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Program Plan

WIPP Integrated Groundwater Hydrology Program, FY03-09

Revision 0

Sandia National Laboratories
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Definitions of Acronyms

AP	Analysis Plan
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
CBFO	Carlsbad Field Office (of DOE)
CCA	Compliance Certification Application
CDF	cumulative distribution function
CFR	Code of Federal Regulations
CH	contact-handled (waste)
C.I.	confidence interval
CMP	Compliance Monitoring Program
COMP	Compliance-Monitoring Parameter
CRA	Compliance Recertification Application
DMP	Detection Monitoring Program
DMW	Detection Monitoring Well
DOE	(United States) Department of Energy
DOI	(United States) Department of the Interior
EEG	Environmental Evaluation Group
EMI	Electrical Micro Imaging
EMP	Environmental Monitoring Plan
EPA	Environmental Protection Agency
FMI	Formation Micro Imager
FMS	Formation Micro Scanner
FY	Fiscal Year
gpm	gallons per minute
GSP	Groundwater Surveillance Program
GWMP	Groundwater Monitoring Program
HQ	Headquarters
HWDU	Hazardous Waste Disposal Unit
HWFP	Hazardous Waste Facility Permit
IGWT	Integrated Groundwater Team
LWA	Land Withdrawal Act
m#/h#	mudstone #/halite #
MCL	Milestone Control Log
MDS	Milestone Description Sheet
MOC	Management and Operating Contractor
NEPA	National Environmental Policy Act
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMHWA	New Mexico Hazardous Waste Act
NMSA	New Mexico Statutes Annotated
NMWQCC	New Mexico Water Quality Control Commission
nSIGHTS	n-dimensional Statistical Inverse Graphical Hydraulic-Test Simulator
OA	(DOE) Office of Assessment
OCD	(New Mexico) Oil Conservation Division

O.D.	outside diameter
OSE	(New Mexico) Office of the State Engineer
P&A	plug and abandon (or plugging and abandonment)
PA	Performance Assessment
PL	Public Law
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
RH	remote-handled (waste)
SA	Scientific Advisor
SNL	Sandia National Laboratories
SOW	Statement of Work
T	transmissivity
TD	total depth
TDS	total dissolved solids
TP	Test Plan
TRU	transuranic
TV	trigger value
USC	United States Code
USI	ultrasonic imaging
UST	underground storage tank
UTM	Universal Transverse Mercator
WBS	Work Breakdown Structure
WTS	Washington TRU Solutions
WIPP	Waste Isolation Pilot Plant
WLMP	Water-Level Monitoring Program
WQSP	Water Quality Sampling Program
2D	two-dimensional
3D	three-dimensional

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1. Introduction

This Program Plan describes the groundwater hydrology-related activities to be performed for the Waste Isolation Pilot Plant (WIPP) from Fiscal Years (FY) 2003 through 2009. The overall objectives of these activities are to resolve questions related to observed water-level changes around the WIPP site, provide data needed for comprehensive modeling of WIPP groundwater hydrology, construct a groundwater monitoring network that can be maintained throughout the operational period of WIPP, and plug and abandon deteriorating steel-cased wells. The description of the activities to be performed in FY04 and beyond represents our best current estimate of the work that will be needed, but these activities are necessarily contingent on the results of previous years' activities.

1.1 Plan Motivation

Groundwater-monitoring and modeling activities at the 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. Continued compliance with regulations must be demonstrated every five years during the operational phase of the WIPP. The monitoring requirements apply not only for the current operational phase (~35 years), but extend through the post-closure phase of the facility to meet applicable regulations. Because of these long-term requirements, DOE's Carlsbad Field Office (CBFO) has developed a *Strategic Plan For Groundwater Monitoring at the Waste Isolation Pilot Plant* (DOE, 2003) that describes: relevant regulatory drivers; the current groundwater-monitoring network and how it has evolved over time; current groundwater program elements; strategies for maintaining compliance; methods for implementing the strategies; and roles and responsibilities of monitoring program participants.

A key element identified in the strategic groundwater-monitoring plan is the need for investigative studies and an implementation strategy to address compliance issues, regulator/stakeholder concerns, or operational and safety issues that may arise during the monitoring period. When such issues arise, DOE CBFO is responsible for directing project participants (e.g., the Management and Operating Contractor (MOC), the Scientific Advisor (SA), etc.) to develop a program plan and implement procedures for conducting the appropriate investigations. To this end, an Integrated Groundwater Team (IGWT) has been created with members from the DOE, the SA (Sandia National Laboratories (SNL)), and the MOC (Washington TRU Solutions (WTS)).

Recently, several issues and regulator/stakeholder concerns related to groundwater hydrology at and around the WIPP site have arisen. In keeping with the requirements of the strategic groundwater plan, DOE CBFO identified the need for an investigative program and, because of the broad scope of the program, directed the development of an integrated program through the collaborative efforts of the IGWT. This document represents the required program plan.

1.2 Technical Focus

This integrated program plan presents an investigation of WIPP groundwater hydrology to address compliance requirements and regulator/stakeholder concerns. The program has four principal components:

- Resolution of water-level-change issues
- Enhancement of groundwater models
- Construction of an optimized well network for Culebra groundwater monitoring
- Plugging and abandonment of deteriorating steel-cased wells

These components are discussed in detail in subsequent sections of this plan.

1.3 Plan Organization

In addition to this introduction, the program plan is organized into eleven distinct sections. Section 2 describes the relevant compliance drivers for each of the identified issues/concerns. Section 3 provides background information for each issue/concern, Section 4 provides a description of the modeling activities that are planned, Section 5 describes the field activities to be performed, Section 6 describes the sequence and scheduling of activities, and Section 7 provides technical details on well drilling, completion, and logging. Roles and responsibilities and a work breakdown structure are described in Section 8. The plan concludes with documentation of planned milestones and deliverables (Sections 9 and 10), a discussion of planned meetings and reporting (Section 11), and a list of cited references (Section 12).

2. Compliance Drivers

All groundwater activities conducted at the WIPP are driven by federal and state regulations, commitments made by the DOE through implementation of program elements, and concerns/issues raised by regulators and stakeholders or DOE program auditors throughout the operational and post-closure phases of the repository. Taken collectively, these governing requirements are termed drivers. The strategic groundwater-monitoring plan (DOE, 2003) provides a detailed discussion of the applicable drivers, a summary of which is given below. Additionally, links between applicable drivers and the components of this program plan are discussed to provide the regulatory justification for the planned technical activities.

2.1 40 CFR Parts 191 and 194 and the Compliance Certification Application

The U.S. Environmental Protection Agency (EPA) standards governing the management and disposal of all spent nuclear fuel, high-level and transuranic (TRU) radioactive wastes are codified in 40 Code of Federal Regulation Part 191 (40 CFR 191) (EPA, 1985; 1993). The WIPP must satisfy these standards because it currently accepts Contact-Handled (CH) TRU waste and could eventually accept Remote-Handled (RH) TRU waste. To demonstrate compliance with EPA standards, WIPP must perform a Performance Assessment (PA). Subpart C of 40 CFR §194.32 specifies that:

(a) Performance assessments shall consider natural processes and events, mining, deep drilling, and shallow drilling that may affect the disposal system during the regulatory time frame.

Groundwater flow represents a potential natural process by which radionuclides released from the repository by inadvertent human intrusion could reach the accessible environment. As the most transmissive fully saturated unit above the repository horizon, the Culebra Dolomite Member of the Rustler Formation is considered the most significant potential groundwater-release pathway for radionuclides. Hence, PA groundwater modeling focuses on flow and transport through the Culebra. To capture the effects of drilling and mining around WIPP on Culebra groundwater flow, models must extend over the areas in which those activities are occurring, and must accurately represent both the properties of the Culebra (e.g., transmissivity) and the conditions driving flow (e.g., hydraulic head).

