancy. Wells in the second group will also be P&A, but the P&A activities may be delayed because of their lower priority. The wells in the third group are those that, with proper maintenance, can remain in the network as currently configured for up to 5 years and perhaps longer; however, some of these wells may also be P&A if problems should arise or if useful data can no longer be obtained or is no longer needed.

P&A protocols are based on requirements established by the NMOSE, which has primacy over all groundwater in the State of New Mexico. For wells on lands owned by the BLM, duplicate notification and requests for authorization to plug and abandon wells are provided as a courtesy. The NMOSE may, at its discretion, overrule federal agencies whose policies fail to meet the stringent requirements for the protection of New Mexico's groundwater.

When plugging a well, isolation of groundwater-bearing intervals is mandated by 72 NMSA 12-1-28 and 72 NMSA 13-1-12. Additionally, within a well bore, commingling of waters from different geological intervals is forbidden. Therefore, minimum standards require cementing these intervals to prevent commingling. If well logs (i.e., developed from the USI testing described above) indicate failure or inadequate bonding by the backside cement, the casing in the well is pulled prior to cementing the well. If the logs indicate good cement behind the casing, the casing is left in the hole and filled with cement from bottom hole to surface. Cementing the well with a continuous plug from bottom hole to surface exceeds NMOSE requirements for placing cement plugs only through the water bearing intervals.

After the well is plugged, a monument is erected with the name of the well, a legal description of the location and the NMOSE file number etched or welded on the surface of the monument. Subsequently, the location and any dedicated access road(s) are reclaimed.

Although the "B" holes drilled at the WIPP site to investigate building foundation conditions are not considered wells, these holes are not currently part of any on-going program at the WIPP and are, therefore, considered orphaned holes. These orphaned holes could potentially allow surface water to recharge the WIPP hydrologic system, particularly the Santa Rosa and Dewey Lake Formations and so will be P&A under this strategic plan. A protocol will be developed and followed to identify, locate and P&A all existing B holes, knowing that some holes may be under existing buildings or pavements.

3.3.3 Replacement Wells

In 2000 and for some period of time earlier, the Culebra water level measurements in Well H-1 became erratic triggering an investigation into the cause. Holes were discovered in the well casing at depths of approximately 12 meters permitting shallow water to enter the well and commingle with the Culebra water in the well. In 2001, the DOE directed the MOC to P&A the well and to replace it with a new well, C-2737; however, the problems observed in H-1 were considered endemic of other wells constructed with cemented steel casing.

To investigate the condition of other wells, the MOC initiated the USI testing and logging program described above. As expected, other wells in the groundwater-monitoring network are showing similar signs of age including casing corrosion and poor cement bonds between both the casing and cement and the formation and cement. Using the preliminary results from the well logging and integrity testing investigations, the DOE forecasts that all cemented steel cased wells within the current monitoring network will likely need to be removed from the network and P&A within the next 5 to 7 years under the P&A program.

The EPA certification and the NMED HWFP both require monitoring of groundwater levels within and around the WIPP LWA boundary. In particular, water levels in the Culebra must be monitored and water levels in the Dewey Lake, Forty-niner, Magenta and Bell Canyon must also be monitored where access is available. The EPA certification, through incorporation of the requirements found in Appendix EMP of the CCA, has identified 46 locations for groundwater monitoring, while the DMP of the HWFP has identified 32 locations (all included in the EMP).

Taking into consideration the compliance monitoring requirements and the condition of existing wells, the DOE recognizes that replacement wells (both Culebra and those required to monitor other water-bearing zones) will need to be drilled and completed as cemented steel-cased wells are P&A and removed from the network. Because of the inconsistency that exists between the numbers of monitoring locations identified in the DMP and EMP, the number and physical location of replacement wells required for compliance is unspecific. The DOE has addressed the issue of replacement wells by directing the integrated groundwater team (IGWT) to conduct an evaluation focused on the following issues:

- Need and condition of each well in the current network
- Current and future requirements for monitoring
- Optimal location of replacement wells
- Costs for maintenance of aging wells and drilling of new wells.

As discussed in Section 7, the IGWT comprises staff members from each of the major WIPP project participants including the DOE, MOC, SA and CTAC. Based on the evaluation, the IGWT will develop and implement a replacement well program plan that addresses numbers of wells and locations, completion interval, and replacement schedule.

3.4 Investigative Studies

Investigative studies may be required at any time during the groundwater monitoring program to address compliance issues, regulator/stakeholder concerns, or operational and safety issues. When such studies are identified, the DOE directs the development of appropriate test and analysis plans and procedures through either the MOC or the SA. Two investigative studies are currently being implemented as follows:

- Culebra water level rise investigation (implemented by the SA)
- Exhaust shaft hydraulic assessment investigation (implemented by the MOC)

The Culebra water level rise investigation was prompted when the SA determined during its most recent COMPs assessment [SNL, 2000b] that water levels in many of the Culebra wells in and around the WIPP LWA boundary were outside the trigger value ranges established for them. As required by the CMP, a study was required to determine the impact of the condition on repository performance even if the observed condition does not or is not expected to affect repository compliance. The exhaust shaft hydraulic assessment investigation focuses on perched shallow water that is leaking into the exhaust shaft and is considered an operational issue.

The activities initiated and planned for both the Culebra and exhaust shaft hydraulic assessment investigations are summarized below under separate headings.

3.4.1 Culebra Water Level Rise Investigation

Groundwater flow in the Culebra was modeled in the CCA using a set of transmissivity (T) fields and appropriate boundary conditions (heads) for the model domain. The T-fields were interpolated from iterative simulations using the "point" values of transmissivity measured from well tests and water-level measurements made at 32 well locations within the modeling domain (a few wells in the domain were not included because they were sufficiently close to those wells used in the modeling and, therefore, represented redundancy). In this process, the simulated T-fields were adjusted from model run to model run until the simulated heads fell within the error ranges estimated for each of the 32 wells where water-level measurements were available

As noted in Section 2, the error ranges of the measured hydraulic heads are now used as trigger values for the assessment of the Culebra groundwater flow COMP conducted annually as required by the CMP. Water levels falling outside the TVs could indicate:

- Well casing or packer failure allowing water to enter the Culebra interval from another interval (geohydrologic unit).
- Human activities, such as pumping or circulation losses during drilling of nearby wells, affecting the water levels in the Culebra wells.
- Errors in the undisturbed heads estimated for the CCA simulations.
- Errors in the conceptual model for the Culebra.

Although some of these indicators could impact compliance (e.g., errors in conceptual models), others likely would not. Regardless of the reason that TVs are exceeded, investigative studies are required to determine the cause of the changed condition and to assess the impact of such change on CCA assumptions.

One such investigative plan [SNL, 2001] is currently in place in response to the most recent COMPs assessment report [SNL, 2000b] submitted to the DOE by the SA. This recent report identified that freshwater head levels in 23 of the 32 Culebra wells used in the CCA simulations appeared to be outside the TV ranges. The head levels in two of these 23 wells can be explained by re-completion activities that introduced foreign fluids into the wells. No similar argument could be made for the water levels in the remaining 21 wells; however for 13 of these remaining 21 wells, freshwater heads could be within the CCA ranges if a lower fluid density than that measured in a 1989 survey was used to convert the measured water levels to freshwater heads. For the remaining eight wells, the freshwater heads exceed the CCA ranges for any reasonable value of well fluid density so these head levels as well as the 13 head levels that could possibly be explained by lower fluid densities triggered the need for further investigation.

The investigative plan [Sandia, 2001] developed to evaluate the changing water levels in the Culebra comprises the following:

- Compile information on events or processes that give a likely explanation for water levels and their changes including temporal and spatial resolution that complement Culebra water level data.
- Refine scenarios and hypotheses about events or processes that may explain the current trends in Culebra water levels and develop approaches for testing that validate or refute these scenarios and hypotheses.
- Apply sensitivity analyses to selected data, as appropriate, to determine if the data are useful in examining scenarios and testing hypotheses.

- Apply analytical or numerical modeling techniques or other means of using water levels and available information to eliminate or bound scenarios and hypotheses relevant to Culebra water levels.
- Summarize the prevailing understanding of the process(es) and events affecting the Culebra hydraulic system, as they are manifest in water levels.
- Re-evaluate Culebra water level ranges or the practicality of performing such a re-evaluation.