The portion of the EPA standards 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 Land Withdrawal Act (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 re-certifications 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 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) In submitting documentation of continued compliance pursuant to section 8(f) of the WIPP LWA, the previous compliance application shall be updated to provide sufficient information for the Administrator to determine whether or not the WIPP continues to be in compliance with the disposal regulations. Updated documentation shall include:
   (1) All additional geologic, geophysical, geochemical, hydrologic, and meteorologic information;
   (2) All additional monitoring data, analyses and results;
   (3) All additional analyses and results of laboratory experiments conducted by the Department or its contractors as part of the WIPP program;
   (4) An identification of any activities or assumptions that deviate from the most recent compliance application;
   (5) A description of all waste emplaced in the disposal system since the most recent compliance certification or re-certification application. Such description shall consist of a description of the waste characteristics and waste components identified in §194.24(b)(1) and §194.24(b)(2);
   (6) Any significant information not previously included in a compliance certification or re-certification application related to whether the disposal system continues to be in compliance with the disposal regulations; and
   (7) Any additional information requested by the Administrator or the Administrator's authorized representative.

Subpart C §194.42 Monitoring

(a) The Department shall conduct an analysis of the effects of disposal system parameters on the containment of waste in the disposal system and shall include the results of such analysis in any compliance application. The results of the analysis shall be used in developing plans for pre-closure and post-closure monitoring required pursuant to paragraphs (c) and (d) of this section. The disposal system parameters analyzed shall include, at a minimum:
   (1) Properties of backfilled material, including porosity, permeability, and degree of compaction and reconsolidation;
   (2) Stresses and extent of deformation of the surrounding roof, walls, and floor of the waste disposal room;
   (3) Initiation or displacement of major brittle deformation features in the roof or surrounding rock;
   (4) Ground water flow and other effects of human intrusion in the vicinity of the disposal system;
   (5) Brine quantity, flux, composition, and spatial distribution;
   (6) Gas quantity and composition; and
   (7) Temperature distribution.

(b) For all disposal system parameters analyzed pursuant to paragraph (a) of this section, any compliance application shall document and substantiate the decision not to monitor a particular disposal system parameter because that parameter is considered to be insignificant to the containment of waste in the disposal system or to the verification of predictions about the future performance of the disposal system.

(c) Pre-closure monitoring. To the extent practicable, pre-closure monitoring shall be conducted of significant disposal system parameter(s) as identified by the analysis conducted pursuant to paragraph (a) of this section. A disposal system parameter shall be considered significant if it affects 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 as soon as practicable; however, in no case shall waste be emplaced in the disposal system prior to the implementation of pre-closure monitoring. Pre-closure monitoring shall end at the time at which the shafts of the disposal system are backfilled and sealed.

(d) Post-closure monitoring. The disposal system shall, to the extent practicable, be monitored as soon as practicable after the shafts of the disposal system are backfilled and sealed to detect substantial and detrimental deviations from expected performance and shall end when the Department can demonstrate to the satisfaction of the Administrator that there are no significant concerns to be addressed by further monitoring. Post-closure monitoring shall be complementary to monitoring required pursuant to applicable federal hazardous waste regulations at parts 264, 265, 268, and 270 of this chapter and shall be conducted with techniques that do not jeopardize the containment of waste in the disposal system.

(e) Any compliance application shall include detailed pre-closure and post-closure monitoring plans for monitoring the performance of the disposal system. At a minimum, such plans shall:

   (1) Identify the parameters that will be monitored and how baseline values will be determined;
   (2) Indicate how each parameter will be used to evaluate any deviations from the expected performance of the disposal system; and
   (3) Discuss the length of time over which each parameter will be monitored to detect deviations from expected performance.

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, 1996), 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, 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.

Monitoring of Culebra groundwater composition, change in flow, and well water levels is 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 Environmental Monitoring Plan (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.

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. 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.

Water Quality Sampling Program. 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 (see Figure 1). 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 collected 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 for specific radionuclides. A complete list of sampled analytes is provided in the EMP.

Water Level Monitoring Program. 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 (Figure 1). The water-level data, along with the hydrologic properties, were used during site characterization to establish flow rates and directions within the various hydrologic units. After certification, most of these wells have remained in the compliance-monitoring network to acquire data to assess changes in flow rates and directions 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 Dolomite Member of the Rustler Formation. However, the WLMP also collects water-level data in wells completed to other hydrologic units including the Dewey Lake Formation; the Forty-niner, Magenta, and Los Medaños Members of the Rustler; the Rustler-Salado contact; and the Bell Canyon Formation.

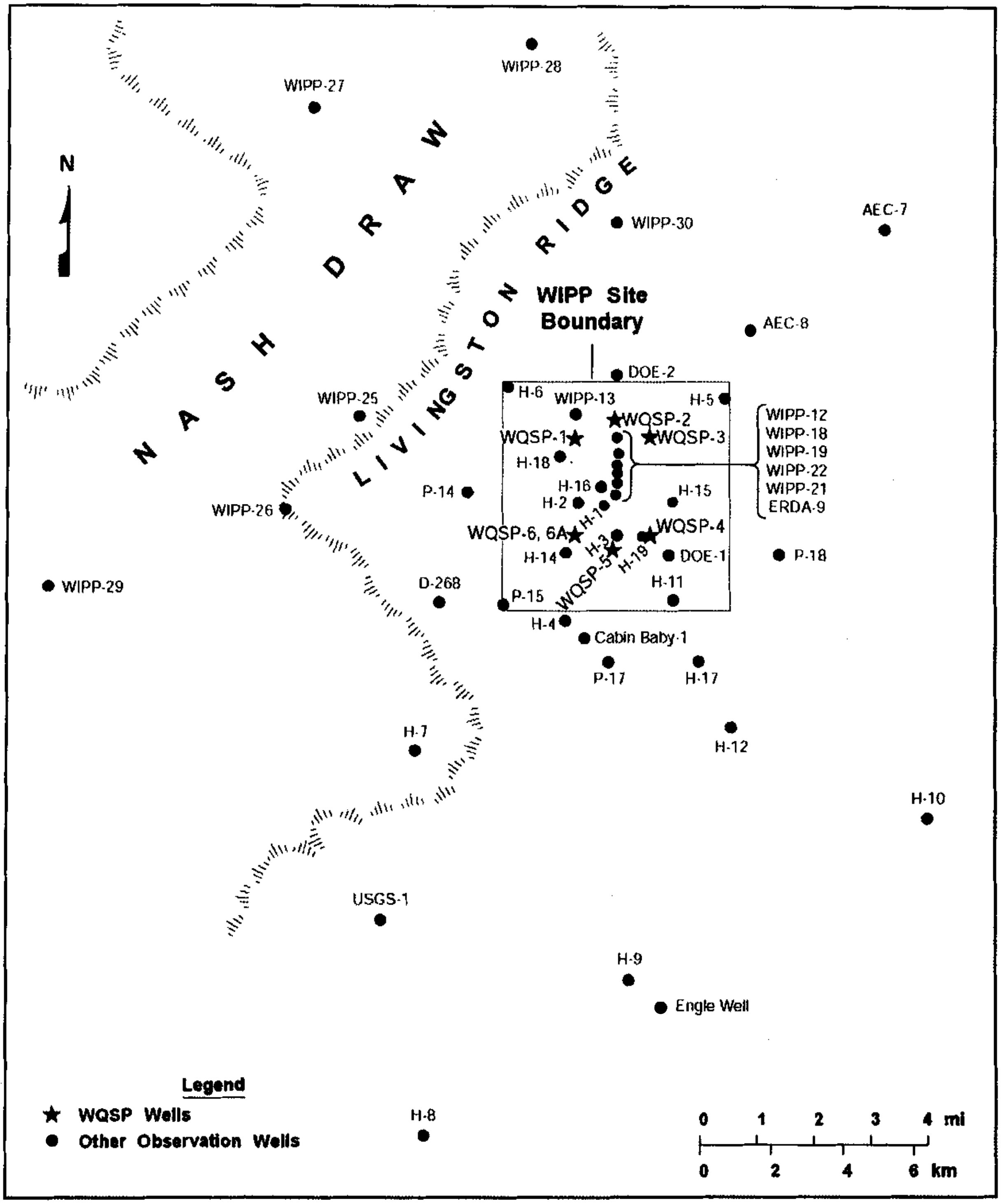

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Figure 1. WIPP monitoring-well network prior to beginning of plugging and abandonment.

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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, 1999). 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.