These studies are the responsibility of the SA as directed by the DOE. In addition, the MOC is supporting the effort by (1) assessing the condition of the wells in the monitoring network through well logging and integrity testing, (2) conducting pressure-density surveys of the waters in the wells of the monitoring network, (3) plugging and abandoning problematic wells as directed by the DOE, and (4) installing replacement and new wells for monitoring as recommended by the SA and directed by the DOE.

Activities specifically identified to support the Culebra investigations include:

- Installation of new wells completed in the Rustler (primarily the Culebra and Magenta dolomite members) and shallower formations (e.g., Dewey Lake)
- Installation of new deep wells completed to the Bell Canyon Formation
- Well testing in and analysis of test data from all new wells
- Development of a Magenta flow model for use in scenario testing
- Geological and geophysical logging using electromagnetics
- Re-assessment of previous well test results using new computational tools to obtain new field T estimates and their uncertainties
- Culebra flow modeling
- Re-assessment of the existing Culebra flow modeling, and possibly development of a new model.

3.4.2 Exhaust Shaft Hydraulic Assessment Program

The Exhaust Shaft Hydraulic Assessment Program was initiated in September 1996 to investigate the source and extent of water seeping into the Exhaust Shaft at the WIPP [DOE, 1997a, 1997b, 2000]. Investigations observed a shallow perched groundwater horizon found in a saturated layer within the lower Santa Rosa perched on the upper Dewey Lake Formation, about 10 to 20 meters below ground surface. During the original drilling of the shaft no water was encountered at that horizon indicating that the presence of water may be related to site activities. Three wells and twelve piezometers were installed over an 80-acre area between September 1996 and July 1997. Water-level and water-quality parameters have been monitored and reported on a regular basis since then. Water-level data indicate a potentiometric high in the northwestern portion of the site near the Salt Water Evaporation Pond. Analysis of samples collected from the monitoring network reveal TDS values ranging from about 2,400 to 130,000 mg/L.

In March 2001, the MOC drilled and installed well C-2737 as a replacement well for H-1 monitoring the Culebra and Magenta dolomite members of the Rustler Formation. C-

2737 is located approximately 800 meters south of the Exhaust Shaft. During drilling fluid was intercepted at a depth of about 19 meters below ground surface, in the upper 6 meters of the Dewey Lake Formation. As a result, a piezometer C-2811 was installed to monitor fluid level and water quality at this horizon. Water-quality samples collected from C-2811 show TDS values of about 2,600 mg/L. The relative proportions of major ion-constituents are similar to that of well C-2507 located 60 meters south of the Exhaust Shaft.

Water-level and water-chemistry data suggest that fluid from the WIPP may extend beyond the immediate site area. But, since the data are insufficient and inconclusive, the assessment program will be continued to further investigate shallow water conditions. The purposes for the continued efforts are: to define the localized-area extent of the fluid in the Santa Rosa/ Dewey Lake Formation; to characterize its water chemistry; to assess current conditions; and, to predict future conditions that might impact WIPP operations. These efforts will likely require the installation of additional wells/piezometers, well testing and analysis, electromagnetic surveys, and flow modeling. Field investigations, including well/piezometer installation, will be directed by the MOC, while the well testing and analysis and flow modeling will directed by the SA.

3.5 Plan Schedules

The current groundwater-monitoring program contains baseline activities (e.g., compliance monitoring and reporting) that will continue through the operational and closure phases of the WIPP and short-term activities (e.g., P&A, replacement and new well construction, and investigative studies) that are expected to be completed within 5 to 7 years, depending on funding levels and assuming:

- USI logging at a rate of 20 per year
- P&A of existing steel-cased wells at a rate of 8 per year
- P&A one deep (> 655 meters) well per year
- Replacement wells will be constructed at 3 locations per year on existing well pads with an average of 2 wells per location (total of 6 replacement wells per year)
- New wells will be constructed at 4 locations per year on new well pads with an average of 2 wells per location (total of 8 new wells per year)
- Replacement and new wells will be tested and the data analyzed within one year following construction

4. Links Between Drivers and the Current Groundwater Program Elements

The links between regulatory drivers and the elements of the current groundwater-monitoring program are shown in Table 4.1. Drivers are subdivided into upper-tier requirements and implementing requirements/documents. The primary program elements include the measurements of Culebra groundwater quality and water levels and the assessment of geohydrologic compliance parameters against performance criteria. Ancillary elements (e.g., well maintenance and replacement) support these primary elements by ensuring the well network provides reliable, accurate information for use in assessments, analyses, and other interpretations relative to groundwater issues and the performance of the WIPP. Investigative studies may be linked to potential compliance issues (e.g., Culebra water level rises) or may merely address operation concerns (e.g., shallow water leaking into the exhaust shaft).

5. Strategic Objectives

5.1 Program Goal

The primary goal of the groundwater strategy is to maintain compliance with the governing regulations. The secondary goal is to improve the effectiveness and efficiency of the current groundwater program within the context of regulatory compliance. The strategy of the groundwater-monitoring program is to (1) use the current program elements to maintain continued compliance with the governing regulations (including analyses of the geohydrologic system to explain change conditions such as the Culebra water levels) and (2) implement a new program element designed to examine systematically the effectiveness of the current program (including available data and relevant information) and to document a plan for a more efficient groundwater monitoring system. The basic groundwater strategy must address three issues that include:

- Compliance
- Monitoring Effectiveness and Efficiencies
- Operational needs

5.1.1 Address Compliance

The governing requirements for the groundwater program are outlined in Section 2.0. The WIPP has developed a groundwater program that has been approved by the various regulatory authorities and has been implemented well before the first waste was received. Therefore, the basic strategy to achieve the first goal of continued compliance with all regulatory requirements is to use and operate under the current proven program elements outlined in Section 3.0.

The groundwater program strategy must also address long-term compliance issues related to the current monitoring program. Important factors that will impact the current groundwater system include, but are not limited to, time, well degradation, unexpected groundwater data fluctuation or results, well maintenance, manpower availability, budgets and changes to existing and out-year related regulatory requirements or implementation of new requirements. For the current program to continue to meet the compliance goal, existing program elements must be continued and additional program elements must be developed to address other long-term factors (e.g., plans to address new regulatory requirements as they arise).

Table 4.3 Links Between Regulatory Drivers and Groundwater-Monitoring Program Elements

Program Element	Element Drivers	
	Upper-Tier	**Implementing**
Culebra Groundwater Measurements		
Water quality	• 40 CFR 191/194 • NMHWA	• CCA Certification &CMP (including MIP, EMP, GMP & WQSP) • WIPP HWFP (including DMP, Site Closure Plan, Site Post-Closure Plan)
Water levels & flow directions	• 40 CFR 191/194 • NMHWA	• CCA Certification & CMP (including MIP, EMP, GMP,& WLMP) • WIPP HWFP (including DMP, Site Closure Plan, Site Post-Closure Plan)
Pressure-density[(a)]	• 40 CFR 191/194 • NMHWA	• CCA Certification & CMP (including MIP, EMP, GMP & WLMP) • WIPP HWFP (including DMP, Site Closure Plan, Site Post-Closure Plan)
Well Maintenance and Replacement		
Well logging and integrity testing	• 40 CFR 191/194 • NMHWA	• CCA Certification & CMP (including MIP, EMP, &GMP) • WIPP HWFP (including DMP, Site Closure Plan, Site Post-Closure Plan) • 72 NMSA 12-1-28
Well plugging and abandonment	• 40 CFR 191/194 • NMHWA	• CCA Certification & CMP (including MIP, EMP &GMP) • WIPP HWFP (including DMP, Site Closure Plan, Site Post-Closure Plan) • 72 NMSA 12-1-28, 72 NMSA 13-1-12
Replacement and new wells	• 40 CFR 191/194 • NMHWA	• CCA Certification & CMP (including MIP, EMP, &GMP) • WIPP HWFP (including DMP, Site Closure Plan, Site Post-Closure Plan) • 72 NMSA 12-1-28, 72 NMSA 13-1-12
Investigative Studies		
Culebra Water Level Rise Investigation	• 40 CFR 191/194 • NMHWA	• CCA Certification & CMP (including MIP) • WIPP HWFP (including DMP)
Exhaust Shaft Hydraulic Assessment Investigation	Not applicable. Considered an operations issue.	Not applicable. Considered an operational issue.

(a) Element required to interpret freshwater-head and flow-direction data.

5.1.2 Address Program Effectiveness and Efficiencies

All long-term programs, such as groundwater monitoring, must be reassessed periodically to determine if the current programs are implemented in the most effective and efficient manner. Additionally, programs that routinely experience change must periodically be assessed to evaluate the complementary impacts of all changes. This groundwater monitoring strategy includes elements to periodically reassess the program and to take advantage of changes such that efficiencies can be implemented and effectiveness improved. Examples include implementing automated groundwater monitoring systems during well maintenance or construction.

The strategy is to implement efficiencies throughout the lifetime of the groundwater program. The efficiencies that are to be addressed by the program include:

- Improvement of well integrity/longevity
- Assurance of data relevance and quality
- Minimization of network requirements (optimize well locations based on data relevance/needs)
- Advancements in data collection techniques
- Improvement of well design and related practices
- Recognition and resolution of long-term issues

5.1.3 Operational Needs

Operational concerns are issues that arise from the day-to-day operation of the site and that are not generally tied to regulatory drivers. An example of an ongoing operational concern includes determining the nature and origin of water leaking into the WIPP exhaust shaft. The groundwater program strategy must be capable of addressing similar operational issues as well as current and unknown future concerns. To accomplish this within the groundwater-monitoring program, the strategy must include an element that deals with operational issues. This program element must be able to determine the data needs of the operational concerns, plan and implement activities that are intended to provide additional information relating to the concerns, and implement the plan.

5.2 Program Strategy

The basis of the groundwater monitoring strategy is to meet the program goals of maintaining regulatory compliance and implementing monitoring efficiencies. To achieve these goals, the strategy addresses three issues specifically relating to (1) compliance, (2) efficiencies, and (3) operational needs. The strategy will be implemented, reviewed periodically, and revised as appropriate by an Integrated Groundwater Team (IGWT) composed of personnel from the DOE, MOC, and SA. Other responsibilities of the IGWT are described below under a separate heading.

The basic strategy for the groundwater monitoring program is to use the current operational elements, wherever possible, to maintain compliance with all regulatory drivers. Elements specifically incorporated into this strategy include the continued monitoring of water levels and groundwater quality, subsequent reporting of data per the regulatory requirements, and assessment of COMPs against the CCA baseline. Other elements included with the current program but not yet fully implemented include well logging and integrity testing, plugging and abandonment of older wells as needed, and the planning for new and replacement wells. These well maintenance and replacement elements as well as investigative studies, such as the examination of changes in Culebra water levels and perched shallow water, will provide information for guiding the future strategy of the groundwater-monitoring program and for identifying potential efficiencies. The current monitoring program also contains elements to address most unexpected results that may be acquired during the operational and post-closure phases. These elements are incorporated into this strategy.

In addition to maintaining the elements of the current groundwater-monitoring program, the strategy calls for new program elements to address efficiencies and evaluate effectiveness by first collecting relevant well and groundwater information, and then using formal assessments to determine the appropriate recommendations for incorporating these efficiencies and ensuring effectiveness. The program elements shall outline, in formal investigative plans, information and data needs and the assessments that shall be used to generate the necessary information to justify implementation of the efficiencies to the DOE, regulators, and the public. Formal reports shall be generated to document the results of these assessments and appropriate QA processes shall be applied. Areas to be addressed within this strategy include:

- Integrity – Determine the current integrity of the well network as well as the factors that impact integrity.
- Optimal Well Network – Determine the most efficient number and locations of wells in the network based on data needs, current well placement, and longevity estimates.
- Data Necessity – Determine the actual data needs and end uses for the data. Ensure that the actual data are appropriate for the end use and re-align the monitoring programs with the data needs. Data needs may change throughout the program because of changes in requirements and/or unexpected site conditions.
- Data Acquisition Efficiencies – Investigate and implement, as appropriate, new methods and equipment for acquiring relevant data. Examples include optimization of data sampling frequencies and automation of measurements, data logging, and data transmission.
- Plugging and Abandonment Efficiencies – Investigate and implement, as appropriate, new techniques, materials, and planning schemes for final P&A of old and obsolete wells.

The IGWT is responsible for planning, assessment, and implementation of appropriate efficiencies identified under the strategy.

Undoubtedly, operational concerns and unplanned/unexpected conditions outside of the current monitoring program will arise. The strategy outlined in this plan will address operational concerns and unexpected conditions as they occur through a formal review and assessment process conducted by the IGWT. The IGWT or its designee shall prepare reports that document the concerns/problems, offer alternative solutions and make recommendations for issue resolution.

5.2.1 Integrated Groundwater Team – Program Oversight

The IGWT is responsible for oversight of the WIPP groundwater-monitoring program and, as such, shall ensure communication between the project participants and authorize all related activities. The IGWT shall be responsible for (1) planning and documenting the results of all assessments that are used to justify changes to the groundwater program, (2) monitoring and/or reporting functions, (3) communicating to DOE management recommendations for changes to the groundwater program, efficiencies and unplanned/out of scope issues, and (4) interfacing with the MOC permitting department to incorporate changes to monitoring requirements stemming from any permit modifications.

5.2.2 Groundwater Program Tasks

The groundwater program strategy calls for the IGWT to oversee the program and therefore to be responsible for specific program tasks needed to achieve the program's goals. The tasks associated with these goals entail planning, scheduling, collecting necessary data and information, and performing formal assessments with the collected information. The basic tasks to be addressed by the IGWT are as follows:

- Determine the nature, scope and availability of existing information and past assessments
  Examples of data and information include:
    - Well integrity testing data
    - Monitoring data
    - Pressure-density survey data
    - Geological and topographical evaluations
    - Hydrologic data
- Evaluate data necessity, check the efficiency of the existing programs, and integrate and streamline the existing programs
- Determine needed assessments, prioritize their implementation, acquire program authorization and budget, communicate short-term schedule (authorized assessments)
- Develop long-term schedules of groundwater activities (assessments, monitoring, maintenance, plugging and abandonment, new well drilling, etc)
- Determine the scope for each planned formal assessment
  Assessments may include:
    - Well Condition
    - Well Optimization

  - Sampling Efficiencies
  - Plugging and Abandonment
  - Cost efficiencies
- Determine what additional data are necessary for the planned assessments
- Develop planning documents for each assessment
- Implement the planned assessments per the project schedule and in accordance with applicable regulations

6. Implementation

The IGWT shall be responsible for implementing the groundwater program strategy outlined in Section 5.0. As stated previously, the current groundwater programs maintain compliance with the regulatory requirements and shall continue to fulfill this role. This section describes in more detail how the current programs are used and how the other elements of the strategy are implemented to incorporate efficiencies and other operational considerations.

6.1 Programs Used to Maintain Compliance

6.1.1 Certifications/Permits and Other Regulatory Requirements

The MOC is responsible for acquiring and maintaining all permits applicable to the groundwater-monitoring program. Specifically, the MOC must maintain compliance with the HWFP requirements for groundwater monitoring, EPA requirements for groundwater monitoring, state permits for well drilling and workovers, and BLM concurrence for well activities. In addition, the MOC is responsible for other permitting/approval activities including those needed to perform well work such as right-of-way, ponds, pits and disposal activities. These activities are detailed in the LMP [DOE, 1993] and the Groundwater Monitoring Plan (GMP).

6.1.2 Monitoring

This work scope includes activities to monitor both groundwater composition and water level at the WQSP wells for NMED and EPA. The MOC is responsible for all activities relating to the groundwater data generation. The work scope for groundwater monitoring includes all activities for records, training and QA. The groundwater data collection activities are described previously in Section 3.0. For the groundwater COMPs, the SA is responsible for assessing the data and comparing the results against PA expectation. The SA has also determined appropriate TVs for the COMPs such that the project can identify conditions that are unexpected or that may lead to an out-of-compliance condition before they may occur.