As discussed earlier, the CCA identified ten COMPs to be monitored. The EPA has accepted these ten parameters through its certification of the WIPP. As such, the CMP 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 (SNL, 2000) 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 (SNL, 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. Exceeding a TV is not to be taken as an indication that continued compliance is in jeopardy, but that further action, such as additional investigative studies, must 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 (T) fields that defined, in part, the flow and transport 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 inferred from well testing 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.

2.2 New Mexico Hazardous Waste Act and WIPP Hazardous Waste Facility Permit

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 Resource Conservation and Recovery Act (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, the New Mexico Environment Department (NMED) has authority over hazardous waste management at the WIPP. The New Mexico Hazardous Waste Act (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.

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.

2.2.1 Detection Monitoring Program

The DMP is included as part of the HWFP (i.e., Module V) 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 (Module V.B.) 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).

Maintenance of the seven DMWs is performed according to the requirements of HWFP Module V.C. The DMWs may be plugged and abandoned (P&A'ed) by submitting a permit modification request to NMED. Plugging and abandonment would be performed in such a manner as to eliminate physical hazards, prevent groundwater contamination, conserve hydrostatic head, and prevent commingling of subsurface waters. A P&A report is to be submitted to NMED 90 days from the date the DMW is removed from the DMP.

Groundwater quality sampling from WQSP-1 through 6 and 6A is required under the DMP (Module V.D. through V.F.) 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[1]. In the second phase, groundwater sampling is 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 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 (Module V.G. and V.H.). 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 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 Dewey Lake, the Forty-niner, the Rustler-Salado contact, and the Bell Canyon. 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 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 measured monthly and, in addition, before each water-quality sampling event.

2.2.2 Site Closure Plan

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 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'ed 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'ed) will be monitored at the same frequency and level of effort described in the DMP for the operational phase.

2.2.3 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-

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

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). Access to BLM lands requires submittal and approval of right-of-way reservations, which may be subject to stipulations that could affect groundwater activities. The BLM, through these stipulations, may require that any well on public lands 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).

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 of the strategic groundwater-monitoring plan for reference (DOE, 2003).

2.3.3 DOE Audits

The EMP that was developed in response to various DOE Orders (e.g., DOE Order 5400.1, DOE Order 5400.5, and DOE/EH-0173T) and that became an integral part of the CCA is subject to regular audits by the DOE Office of Assessment (OA) Team. These audits assess if field sites, such as WIPP, are implementing the orders and commitments of the DOE. Recommendations and findings from these audits could potentially result in changes to and issuance of new requirements related to groundwater hydrology.

2.3.4 New Mexico Statutes Annotated 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 (OSE). Two New Mexico Statutes Annotated (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 OSE 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 OSE. 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 OSE.
- Well drillers must be licensed by the OSE 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 OSE must be notified of the drilling of replacement and supplemental wells.
- The OSE 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 OSE 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.

2.3.5 New Mexico Water Quality Act

The New Mexico Water Quality Act is a state statute promulgated to address water-quality standards for surface and groundwaters of the State of New Mexico, the prevention or abatement of water pollution, and management of the disposal of septage and sludge. This act established the New Mexico Water Quality Control Commission (NMWQCC) and mandated the development of standards and regulations required to implement the act. The regulations promulgated by the NMWQCC are the Water Quality Control Commission Regulations (20.6.2 NMAC) and the Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC). Because no surface waters exist at the WIPP site, surface water regulations do not apply directly; however, groundwater does exist at the site and is, therefore, protected under the act. The general premise of 20.6.2 NMAC is controlling discharges onto or below the surface of the ground to protect groundwater sources that have an existing total dissolved solids (TDS) concentration of 10,000 mg/L or less TDS, for present and potential future use as domestic and agriculture water supply. Discharge in this context is defined as spilling, leaking, pumping, pouring, emitting, emptying, or dumping into water or in a location and manner where there is reasonable probability that the discharge substance will reach subsurface water. The Secretary of the NMWQCC shall be notified of any planned discharge that may move directly or indirectly into the groundwater and shall notify the discharger, within 60 days, if a discharge permit is required.

2.3.6 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

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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.

2.4 Links Between Drivers and Program Components

2.4.1 Resolution of Water-Level-Change Issues

Monitoring of water levels at and near the WIPP site is a requirement of both the CCA and the HWFP. Water-level measurements, cast in terms of equivalent freshwater heads, are used to determine flow rate and direction and to assess continued compliance of the WIPP with applicable regulations. In the COMPs assessment for the year 2000 (SNL, 2001), freshwater heads were compared to trigger value ranges established for 28 of the 32 wells used in generation of the CCA Culebra T fields (water levels in the other four wells could not be determined because the wells had been removed from the monitoring network, i.e., plugged and abandoned, or converted to monitor units other than the Culebra). Of these 28 measurements, freshwater heads in 21 wells appeared to be outside the trigger value ranges, 20 higher and one lower than expected. Head changes in four of the wells could be explained by problems with well casings and/or leaking packers, leaving 17 wells with unexpectedly high freshwater heads. Exceeding trigger values does not mean that continued compliance is in jeopardy, but that further action must be taken.

As a result of the observed water-level changes, EPA has indicated that DOE must incorporate information in the Compliance Recertification Application (CRA) that reflects new knowledge related to the current conceptualization of the WIPP hydrogeology (EPA, 2002). Specifically, EPA has stated:

> "Given recent hydrogeologic data from around the WIPP site, the CRA must justify use of the current conceptual model for shallow geology and the conceptual model implementation in BRAGFLO, SECO, and other appropriate PA codes. Alternatively, the conceptual model should be changed and undergo review by a conceptual model peer review panel."

In addition, the Environmental Evaluation Group (EEG), a stakeholder on WIPP matters, has expressed concerns "over the continuing water level increases in the Culebra aquifer, the possible ramifications on recertification, any deleterious impact on DOE's ability to identify and mitigate fluid injection activities in this resource-rich area, and most importantly, the potential impact on the performance of the repository (EEG, 2002)." Furthermore, EEG states that "unless the source of the increases is identified, the validity of the Culebra conceptual model is in question."

Based on requirements for further investigations when trigger values are exceeded and the concerns expressed by the EPA and EEG, investigative studies have been defined to resolve the water-level changes and are presented in this plan.

2.4.2 Enhancement of Groundwater Models

One of the assumptions underlying the Culebra model used for the CCA was that the Culebra could be considered to be at steady-state. That is, water levels in the Culebra were not expected to change except in response to long-term changes in climatic conditions, with response times on the order of hundreds to thousands of years. Over the period during which WIPP will be monitored, no changes in water levels were expected. The changes in water levels that have been observed are not consistent with this assumption of steady-state conditions. Consequently, our groundwater models must be enhanced to take into account the factors that may be contributing to the observed water-level changes to satisfy the requirements of 40 CFR §194.32(a) cited above in Section 2.1.

2.4.3 Construction of an Optimized Well Network for Culebra Monitoring

Monitoring of Culebra water quality and water levels at and near the WIPP site is a requirement of both the CCA and the HWFP. Water-level measurements, cast in terms of equivalent freshwater heads, are used to determine flow rate and direction for the HWFP. Water quality and freshwater heads are used to assess continued compliance of the WIPP with both EPA certification and HWFP requirements.

Based on the regulatory drivers, the monitoring well network has two requirements: monitoring water quality and water levels in the seven DMP wells (WQSP-1 through 6 and WQSP-6A) and monitoring of water levels only in the other wells in the existing well monitoring network. The six WQSP wells completed to the Culebra are pumped twice a year for water-quality samples. This pumping causes the water levels in these wells to be in a continual state of fluctuation, and prevents the data from these wells from being used to determine the groundwater flow rate and direction as required by the HWFP. The requirements for determination of flow rate and direction are in fact met by the monitoring performed in wells other than the six Culebra DMP WQSP wells. Thus, maintenance of an adequate network of wells apart from the DMP (WQSP) wells is essential in meeting our regulatory requirements.

The existing well network includes approximately 70 wells. Many of these wells were converted geologic core holes or potash resource evaluation holes, so were not constructed or located specifically for characterizing the WIPP groundwater hydrology. In addition, most of the existing wells are steel-cased and were constructed more than 20 years ago. Because of age and the corrosive brine environments in some wells, the steel casings are deteriorating, requiring that they be P&A'ed. It is likely that all steel-cased wells will need to be P&A'ed within the next 5 to 10 years, thereby reducing the number of wells in the monitoring network to a value less than that needed to quantify flow rate and direction accurately.

Issues of current well location, age, and P&A suggest that wells will need to be replaced and, in some cases, relocated. These issues raise the question of what constitutes an adequate network of wells for monitoring WIPP hydrology. In a homogeneous medium under steady-state conditions, three wells along the northern WIPP boundary and three wells along the southern boundary might be adequate to define groundwater flow direction and velocity across the site assuming the hydraulic gradient trends north to south. The Culebra, however, is not a homogeneous medium, nor does it appear to be at steady-state. The transmissivity of the Culebra varies over six orders of magnitude from east of the WIPP site to Nash Draw located west of the site. This heterogeneity causes both flow direction and velocity to be highly variable and location-specific. In order to understand flow patterns on the WIPP site, more wells are needed than simply three upgradient and three downgradient. In addition, monitoring since the time of the CCA has shown that water levels in the Culebra and other strata change in response to a variety of stresses originating off the WIPP site. If the monitoring network were restricted to wells only on the WIPP site, there would be little chance of understanding why water levels were changing. Thus, an optimized monitoring network should include wells both on the WIPP site and several miles from the WIPP site in key locations. Justification for the number of wells and their locations is provided in Section 5.

2.4.4 Plugging and Abandonment of Deteriorating Steel-Cased Wells

As discussed above, the steel-cased wells in the existing groundwater-monitoring network are deteriorating because of age and the corrosive brine environment in some of the wells. Several wells have already been P&A'ed and others will need to be P&A'ed based on ultrasonic imaging tests conducted recently by the MOC. P&A requirements are addressed in the HWFP (Module V.C.), BLM special stipulations (attached to Right-of-Way No. NM-108365 (WIPP well bores), subsection 2(a)(b)), and in NMSA statutes enforced by the New Mexico Office of the State Engineer (Articles 4-19.1 & 4-20.2 of the OSE "Rules and Regulations Governing Drilling of Wells and Appropriation and Use of Groundwater in New Mexico").

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3. Background

Background information about the four program components defined above is presented in this section to provide a context for the planned activities discussed in subsequent sections.

3.1 Observed Water-Level Changes and Potential Causes

Water-level records (hydrographs) from the WIPP wells reveal a variety of changes since monitoring began in the earliest wells in 1977. Hydrographs from the wells within the 16 square miles of the WIPP site typically show myriad effects because of the extensive well testing and shaft activities that occurred in the 1980's. Hydrographs from wells in Nash Draw and P-14 typically do not show responses to tests conducted on the WIPP site, but nevertheless show broad rising and falling trends over periods of several years (Figure 2). Since 1989, a general long-term rise has been observed in both Culebra and Magenta water levels (e.g., Figure 3) over a broad area including Nash Draw. At the time of the CCA, this long-term rise was recognized, but was thought (outside of Nash Draw) to represent the recovery from the accumulation of tests and shaft leakage that had occurred at the WIPP site since the late 1970's. Water levels in Nash Draw were thought to respond to changes in the amounts of potash mill effluent discharged into the draw (e.g., Silva (1996)). As the rise in water levels has continued over recent years, however, observed heads have exceeded the ranges of uncertainty established for the steady-state heads in most of the 32 wells used in calibration of the T fields for the CCA, throwing into question the earlier explanation for the rise. In addition, short-term fluctuations of unknown origin in Culebra water levels have occurred in specific areas (e.g., Figure 4).

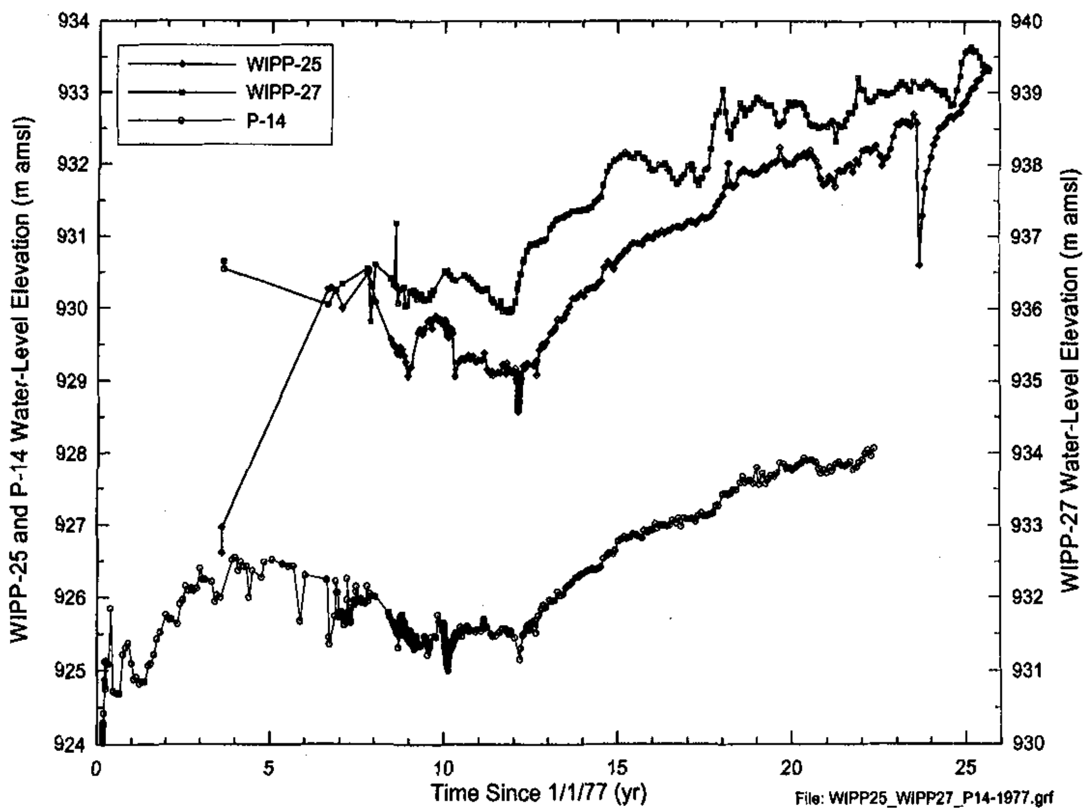

Figure 2. Water-level trends in Nash Draw wells and P-14.

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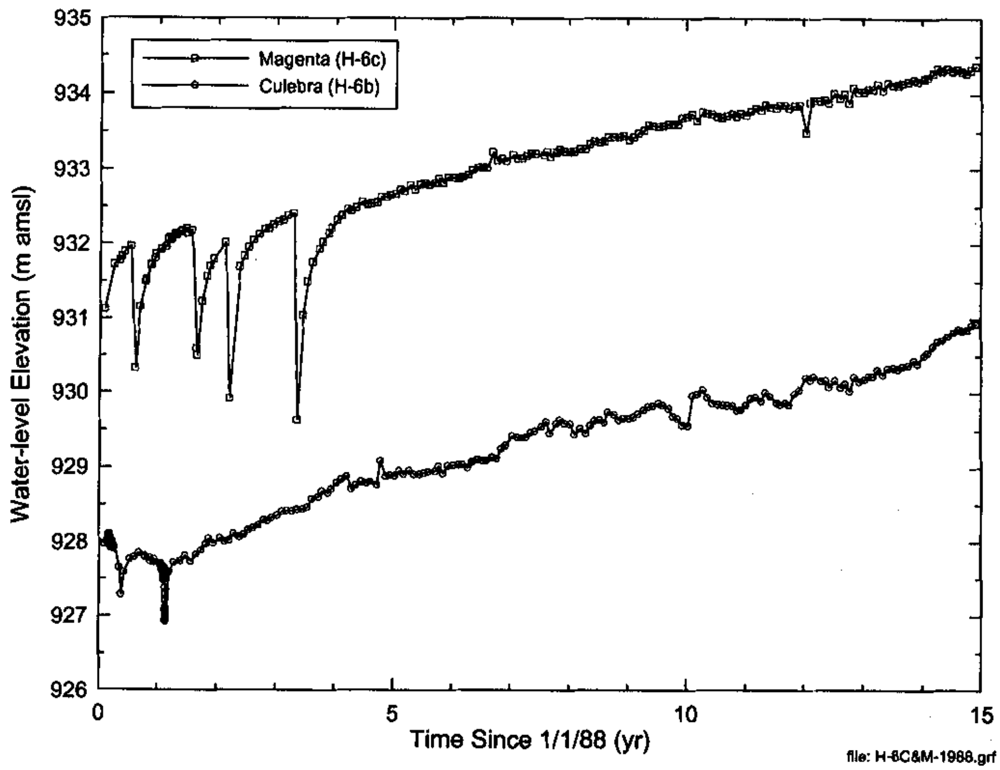

Figure 3. Rising Culebra and Magenta water levels at H-6.