6.1.3 Reporting

Major reporting requirements for the groundwater-monitoring program are documented in the DOE's Reporting Implementation Plan [DOE, 1999a]. In monitoring for the NMED HWFP, the GMP (including the WQSP and WLMP) generates the information for DOE to report biannual groundwater composition analysis results. Groundwater level information is also reported to determine changes in groundwater flow. In monitoring for the EPA Certification, the SA assesses data from the MOC's WQSP and WLMP to derive the COMPs for changes in groundwater composition and flow. These parameters are reported to the DOE for inclusion in the 40 CFR 194.4(b)(4) report. The general reporting strategy is to gather and assess the data as they are generated and to report to DOE any anomalous conditions.

Both the HWFP and EPA Certification reporting plans use the same data that is acquired by the MOC under the GMP (section 6.1.1); however, the use of the same data is for different reasons. The HWFP reporting program is modeled after the RCRA groundwater monitoring requirements for shallow landfills that include establishing baseline conditions before waste is disposed in the landfill and monitoring for contaminant releases in an aquifer directly below the landfill once disposal has been initiated (highly improbable at WIPP since the monitored water bearing zone is above the repository). The EPA COMPs program uses the same data generated by the GMP to determine if changes in the data indicate a condition that is either outside CCA baseline expectations for the data or counter to assumptions made concerning the behavior of the groundwater system for PA (section 6.1.2). The data used by both programs are reported in the ASER. The EPA COMPs are reported in the Annual COMPs Assessment Report.

6.1.4 Change Management

Each groundwater program participant shall use their existing change-management process to implement necessary changes to the groundwater-monitoring program. The CBFO's Quality Assurance Program Document (QAPD) [DOE, 1999b] requires all program participants to follow specific guidelines to ensure that all changes are documented, traceable and auditable. These requirements ensure that changes made to the groundwater program are implemented such that all approvals and permits/permit modifications are made prior to implementation and that associated changes to processes/procedures and training meet QA change-management requirements. All planned changes to the groundwater-monitoring program shall also be communicated to the CBFO/ORC and the MOC regulatory sections early in the change process so that they can determine if the planned changes must be reported per regulatory requirements.

6.1.5 Quality Assurance

The WIPP groundwater-monitoring program falls under the CBFO's Quality Assurance Program outlined in their QAPD [DOE, 1999b]. This QA program complies with and incorporates all regulatory QA requirements. Each of the project participants must comply with the CBFO's QAPD and ensure that each of the individual programs complies with all regulatory QA requirements. Specifically, all programs for EPA monitoring requirements must meet NQA standards. QA must be applied to all data generation and assessment activities, training, record keeping, reporting, document generation and controls, procurement and all chain-of-custody processes. All monitoring programs shall be audited by the DOE/CBFO or its designee and shall also accommodate regulator audits.

6.2 Programs to Evaluate Effectiveness and Address Efficiencies

6.2.1 Assessment Program

The strategic plan, through actions of the IGWT, shall initiate a program to assess, recommend, and implement efficiencies within the groundwater-monitoring program and to evaluate the effectiveness of the program and identified efficiencies. The regulatory drivers that require monitoring also allow for changes to be made to the monitoring system that were described in the original permits/certifications. The groundwater-monitoring strategy includes a program to actively research the program drivers, the available information on the groundwater system, and available technologies to develop revisions to the groundwater-monitoring system.

The assessment program, under direction of the IGWT, shall outline in formal plans, what information and data are needed and what assessments shall be used to generate necessary information to justify the efficiencies to DOE, the public and the regulators. Formal reports shall be generated to document the results of these assessments. The IGWT shall assign program participants to generate the formal reports. These reports shall be generated using the assigned program participants QA program unless the documents are to be DOE reports. In the latter case, the DOE QA program (document preparation and control) shall be used.

The IGWT shall also address operational concerns by assessing the issues, planning appropriate activities and formally documenting results of these activities for use in justifying a recommendation to the project organization expressing the operational concern. The IGWT shall assign program participants to lead these activities.

6.2.2 Action Priority List

The implementation of the groundwater strategy entails many activities that have been described previously in this document. Priorities must be assigned to these activities such that the project meets all regulatory requirements and that the results necessary for one activity are available for other activities in a timely manner. The following is a prioritized list of the base activities and supplemental activities for the groundwater-monitoring program. Base activities are those that maintain compliance with the regulatory drivers and supplemental activities are those that support all other monitoring program functions.

Base Activities:
HWFP and EPA Groundwater Quality Sampling and Groundwater Head Measurements
Groundwater Density Survey
Well Maintenance and Repair
Well Integrity Testing/Well Logging
Culebra Water Level Rise Program (Regulatory/Stakeholder/PA Issues)

Supplemental Activities:
Magenta Testing and Modeling Program
Plugging and Abandonment
Exhaust Shaft Shallow Water Assessment Program

Efficiencies
Monitoring Assessment
Operational Needs
New Well/Replacement Program

Base activities have the highest priority since they are necessary to meet the regulatory commitments to monitor the WIPP, supplemental activities are prioritized such that issues that could lead to out-of-compliance conditions have the highest priority while efficiency related programs have the lowest priority. As the WIPP project fulfills its mission, priorities of the groundwater-monitoring program will shift toward minimizing the monitoring network and manpower requirements. Eventually, all WIPP wells will be decommissioned and plugged consistent with applicable regulations.

7. Roles and Responsibilities

Implementation of this strategic groundwater-monitoring strategy will require integration among the DOE/CBFO, the MOC, the SA, and the CTAC. Although the IGWT will be given oversight over the monitoring programs and elements, specific roles and responsibilities for individual project participants still remain and include:

DOE/CBFO

- Overall program management and oversight
- Approval of schedules, milestones and budgets
- Reporting and information exchange with regulators/stakeholders
- Dissemination of information among project participants
- Lead and participate in the IGWT

MOC

- Collect and disseminate groundwater-monitoring data in accordance with the WIPP HWFP
- Maintain, review and revise, as appropriate, relevant monitoring plans (e.g., EMP, GMP, etc)
- Acquire and maintain applicable permits
- Communicate and interface with NMOSE, BLM, and other Federal, state and local agencies on site activities as appropriate
- Continue implementing the current groundwater program elements and develop and implement new program elements as required
- Participate in the IGWT
- Perform studies to investigate perched shallow water
- Perform well maintenance, sampling and water disposal as appropriate
- Perform well logging and integrity testing
- Schedule plugging and abandonment of wells

SA

- Conduct COMPs assessment and report results in accordance with 40 CFR 194.42
- Maintain, review and revise, as appropriate, relevant compliance monitoring programs
- Continue implementing the current groundwater program elements and develop and implement new program elements as required
- Participate in the IGWT
- Perform studies to investigate changed conditions and to assess the impacts of such conditions on PA (e.g., Culebra water level rises)
- Evaluate PA needs during WIPP re-certification and develop monitoring approaches to meet these needs

CTAC

- Conduct regulatory compliance oversight evaluations
- Review program plans
- Quality assurance

The IGWT, as directed by DOE/CBFO, will resolve differences in interpretation of the roles and responsibilities of the project participants that may arise during the groundwater-monitoring period. Furthermore, the IGWT will provide the appropriate checks and balances to ensure that the activities of one project participant do not adversely affect the activities of the other participants.

8. Other Requirements

All activities conducted under this strategic plan shall meet the requirements put forth in the DOE/CBFO QAPD [DOE, 1999b], individual project participant QA plans, standard operating procedures, and necessary ES&H procedures. Other requirements not directly related to groundwater monitoring but that may affect the operation of monitoring activities are given in Appendix B.

9. Plan Life Cycle

The life cycle of this strategic groundwater-monitoring plan covers both the operational and post-closure phases of the WIPP. Because of the long-term requirements for the plan, periodic reviews and updates shall be scheduled. The reviews/updates will be performed by the IGWT with the first to be completed one year after the next revision to the EMP is approved (scheduled for 2003). Subsequent reviews/updates will follow every three years.