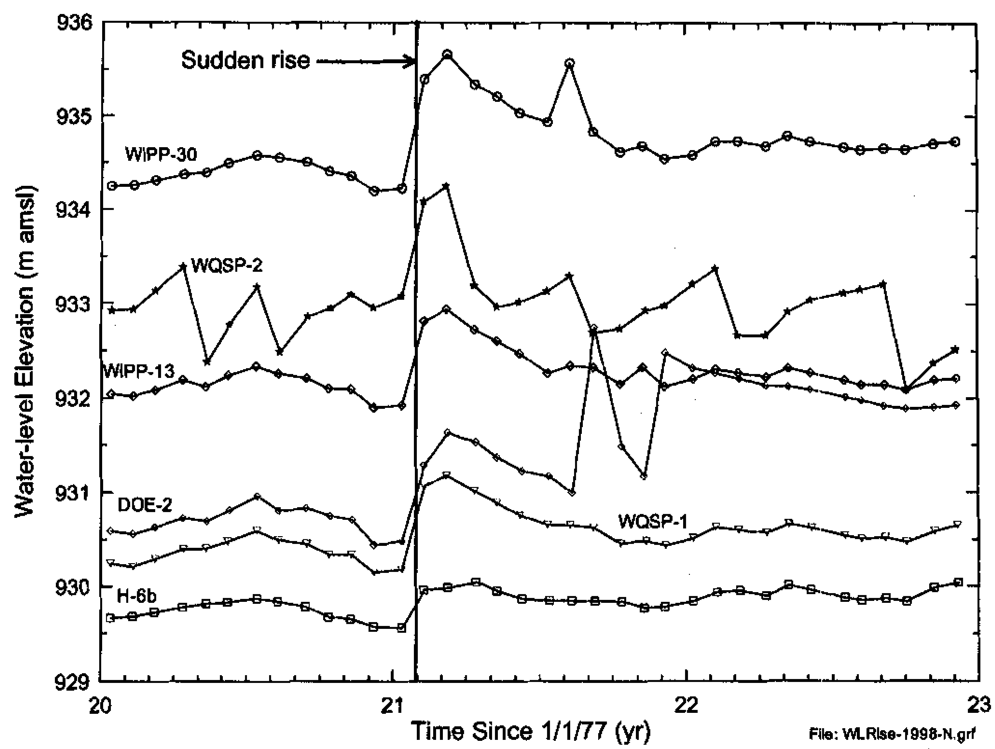

Figure 4. Example of short-term water-level fluctuation north of WIPP.

In addition to the water-level changes discussed above, significant water-level fluctuations have also been observed in the Culebra at H-9 south of the WIPP site (Figure 5). These changes have propagated to the north to wells near the southern WIPP site boundary such as P-17 and H-12. Because of the presence of salt-water-injection wells several miles northeast of H-9 and extensive oil and gas drilling around H-9 (see Figure 6), speculation as to the cause of the water-level changes has centered on leaking boreholes (Silva, 1996). The target horizon for salt-water-injection wells (indicated by single diagonal lines in Figure 6) lies in the Bell Canyon or deeper formations. For water being injected at those depths to be influencing Rustler aquifers, it would have to be leaking either around the casing in the injection wells themselves or through other wells, perhaps improperly plugged and abandoned (P&A'ed wells are marked by horizontal bars in Figure 6), that penetrate the injection horizon.

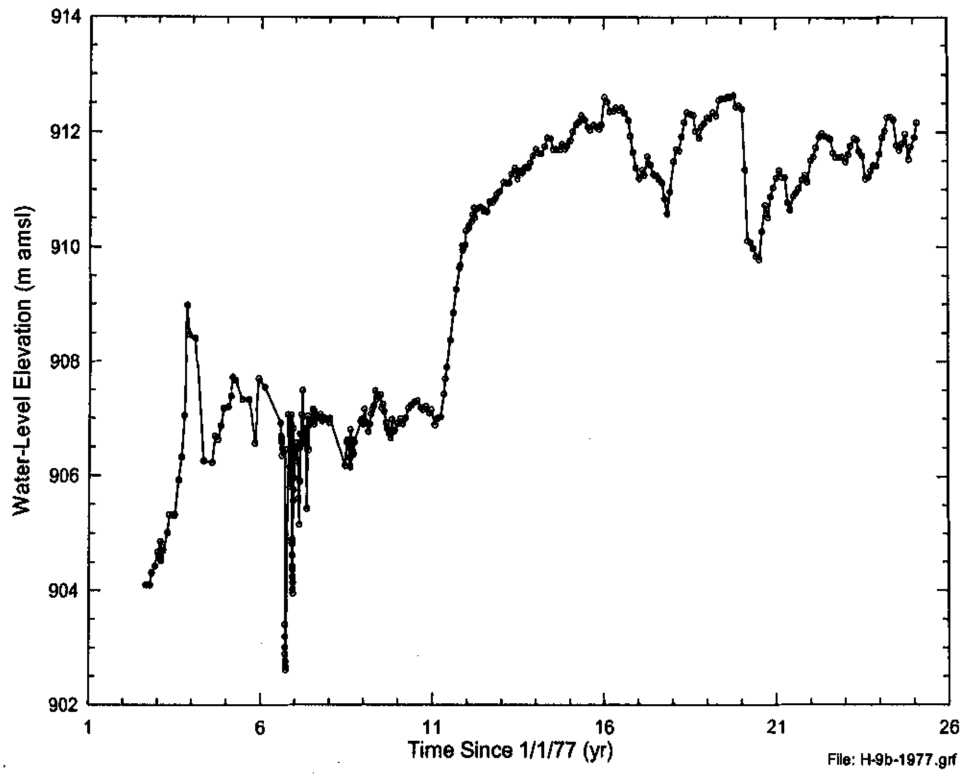

Figure 5. Culebra water levels at H-9.

Other possible explanations for observed water-level changes center on potash exploration holes. The potash exploration holes shown on Figure 6 are used to evaluate potash resources in the upper Salado, and are typically plugged and abandoned shortly after drilling. Some of these holes date back to the first half of the twentieth century, when plugging and abandonment practices were not as rigorous as they are today. From a search of BLM records, plugging and abandonment records were found for 576 exploration holes in the vicinity of the WIPP site (T 20-24 S, R 30-32 E). Figure 7 shows the locations of 84 of these holes that were not filled with cement to the ground surface, but were instead filled with mud, sand, cuttings, salt cuttings, and/or brine, or were simply left open. These holes provide potential avenues for vertical hydraulic communication among the formations above the Salado.

Figure 6. Petroleum and potash industry boreholes around the WIPP site.

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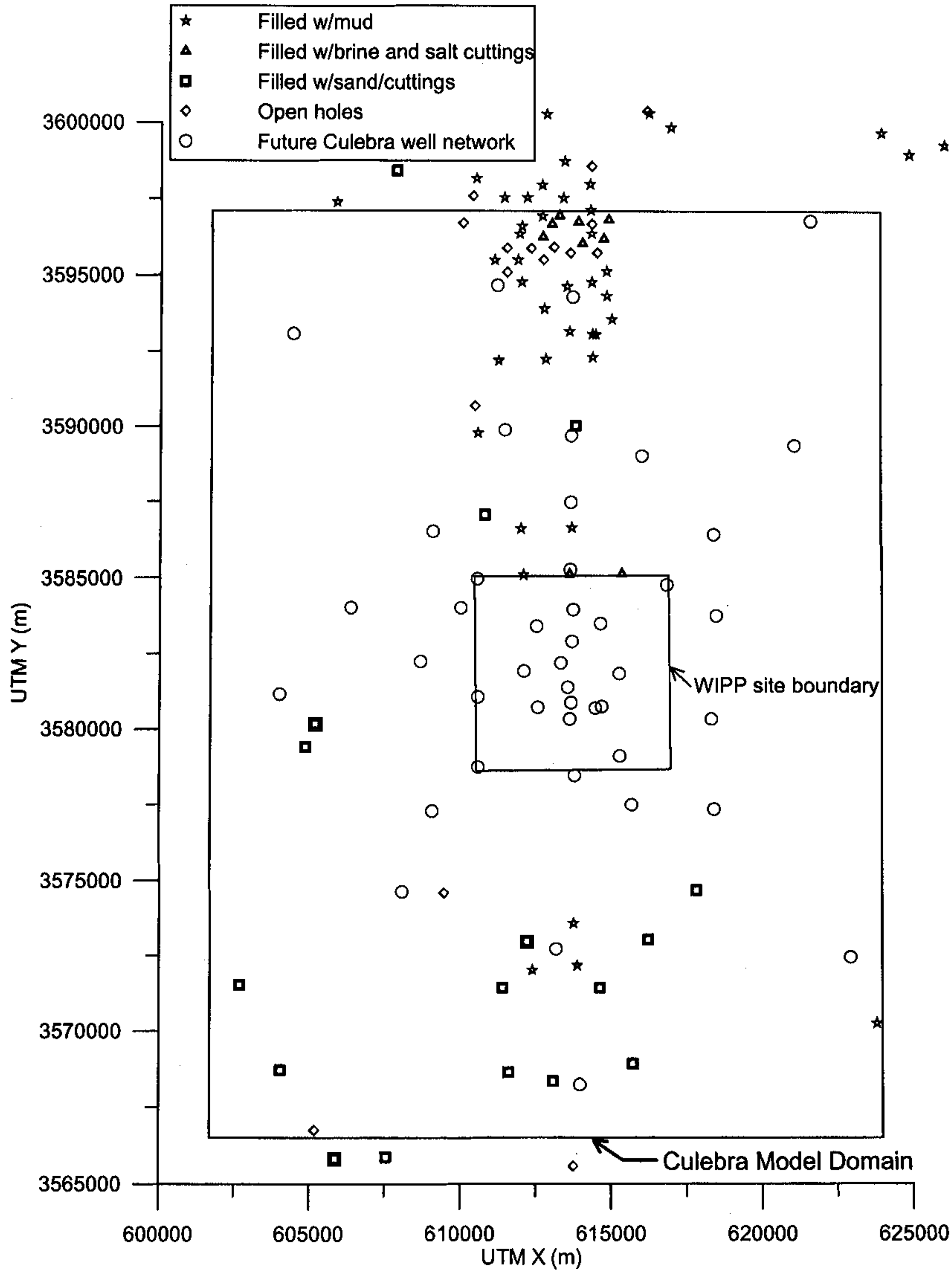

Figure 7. Potentially leaky potash holes.

Many of the poorly plugged potash holes are located near, and in some cases beneath, the Mississippi East tailings pile located 7 to 8 miles due north of the WIPP site (Figure 8). Disposal of mine tailings and refining-process effluent at that location began in 1965. Records obtained from the New Mexico State Engineer show how much water has been pumped from local aquifers (Ogallala or Capitan) each year since 1973 for use in the potash-refining process (Figure 9). Since 1973, an average of 2400 acre-feet of water per year has been pumped. Based on knowledge of the potash refining process, we estimate that approximately 90% of this water is discharged onto the tailings pile. Geohydrology Associates (1978) estimated that approximately half of the brine discharged seeps into the ground annually, while the remainder evaporates. Therefore, on average, approximately 1100 acre-ft of brine may be infiltrating each year. Brine from this tailings pile may enter the Rustler through leaky boreholes and/or by first moving laterally into Nash Draw and then downward through subsidence fractures that have opened over potash mine workings (Figure 10).

Since the time of the CCA and the modeling reported by Corbet and Knupp (1996), many new petroleum exploration holes have been drilled around the WIPP site, as shown by the blue wells on Figure 6. A review of new and additional well logs from the potash and petroleum industries has identified two potential "re-entrants" of Salado dissolution extending from Nash Draw under the surface of Livingston Ridge to the southeast (see blue line on Figure 8). If these dissolution re-entrants are present and have increased the permeability of the Rustler and shallower units, they may provide local short-circuits of the flow system that were not captured by the CCA modeling.

Based on the information discussed above, three scenarios have been defined that are thought to have the potential to affect water levels and are considered worth investigating further:

1. Leakage from the Mississippi East tailings pile/ponds causing locally elevated Culebra and Magenta heads, which then propagate to the south;
2. Leakage through boreholes that are poorly cased or improperly plugged and abandoned, including both leakage among units above the Salado and leakage from units (or injection) below the Salado; and
3. High-T conduits caused by dissolution extending from Nash Draw to the (south)east allowing heads in Nash Draw to affect heads under Livingston Ridge (including the WIPP site) more than previously thought.

Note that these scenarios are not mutually exclusive, and may all be contributing to the observed water-level fluctuations.

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WIPP SITE AND SURROUNDING AREAS

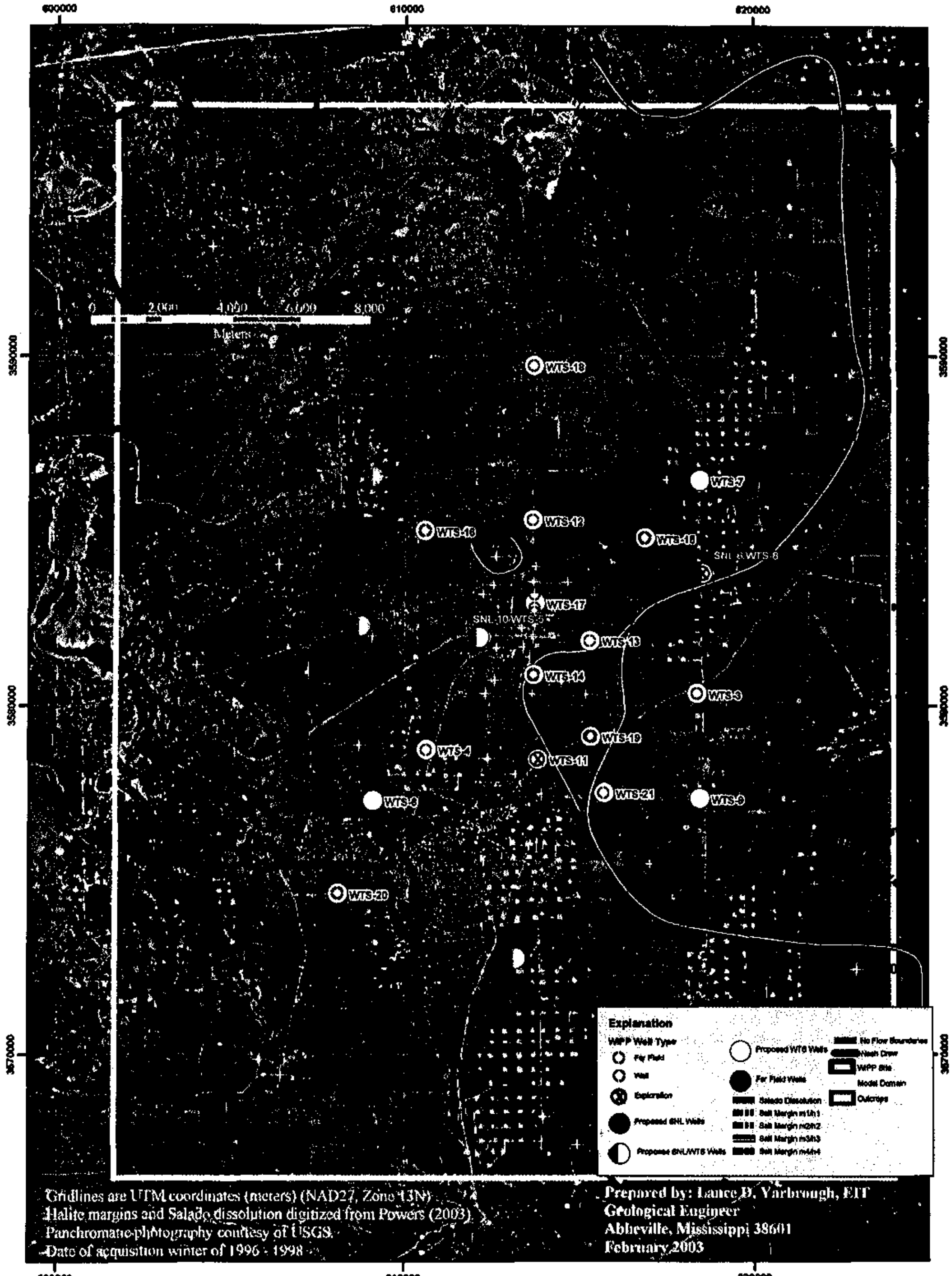

Figure 8. Air-photo map of WIPP area showing halite margins, locations of planned new wells, and Culebra model domain.