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Appendix A

Summary of Boreholes/Wells Drilled and Completed at the WIPP Site

Table A-1 Description of Surface-Drilled WIPP Boreholes[(a)]

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[(b)] (ft bgs/Unit)	Status
AEC-7 **(deepened)**	**03/19/74 – 04/18/74** **02/27/79 – 05/06/79**	**3656**	**3906** **4720**	**Castile (Anhydrite II)** **Bell Canyon (Olds Sandstone)**	**NA** **859 - 890/Cul**	**8.625-in. steel casing to 1004 ft (upper Salado), borehole plugged with cement from 4455 to 4483 ft. Bridge plug set in casing at 954 ft. Culebra monitoring well.**
AEC-8 **(deepened)**	**04/24/74 – 05/19/74** **06/28/76 – 08/05/76**	**3532**	**3019** **4911**	**Castile (Anhydrite II)** **Bell Canyon (Ford Shale)**	 **4832 – 4845/BC**	**8.625-in. steel casing to 874 ft (Los Medanos member), 5.5-in. casing to 4907 ft with cement to 868.5 ft. Bell Canyon monitoring well with PIP set at 4825.5 ft.**
B-25	12/01/78 – 01/05/79	3408	902	Upper Salado	NA	Plugged. Originally used to define lithology & stratigraphy for shaft design and to conduct hydrological tests.
Cabin Baby-1 **(deepened)**	**05/31/74 – 02/08/75** **08/12/83 – 08/28/83**	**3320**	**4151** **4291**	**Bell Canyon** **Bell Canyon (Hays Sandstone)**	**NA** **503 - 529/Cul** **4040 – 4291/BC**	**13.375-in. steel casing to 650 ft (just above Rustler/Salado contact). Culebra and Bell Canyon monitoring well using double PIP system with PIPs set at 604 ft and 4020 ft.**
C-2505	**10/01/96**	**3413**	**97**	**Dewey Lake**	**44 – 69/SR-DL** **Gravel: 44-69 ft**	**4.5-in. PVC casing to 65 ft. Slotted casing through Santa Rosa/Dewey Lake contact. Cemented annulus to 41.5 ft; Bentonite clay from 41.5 to 44 ft; gravel pack from 44 to 69 ft.**
C-2506	**09/26/96**	**3413**	**69**	**Dewey Lake**	**44.5 - 69/SR-DL** **Gravel: 44.5-69 ft**	**4.5-in. PVC casing to 65 ft. Slotted casing through Santa Rosa/Dewey Lake contact. Cemented annulus to 41.5 ft; Bentonite clay from 41.5 to 44.5 ft; gravel pack from 44.5 to 69 ft.**
C-2507	**10/02/96**	**3410**	**73**	**Dewey Lake**	**43 – 73/SR-DL** **Gravel: 43-73 ft**	**4.5-in. PVC casing to 69 ft. Slotted casing through Santa Rosa/Dewey Lake contact. Cemented annulus to 39 ft; Bentonite clay from 39 to 43 ft; gravel pack from 43 to 73 ft.**

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[(b)] (ft bgs/Unit)	Status
C-2737	**02/14/01 – 03/09/01**	**3397**	**710**	**Rustler (Los Medanos)**	**562 - 587/Mag 675 - 698/Cul**	**Fiberglass casing. Magenta and Culebra monitoring well.**
C-2811	**03/12/01**	**3399**	**80**	**Dewey Lake**	**50 – 80/SR-DL Gravel: 50-80 ft**	**2-in. PVC casing to 80 ft. Slotted casing through Santa Rosa/Dewey Lake contact. Cemented annulus to 15 ft; Bentonite clay from 15 to 50 ft; gravel pack from 50 to 80 ft.**
D-268	1984	3279	1411	Salado	NA	Used for hydrological testing and monitoring of the Culebra. Later plugged back to 493 ft. with custody transferred to Mills Ranch
DOE-1	**07/14/82 – 07/28/82**	**3465**	**4057**	**Castile (Anhydrite I)**	**820 - 843/Cul**	**10.75-in. steel casing to 1118 ft (upper Salado). Bridge plug set at 890.7 ft. Culebra monitoring well.**
DOE-2 **(deepened)**	**08/28/84 – 09/18/84** **04/29/85 – 06/08/85**	**3418**	**981** **4325**	**Upper Salado** **Bell Canyon (Hays Sandstone)**	**NA** **702 – 728/Mag**	**9.625-in. steel casing to 1009 ft (upper Salado). Magenta monitoring well with bridge plugs set at 869 ft and 737 ft. Culebra also perforated at 822 to 848 ft.**
ERDA-6	06/13/75 – 09/18/75	3540	2775	Castile	NA	Plugged from 2560 to 2773 ft with cement and hole filled with brine. 8.625-in. steel casing to 880 ft. Originally drilled to evaluate stratigraphy at first proposed WIPP site.
ERDA-9	**04/28/76 – 06/04/76**	**3409**	**2877**	**Castile (Anhydrite III)**	**705.5 - 728.5/Cul**	**10.75-in. steel casing to 1033 ft (upper Salado). Well drilled with diesel. Culebra monitoring well with bridge plug set at 758 ft.**
ERDA-10	08/18/77 – 10/14/77	3371	4417	Bell Canyon (Olds Sandstone)	NA	Plugged to surface. Originally drilled to evaluate dissolution.
H-1	05/20/76 – 06/09/76	3403	848	Upper Salado	NA	Plugged to surface. Originally drilled for hydrologic testing and monitoring of Rustler Members.

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[(b)] (ft bgs/Unit)	Status
H-2a **(deepened)**	**02/14/77 – 02/19/77** **07/12/83 – 07/17/83**	**3377**	**563** **672**	**Rustler (Magenta)** **Rustler (Los Medanos)**	**NA** **623 - 645/Cul**	**4.5-in. steel casing to 623 ft (Tamarisk). Culebra monitoring well with screen set across Culebra interval.**
H-2b1	**02/07/77 – 02/14/77**	**3378**	**661**	**Rustler (Los Medanos)**	**510 - 538/Mag**	**6.625-in. steel casing to 609 ft (Tamarisk). Magenta monitoring well. Note: Culebra interval is open but is isolated from the Magenta by a bridge plug.**
H-2b2	**07/16/83 – 07/30/83**	**3377**	**660**	**Rustler (Los Medanos)**	**623 - 645/Cul**	**5.5-in. steel casing to 620 ft (Tamarisk). Culebra monitoring well with screen set across Culebra interval.**
H-2c	**01/28/77 – 02/05/77**	**3377**	**795**	**Upper Salado**	**618 - 655/Cul**	**6.625-in. steel casing to 742 ft (Los Medanos). Culebra monitoring well.**
H-3b1	**07/25/76 – 08/12/76**	**3389**	**902**	**Upper Salado**	**562 - 590/Mag**	**6.625-in. steel casing to 891 ft (upper Salado). Magenta monitoring well. Note: Culebra and Rustler/Salado contact intervals are also perforated and isolated using bridge plugs.**
H-3b2	**10/25/83 – 11/08/83**	**3389**	**725**	**Rustler (Los Medanos)**	**676 - 700/Cul**	**5.5-in. steel casing to 673 ft (Tamarisk). Culebra monitoring in open-hole.**
H-3b3	**11/15/83 – 12/16/83**	**3388**	**730**	**Rustler (Los Medanos)**	**673 - 696/Cul**	**5.5-in. steel casing to 670.5 ft (Tamarisk). Culebra monitoring in open-hole.**
H-3d (H-3b4)	**03/31/87 – 04/22/87**	**3387**	**554**	**Rustler (Forty-niner)**	**0 - 507/DL** **536 - 546/49er**	**8.625-in. steel casing to 39 ft (Dewey Lake). Dewey Lake and Forty-niner claystone monitoring in open-hole with PIP set at 517 ft.**
H-4a	04/30/78 – 05/22/78	3333	532	Rustler (Los Medanos)	NA	Plugged to surface. Originally drilled for hydrological testing of Magenta and Culebra.
H-4b	**04/30/78 – 05/15/78**	**3333**	**529**	**Rustler (Los Medanos)**	**498 - 522/Cul**	**5.5-in. steel casing to 476 ft (Tamarisk). Culebra monitoring in open-hole.**
H-4c	**04/30/78 – 05/09/78**	**3334**	**661**	**Upper Salado**	**377 - 403/Mag**	**5.5-in. steel casing to 610 ft (Los Medanos). Magenta monitoring well. Note: Culebra interval has been perforated but isolated from other units using bridge plugs.**

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[b] (ft bgs/Unit)	Status
H-5a	**05/22/78 – 06/20/78**	**3506**	**930**	**Rustler (Los Medanos)**	**897 - 920/Cul**	**5.5-in. steel casing to 774 ft (Forty-niner). Culebra monitoring in open-hole.**
H-5b	**05/22/78 – 06/13/78**	**3506**	**925**	**Rustler (Los Medanos)**	**897 - 920/Cul**	**5.5-in. steel casing to 881 ft (Tamarisk). Culebra monitoring in open-hole.**
H-5c	**05/22/78 – 06/03/78**	**3506**	**1076**	**Upper Salado**	**788 - 812/Mag**	**5.5-in steel casing to 1024 ft (Los Medanos). Magenta monitoring well.**
H-6a	**07/06/78 – 07/11/78**	**3347**	**637**	**Rustler (Los Medanos)**	**604 – 627/Cul**	**5.5-in. steel casing to 475 ft (Magenta). Culebra monitoring well. Also completed across Magenta.**
H-6b	**06/27/78 – 07/05/78**	**3348**	**640**	**Rustler (Los Medanos)**	**604 - 627/Cul**	**5.5-in. steel casing to 590 ft (Tamarisk). Culebra monitoring in open-hole.**
H-6c	**06/20/78 – 06/26/78**	**3348**	**741**	**Upper Salado**	**490 - 514/Mag**	**5.5-in. steel casing to 699 ft (Los Medanos). Culebra monitoring well. Bridge plugs set to isolate Magenta from Culebra and Culebra from Rustler/Salado contact open-hole.**
H-7a	09/18/79 – 09/22/79	3164	154	Rustler (Tamarisk)	NA	Plugged. Originally drilled for hydrological testing and monitoring of the Magenta.
H-7b1	**09/13/79 – 09/18/79**	**3164**	**286**	**Rustler (Los Medanos)**	**237 - 283/Cul**	**7-in. steel casing to 230 ft. (Tamarisk). Culebra monitoring in open-hole.**
H-7b2	**09/02/83 – 09/21/83**	**3164**	**295**	**Rustler (Los Medanos)**	**232 - 280/Cul**	**7-in. steel casing to 230 ft (Tamarisk). Culebra monitoring in open-hole.**
H-7c	09/06/79 – 09/13/79	3163	420	Upper Salado		7-in. steel casing to 356 ft (Salado), slotted liner from 347 to 420 ft. Inactive well.
H-8a	**09/07/79 – 09/18/79**	**3433**	**505**	**Rustler (Tamarisk)**	**466 - 488/Mag**	**7-in. steel casing to 452 ft (Forty-niner). Magenta monitoring in open-hole.**
H-8b	08/06/79 – 08/12/79	3433	624	Rustler (Los Medanos)	NA	Ownership transferred to local rancher.
H-8c	**07/27/79 – 08/06/79**	**3433**	**808**	**Upper Salado**	**734 - 808/R-S**	**7-in. steel casing to 734 ft (Los Medanos). Rustler/Salado contact monitoring in open-hole.**

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[(b)] (ft bgs/Unit)	Status
H-9a (deepened)	07/09/79 – 09/05/79 07/21/83 – 07/27/83	3405	559 692	Rustler (Tamarisk) Rustler (Los Medanos)	NA NA	Plugged to surface. Originally drilled for hydrological testing and monitoring of Culebra.
H-9b	**08/14/79 – 08/28/79**	**3406**	**708**	**Rustler (Los Medanos)**	**647 - 677/Cul**	**7-in. steel casing to 638 ft (Tamarisk). Culebra monitoring in open-hole.**
H-9c	**08/01/79 – 08/24/79**	**3406**	**816**	**Upper Salado**	**525 - 555/Mag**	**7-in. steel casing to 783 ft (Los Medanos). Magenta monitoring well. Note: Well also completed to Culebra and Rustler/Salado contact with bridge plugs set for isolation.**
H-10a	**08/21/79 – 08/26/79**	**3687**	**1318**	**Rustler (Tamarisk)**	**1256 - 1280/Mag**	**7-in. steel casing to 1243 ft (Forty-niner). Magenta monitoring in open-hole.**
H-10b	10/07/79 – 10/13/79	3687	1398	Rustler (Los Medanos)	NA	Plugged to surface. Originally drilled for hydrological testing and monitoring of Culebra.
H-10c	**08/11/79 – 08/20/79**	**3687**	**1538**	**Upper Salado**	**1353 - 1383/Cul**	**7-in. steel casing to 1483 ft (Los Medanos). Hole cemented from TD to 1420 ft. Culebra monitoring.**
H-11b1	**08/03/83 – 09/02/83**	**3411**	**785**	**Rustler (Los Medanos)**	**730-756/Cul**	**5.5-in. steel casing to 732 ft (Culebra). Culebra monitoring in open-hole.**
H-11b2	**10/01/83 – 11/28/83**	**3411**	**776**	**Rustler (Los Medanos)**	**622 - 650/Mag**	**5.5-in. steel casing to 733 ft (Culebra). Magenta monitoring with bridge set at 664 ft.**
H-11b3	12/01/83 – 01/04/84	3412	789	Rustler (Los Medanos)	NA	Plugged from TD up into casing. Will eventually be plugged to surface.
H-11b4	**02/23/88 – 03/15/88**	**3410**	**765**	**Rustler (Los Medanos)**	**723 - 746/Cul**	**5.5-in. steel casing to 714 ft (Tamarisk). Culebra monitoring in open-hole.**
H-12	**10/04/83 – 10/18/83**	**3426**	**1001**	**Upper Salado**	**823 - 850/Cul**	**5.5-in. steel casing to 820 ft (Tamarisk). Culebra monitoring in open-hole.**
H-13	Not drilled.					

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[b] (ft bgs/Unit)	Status
H-14	**09/25/86 – 10/23/86**	**3346**	**589**	**Rustler (Los Medanos)**	**428 - 455/Mag**	**5.5-in. steel casing to 532 ft (Tamarisk). Magenta monitoring well with bridge plug set at 461 ft.**
H-15	**10/24/86 – 11/14/86**	**3480**	**900**	**Rustler (Los Medanos)**	**751 - 780/Mag**	**5.5-in. steel casing to 853 ft (Tamarisk). Magenta monitoring well with bridge plug set at 793.5 ft.**
H-16	**07/13/87 – 08/18/87**	**3410**	**851**	**Upper Salado**	**532 - 590/49er 590 - 616/Mag 616 - 702.5/Tam 702.5 - 724.4/Cul 724.4 - 841.5/LM**	**7-in. steel casing to 469 ft (Dewey Lake). Well covered over and no longer accessible for direct water level readings. Pressure in five intervals read continuously using pressure transducers. Intervals separated by inflatable packers.**
H-17	**09/21/87 – 11/04/87**	**3384**	**880**	**Upper Salado**	**706 - 731/Cul**	**7-in. steel casing to 692 ft (Tamarisk). Culebra monitoring in open-hole.**
H-18	**09/29/87 – 11/18/87**	**3413**	**840**	**Upper Salado**	**575 - 601/Mag**	**7-in. steel casing to 673 ft (Tamarisk). Magenta monitoring with bridge plug set at 614.2 ft.**
H-19b0	**03/28/95 – 04/23/95**	**3417**	**779**	**Rustler (Los Medanos)**	**740 - 764/Cul**	**9.625-in. fiberglass casing to 732 ft (Tamarisk). Culebra monitoring in open-hole.**
H-19b1	02/13/95 – 03/21/95	3417	733	Rustler (Tamarisk)	NA	Plugged. Originally drilled for tracer test but tools lost in hole so well was abandoned.
H-19b2	**05/10/95 – 05/20/95**	**3417**	**785**	**Rustler (Los Medanos)**	**741.6 – 765/Cul**	**7-in. fiberglass casing to 732 ft (Tamarisk). 5.5-in. PVC liner from 766 ft to 780 ft (Los Medanos). Culebra monitoring in open-hole.**
H-19b3	**04/23/95 – 05/09/95**	**3417**	**785**	**Rustler (Los Medanos)**	**740 - 765/Cul**	**7-in. fiberglass casing to 732 ft (Tamarisk). 5.5-in. PVC liner from 762 ft to 782 ft (Los Medanos). Culebra monitoring in open-hole.**
H-19b4	**5/20/95 – 06/05/95**	**3416**	**782**	**Rustler (Los Medanos)**	**738.5 – 762/Cul**	**7-in. fiberglass casing to 731 ft (Tamarisk). 5.5-in. PVC liner from 762 ft to 782 ft (Los Medanos). Culebra monitoring in open-hole.**
H-19b5 (deepened)	**06/11/95 – 07/06/95 08/25/95 – 08/26/95**	**3417**	**736 786**	**Rustler (Tamarisk) Rustler (Los Medanos)**	**NA 737 - 761/Cul**	**7-in. fiberglass casing to 731 ft (Tamarisk). 5.5-in. PVC liner from 763 ft to 783 ft (Los Medanos). Culebra monitoring in open-hole.**