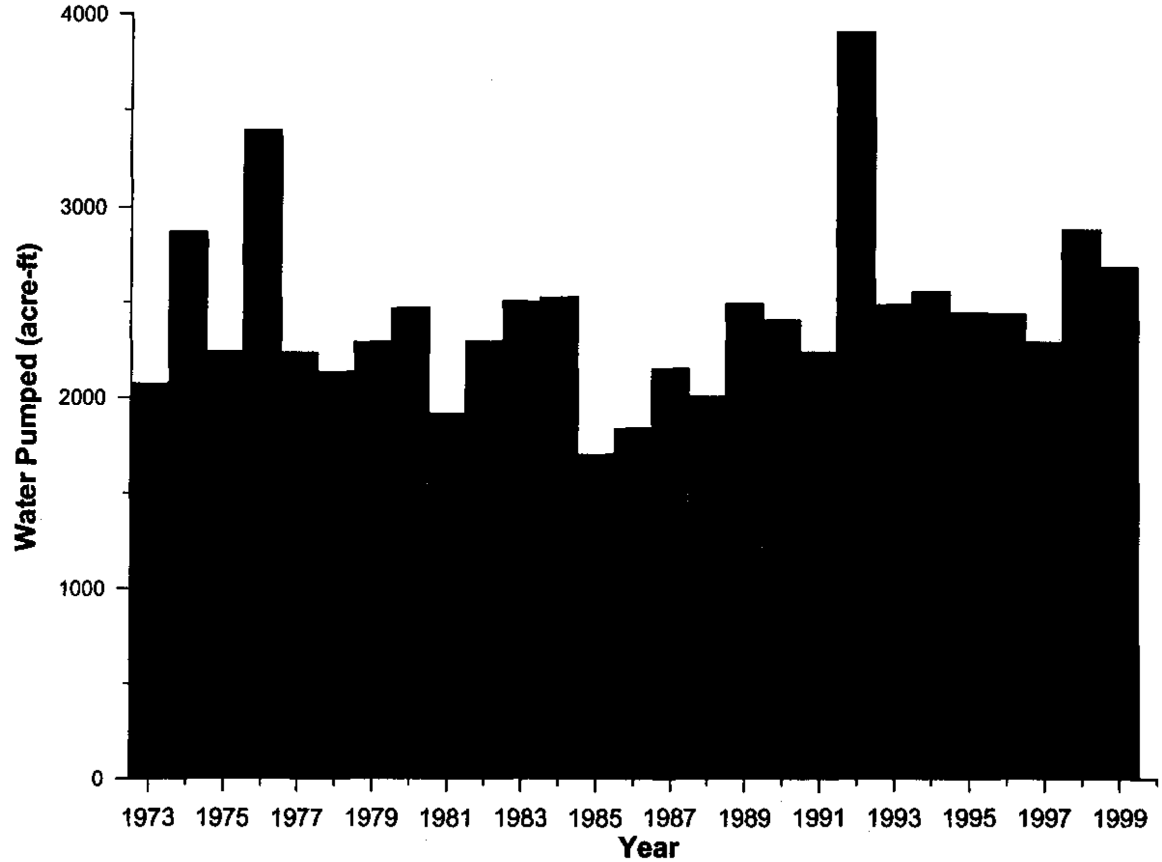

Figure 9. Annual water pumpage at Mississippi East potash mill location.

3.2 CCA Conceptual and Numerical Hydrogeologic Models

For the CCA, a basin-scale conceptual model of WIPP hydrology was developed and evaluated using a three-dimensional numerical model (Corbet and Knupp, 1996). In this conceptual model, groundwater flow in the Culebra in the vicinity of the WIPP site is considered a portion of a larger hydrologic system that includes all of the strata overlying the Salado Formation. This system extends laterally well beyond the WIPP site to the boundaries of the groundwater basin. A continuous water table extends across this basin, generally in the Dewey Lake Redbeds, although in some locations it may be present in rock of such low permeability that it is not easily observed. The shape and elevation of the water table largely determine rates and directions of groundwater flow in the Culebra and other units. The water table and modern-day pattern of groundwater flow have not fully equilibrated to the drier climate that has prevailed since the end of the Pleistocene, with the result that water levels might be expected to be slowly declining. Water levels might rise or fall by a few meters over a period of centuries, however, in response to cycles of wetter and drier climate that have occurred over the past 8,000 years. The lag time between a climate change and the resulting water-level change is probably several centuries.

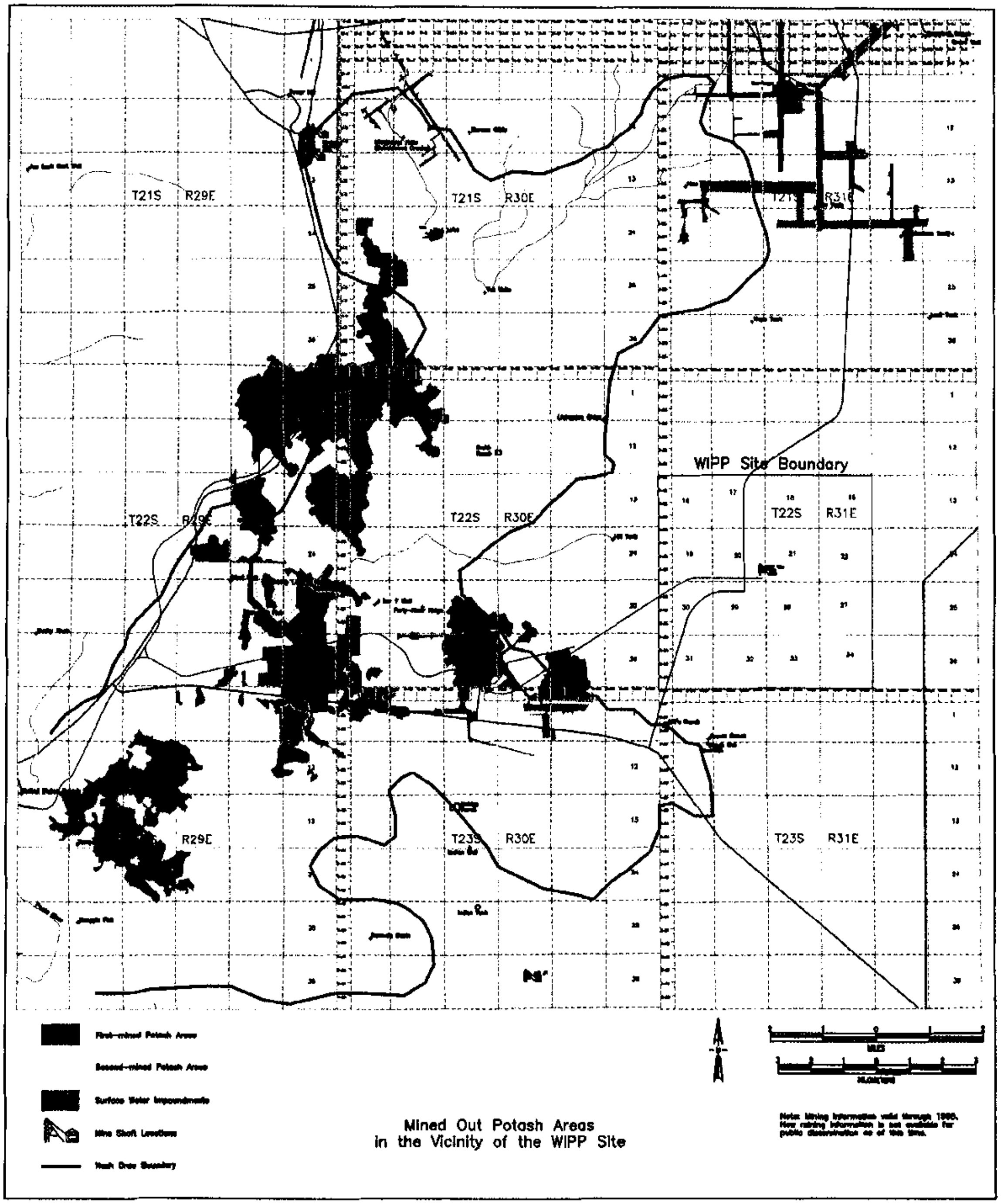

Figure 10. Mined areas in Nash Draw.