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[(b)] (ft bgs/Unit)	Status
H-19b6 **(deepened)**	**07/10/95 – 07/26/95** **08/23/95 – 08/24/95**	**3417**	**736** **788**	**Rustler (Tamarisk)** **Rustler (Los Medanos)**	**NA** **739 - 765/Cul**	**7-in. fiberglass casing to 730 ft (Tamarisk). 5.5-in. PVC liner from 766 ft to 786 ft (Los Medanos). Culebra monitoring in open-hole.**
H-19b7	**07/26/95 – 08/18/95**	**3417**	**785**	**Rustler**	**739.5 - 764/Cul**	**7-in. fiberglass casing to 731 ft (Tamarisk). 5.5-in. PVC liner from 764 ft to 784 ft (Los Medanos). Culebra monitoring in open-hole.**
P-1 to P-13	13 holes used for potash resource evaluation. All casings pulled and holes plugged to surface.					
P-14	09/24/76 – 10/03/76	3358	1545	Salado (Below McNutt Potash)	NA	Plugged. Originally drilled for potash resource evaluation. Later used to monitor the Culebra and Rustler/Salado contact.
P-15	10/04/76 – 10/14/76	3310	1465	Salado (Below McNutt Potash)	NA	Plugged. Originally drilled for potash resource evaluation. Later used to monitor the Culebra and Rustler/Salado contact.
P-16	Hole used for potash resource evaluation. Casing pulled and hole plugged to surface.					
P-17	**10/18/75 – 10/26/76**	**3340**	**1660**	**Salado (Below McNutt Potash)**	**558 - 586/Cul**	**4.5-in. steel casing to 751 ft (Salado). Hole plugged from 731 to 1660 ft. Bridge plug set at 674 ft. Culebra monitoring well.**
P-18	10/19/76 – 11/05/76	3478	1998	Salado (Below McNutt Potash)	NA	Plugged to surface. Originally drilled for potash resource evaluation. Later used to monitor Culebra and Rustler-Salado contact.
P-19 to P-21	3 holes used for potash resource evaluation. All casings pulled and holes plugged to surface.					
WIPP-11	02/06/78 – 03/14/78	3426	3570	Castile (Anhydrite I)	NA	Plugged to surface. Originally drilled to evaluate presence/absence of salt deform.
WIPP-12 **(deepened)**	**11/09/78 – 12/07/78** **11/17/81 – 01/01/82**	**3472**	**2776** **3928**	**Upper Salado** **Castile (Anhydrite I)**	**NA** **815 - 840/Cul**	**9.625-in. steel casing to 1002 ft. Cement/sand plug installed from 2784 to 3000 ft. Culebra monitoring well with bridge plug set at 984 ft.**
WIPP-13 **(deepened)**	**07/26/78 – 08/06/78** **08/26/79 – 10/05/79**	**3405**	**1025** **3850**	**Upper Salado** **Castile (Anhydrite I)**	**NA** **702 - 727/Cul**	**9.625-in. steel casing to 1023 ft. Culebra monitoring well with bridge plug set at 945.2 ft.**

Well I.D.	**Drilling Start/End Date**	**Surface Elevation (ft)**	**Total Depth (ft)**	**Formation at Total Depth**	**Completion Interval[(b)] (ft bgs/Unit)**	**Status**
WIPP-14	05/01/81 – 06/08/81	3429	1000	Upper Salado	NA	Plugged. Originally drilled in karst-like feature centered on a negative gravity anomaly
WIPP-15	03/08/78 – 04/05/78	3269	811	Santa Rosa	NA	Hole relinquished to land owner for use as a water well after initially loaded with mud and capped.
WIPP-16	01/11/80 – 02/08/80	3383	1300	Rustler (Los Medanos)	NA	Plugged. Originally drilled to characterize breccia pipe and displacement of beds.
WIPP-17	Not drilled. Technical justification for hole satisfied by data obtained from earlier holes.					
WIPP-18	**03/14/78 – 03/30/78**	**3456**	**1060**	**Upper Salado**	**676 - 702/Mag**	**5.5-in. steel casing to top of Salado. Magenta monitoring with bridge plug set at 716 ft. Also perforated through the Culebra.**
WIPP-19	**04/06/78 – 05/08/78**	**3433**	**1038**	**Upper Salado**	**756 - 779/Cul**	**5.5-in. steel casing to top of Salado. Culebra monitoring well.**
WIPP-20	Not drilled. Technical justification for hole satisfied by data obtained from earlier holes.					
WIPP-21	**05/24/78 – 05/26/78**	**3417**	**1045**	**Upper Salado**	**729 - 753/Cul**	**5.5-in. steel casing to top of Salado. Culebra monitoring well.**
WIPP-22	**05/08/78 – 05/23/78**	**3426**	**1450**	**Salado (Below McNutt Potash)**	**742 - 764/Cul**	**5.5-in. steel casing to top of Salado. Culebra monitoring well.**
WIPP-23	Not drilled. Technical justification for hole satisfied by data obtained from earlier holes.					
WIPP-24	Not drilled. Technical justification for hole satisfied by data obtained from earlier holes.					
WIPP-25	**08/28/78 – 09/07/78**	**3213**	**655**	**Upper Salado**	**300 - 330/Mag 445 - 475/Cul**	**5.5-in. steel casing to 649 ft (Salado). Culebra and Magenta monitoring with PIPs set at 365 ft and 573 ft. Casing also perforated from 579 to 608 ft (Rustler/Salado contact).**
WIPP-26	**08/28/78 – 09/06/78**	**3152**	**503**	**Upper Salado**	**185 - 210/Cul**	**5.5-in. steel casing to 502 ft (Salado). Culebra monitoring with PIPs set at 139 and 269 ft. Casing also perforated from 70 to 100 ft (Magenta) and from 288 to 329 ft (Rustler/Salado contact).**

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[b] (ft bgs/Unit)	Status
WIPP-27	**09/12/78 – 10/09/78**	**3177**	**592**	**Upper Salado**	**290-320/Cul**	**5.5-in. steel casing to 588 ft (Salado). Culebra monitoring with PIPs set at 267 and 399 ft. Casing also perforated from 175 to 195 ft (Magenta), from 425 to 460 ft (Rustler/Salado contact), and from 483 to 513 ft (Salado).**
WIPP-28	08/07/78 – 08/25/78	3347	801	Upper Salado	NA	Plugged to surface. Originally drilled to define stratigraphy and hydraulics of Nash Draw and later perforated through Magenta, Culebra, and Rustler-Salado contact.
WIPP-29	**10/02/78 – 10/10/78**	**2977**	**378**	**Salado (Below McNutt Potash)**	**10 - 45/Cul**	**5.5-in. steel casing to 376 ft (Salado). Culebra monitoring with PIP set at 204 ft. Salado also perforated from 216 to 250 ft.**
WIPP-30	**09/08/78 – 09/23/78**	**3428**	**912**	**Upper Salado**	**510 - 540/Mag 629 - 655/Cul**	**5.5-in. steel casing to 912 ft (Salado). Magenta and Culebra monitoring with PIPs set at 585 ft and 701 ft. Rustler-Salado contact also perforated from 731 to 753 ft.**
WIPP-31 (deepened)	09/18/78 – 10/04/78 07/18/80 – 09/29/80	3401	810 1982	Breccia Breccia (below Yates FM)	NA	Plugged. Originally drilled to characterize breccia pipe. Used as monitoring well for two years.
WIPP-32	08/07/79 – 08/16/79	3023	390	Salado (Below McNutt Potash)	NA	Plugged. Originally drilled to investigate existence of breccia pipe. None found.
WIPP-33	07/17/79 – 07/25/79	3323	840	Salado	NA	Plugged. Originally drilled to investigate stratigraphy of small depression.
WIPP-34	08/16/79 – 09/01/79	3433	1820	Salado (Lower Unit)	NA	Plugged. Originally drilled to investigate possible karst feature. Revealed normal stratigraphy.
WQSP-1	**09/13/94 – 09/16/94**	**3417**	**737**	**Rustler**	**Cul Sand: 648-651 ft Gravel: 651-712 ft**	**5-in. fiberglass casing to 550 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs.**

Well I.D.	Drilling Start/End Date	Surface Elevation (ft)	Total Depth (ft)	Formation at Total Depth	Completion Interval[(b)] (ft bgs/Unit)	Status
WQSP-2	**09/06/94 – 09/10/94**	**3461**	**846**	**Rustler**	**Cul Sand: 790-793 ft Gravel: 793-846 ft**	**5-in. fiberglass casing to 770 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs.**
WQSP-3	**10/20/94 – 10/26/94**	**3477**	**879**	**Rustler**	**Cul Sand: 827-830 ft Gravel: 830-880 ft**	**5-in. fiberglass casing to 797 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs.**
WQSP-4	**10/05/94 – 10/07-94**	**3430**	**800**	**Rustler**	**Cul Sand: 752-755 ft Gravel: 755-800 ft**	**5-in. fiberglass casing to 715 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs.**
WQSP-5	**10/12/94 – 10/13/94**	**3382**	**681**	**Rustler**	**Cul Sand: 623-626 ft Gravel: 626-681 ft**	**5-in. fiberglass casing to 616 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs.**
WQSP-6	**09/22/94 – 09/30/94**	**3362**	**617**	**Rustler**	**Cul Sand: 567-570 ft Gravel: 570-620? ft**	**5-in. fiberglass casing to 560 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs.**
WQSP-6a	**10/28/94 – 10/31/94**	**3361**	**225**	**Dewey Lake**	**DL Sand: 172-175 ft Gravel: 175-225 ft**	**5-in. fiberglass casing to 152 ft. Culebra monitoring through 25-ft fiberglass slotted screen with sand and gravel packs**

(a) Bold-faced entries represent active boreholes.

(b) BC – Bell Canyon; Cul – Culebra; DL – Dewey Lake; Mag – Magenta; R-S – Rustler/Salado Contact; SR – Santa Rosa; Tam – Tamarisk; LM – Los Medanos; 49er – Forty-niner; NA – Not applicable.

Appendix B

Other Related Requirements

Rule, Standard or Regulation	Impact on Groundwater Monitoring
Federal Land Policy and Management Act	Ensures that public lands are managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use.
EPA Emergency Planning and Community Right-To-Know Act (EPCRA)	40 CFR Part 355 – Emergency Planning and Notification 40 CFR Part 370 – Hazardous Chemical Reporting: Community Right-To-Know 40 CFR Part 372 – Toxic Chemical Release Reporting: Community Right-To-Know
EPA Clean Air Act	Most provisions of this act do not apply to the WIPP; however, groundwater-monitoring activities may need to address some issues (e.g., use of large diesel generators).
EPA Clean Water Act	40 CFR Part 122 is relevant to the WIPP; however, because there are no point-source discharges into navigable waters at WIPP, the facility is not required to obtain a standard National Pollutant Discharge Elimination System (NPDES) permit.
EPA Safe Drinking Water Act	EPA has delegated authority for this act to the State of New Mexico. (Note: No groundwater from site used for drinking water)
EPA Federal Insecticide, Fungicide, and Rodenticide Act	Controls use, storage, and disposal of pesticides at WIPP.
EPA Noise Control Act	WIPP is in compliance with OSHA standards under 29 CFR 1910.95.
Council on Environmental Quality – National Environmental Policy Act (NEPA)	Requires EAs, EISs, as appropriate, for site activities including well pad/road construction, pits, storage tank sites, etc.
DOE Atomic Energy Act	Contains authority for DOE to develop policies, issue Orders, and promulgate regulations that address environmental, safety, and health protection aspects of radioactive waste and nuclear materials. Implemented through Orders, notices, and directives.
DOE NEPA Implementation	DOE adopted the NEPA regulations through the establishment of 10 CFR 1021, NEPA Implementing Procedures. Requires EISs, supplemental EISs, RODs, MAPs, and EAs.
NRC Atomic Energy Act	10 CFR 71, Packaging and Transportation of Radioactive Material
DOT Hazardous Materials Transportation Act (HMTA)	Deals with regulations for transporting hazardous wastes
DOI (BLM), Materials Act of 1947	Specifically cited in the LWA and requires the development of a land management plan. Deals only with disposal of salt tailings.
DOI (BLM), Federal Land Policy and Management Act (FLPMA)	Specifically cited in the LWA and requires the development of a land management plan. Deals with right-of-way reservations and temporary-use permits. Must restore land, comply with applicable air- and water-quality standards, protect scenic, cultural, & aesthetic value, etc
DOI (BLM), Public Rangelands Improvement Act	Specifically cited in the LWA and requires the development of a land management plan. Deals with grazing management.
DOI (BLM) Taylor Grazing Act	Specifically cited in the LWA and requires the development of a

	land management plan. Deals with grazing management.
DOI (Fish and Wildlife Service) Bald & Golden Eagle Protection Act	Generally not applicable to WIPP because no bald or golden eagles are nesting at the WIPP.
DOI (Fish and Wildlife Service) Migratory Bird Treaty Act	Applicable parts of Act are implemented.
DOI (Fish and Wildlife Service) Endangered Species Act	Generally not applicable because the WIPP will have no impact on any threatened or endangered species.
Advisory Council on Historic Preservation, National Historic Preservation Act	WIPP contains archaeological sites, therefore, a plan of treatment of such sites must be developed in case such a site is in an area where WIPP activities may occur.
NMED, NM Solid Waste Act	20.9.1 NMAC – Deals primarily with landfills. Generally not applicable at the WIPP because the WIPP construction landfill has no hazardous waste and qualifies for an exemption under § 108 of the SWMR.
NMED, NM Environmental Improvement Act	Basically, created the NMED and authorized its authority for environmental issues.
NMED, NM Groundwater Protection Act	Act governs USTs (some USTs exist on site)
NMED, NM Air Quality Control Act	Generally follows the Federal Clean Air Act
NMED, NM Water Quality Act	Generally follows the Federal Clean Water Act. Governs sewage effluent disposal and nonhazardous brine disposal. (Note: water from well pumping ends up in brine disposal ponds) DP-831 General Requirement, Record-keeping The discharger must maintain a written record of ground-water and wastewater quality analyses at the facility. The information must be recorded and made available to the NMED upon request.
NMED, NM Drinking Water Regulations	Sampling of WIPP water distribution system.
NM Dept. of Public Safety, NM Hazardous Chemicals Information Act	Requires WIPP to notify State if extremely hazardous materials exist at or above threshold levels and if a release occurs.
NM Dept. of Public Safety, NM Emergency Management Act	Requires appropriate emergency resources and an emergency management plan.
NM Office of Cultural Affairs, NM Prehistoric and Historic Sites Preservation Act	Complements federal NHPA. Note: This act was invoked for the construction of 6 new well pads and will be invoked again for any new wells.
NM Commissioner of Public Lands, NM State Implementation of FLPMA	Complements and implements the Federal Land Policy and Management Act (FLPMA).
NM Dept of Game and Fish, NM State Implementation of the Bald and Golden Eagle Protection Act	Complements and implements the Bald and Golden Eagle Protection Act.
NM Dept of Game and Fish, NM Wildlife Conservation Act, Implementing the Endangered Species Act	Complements and implements the Endangered Species Act.
NM Dept of Agriculture, NM Pesticide Control Act	Deals with storage, use, transportation, disposal, etc of pesticides and pesticide-related devices.