Dissolution of the upper Salado, and associated subsidence, collapse, and fracturing, have resulted in a zoned distribution of permeability in the overlying units. Permeabilities are orders of magnitude higher in areas where dissolution has disrupted stratigraphic layering than in areas where the strata are intact. The WIPP site lies in the transition region between these two areas. None of the water in the Culebra at the WIPP site is thought to originate where the Culebra crops out or where overlying units have been removed or fractured (i.e., west and northwest of WIPP), but instead is thought to come from the east and northeast. The time required for water to travel from the water table upgradient of WIPP to the Culebra at the WIPP site is probably on the order of thousands to tens of thousands of years. Within the WIPP site boundary, groundwater inflow to the Culebra is predominantly from lateral flow, with a minor component coming from very slow leakage from the overlying Tamarisk—none of it comes from precipitation on the WIPP site land surface. Nearly all of the groundwater within the Culebra exits the WIPP site by lateral flow, so treating the Culebra as a fully confined aquifer was considered a reasonable approach to simulating off-site transport of radionuclides.

Because of the distance of the WIPP site from the natural hydrologic boundaries of the groundwater basin and the long times required for changes in the boundary conditions to be manifested at WIPP, we assumed for the CCA that, except for the residual hydrologic effects of WIPP's own activities, the Culebra at WIPP could be considered to be under steady-state conditions. Culebra transmissivity (T) fields were generated by, first, kriging the values of T inferred from hydraulic tests at individual wells to generate continuous distributions of T over the model domain. This was done using indicator categorical simulation to preserve the observed difference between low-T ($\log T < -5.9$ m^2/s) and high-T regions of the Culebra (see Appendix TFIELD in DOE, 1996). These T fields were then calibrated using a pilot-point method to inferred steady-state freshwater head values at 32 wells and to transient responses observed in connection with large-scale pumping tests, shaft construction, and leakage into shafts.

Three sets of 100 equally probable realizations of the Culebra T field were created (CCA replicates 1, 2, and 3). Groundwater flow and radionuclide transport through these T fields were simulated to assess the radionuclide releases that might occur from the WIPP repository to the accessible environment under undisturbed conditions, conditions of increased potash mining near WIPP in the future, and potential human intrusion of the repository.

3.3 Monitoring Network

Historically, WIPP has monitored water levels in the Culebra, Magenta, and other water-bearing zones from a network of oil-field-style steel-cased wells that were drilled for site-characterization purposes. Using these wells, WIPP has been able to present adequate groundwater flow rate and direction data in the past to gain certification of the repository and the HWFP. However, most of these wells were drilled over 20 years ago and are now beginning to fail because they are exposed to high-salinity groundwater that corrodes and deteriorates the steel well casing and cement bond between the casing and borehole wall. As the individual wells begin to fail or provide data that are uncertain, our ability to provide the data required to maintain compliance with the repository certification and the HWFP is impaired. At some point, we will not have sufficient wells to continue to define groundwater flow rate and direction as required by the HWFP and the CCA. Thus, we must begin to replace the old wells that are plugged or that are providing unreliable data so that we can demonstrate to the regulators the same level of knowledge, if not greater, that we exhibited when we gained our initial certification and permit.

In addition to the units above the Salado, WIPP has also monitored water levels in the Bell Canyon Formation, below the Salado and Castile Formations. The Bell Canyon is one of the primary targets for oil exploration around the WIPP site, and is also the receiving horizon for salt-water-disposal injection wells. Monitoring in the Bell Canyon provides assurance that petroleum-industry activities around the WIPP site are not altering conditions in the Bell Canyon in such a way as to compromise WIPP's performance. Accordingly, we must maintain the capability to continue monitoring in the Bell Canyon.

3.4 Plugging and Abandonment

As wells deteriorate and lose integrity, or as they are no longer needed, they must be plugged and abandoned in accordance with the regulations described in Section 2. Plugging and abandonment must be coordinated with installation of new wells, however, to ensure that an adequate network to meet our monitoring requirements exists at all times.

The typical failure mode for steel-cased wells around the WIPP site is by holes developing in the casing through corrosion (rust). The high-salinity brines found in wells around the WIPP site accelerate rust compared to fresh water. In addition, wells west of the site in Nash Draw are subject to ground movement caused by subsidence over potash mines. This earth movement may cause the cement bond behind the well casing to fracture. When such fracturing occurs, fluids may migrate behind the casing, allowing corrosion to occur on both the inner and outer surfaces of the casing. This type of condition was found to have occurred at well WIPP-28, located at the north end of Nash Draw, when it was plugged and abandoned.

To date, eight steel-cased WIPP wells have failed at ages between 21 and 23 years. The majority of the remaining steel-cased WIPP wells are at least 20 years old, and none are expected to survive beyond approximately 2010.

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4. Modeling Activities

As discussed above, enhanced conceptual and numerical models of WIPP hydrology will be developed as part of this program. This activity has several distinct phases. First, an assessment begun in FY02 of the effects of water levels outside the calibrated ranges on the validity of the CCA T fields will be completed. This assessment is being performed using what might be termed a "first generation" of new T fields based on an enhanced conceptual model of the Culebra. When completed, these first-generation T fields will be used in compliance calculations for the first WIPP CRA in 2003, and in a preliminary assessment of the scenarios outlined in Section 3.1. As the field activities discussed in Section 5 are completed and provide new data, the conceptual model will be enhanced further, and a "second generation" of Culebra T fields will be created. At the same time, a model of Magenta hydrology will be developed that can be linked, as appropriate, to the new Culebra model. The final result will be a new, peer-reviewed model, or set of models, that can be used in compliance calculations for the second WIPP CRA in 2008.

4.1 Revised Conceptual Model and First-Generation Base T Fields

While the conceptual basin-scale model described in Section 3.2 above is still considered essentially correct, some refinement of it is now thought to be necessary to account for localized conditions as described in the models of Holt and Powers (1988) and Holt (1997). The basin-scale conceptual model was the product, in part, of a 3D regional modeling study using 2-km by 2-km cells. The existence and effects of smaller scale features could not be assessed during that study. Such features might create local conditions different than those predicted by the regional model. In addition, our earlier conceptual model did not include anthropogenic influences that might currently be affecting the system, but instead assumed that, apart from hydrologic disturbances caused by WIPP's own activities, the hydrologic system was essentially at steady state.

Holt and Powers (1988) developed a more detailed conceptual model for the Rustler Formation based on examination of drillhole logs, core, outcrops, and shaft exposures. Holt (1997) later refined this model with respect to the Culebra. Holt and Powers observed four horizons within the Rustler Formation where mudstone is present. In some locations, halite is found with the mudstone at these horizons whereas in other locations it is not. They identified these horizons, shown in Figure 11, as follows:

m1/h1—below the anhydrite layer in the middle of the Los Medaños Member
m2/h2—immediately below the Culebra at the top of the Los Medaños Member
m3/h3—between anhydrite layers in the lower Tamarisk Member
m4/h4—between anhydrite layers in the middle of the Forty-niner Member

Based on drillhole logs, they mapped the margins of the halite-bearing zones as shown (updated with more recent information) in Figure 8. The Rustler dips to the east from Nash Draw, and halite is found east of the margins, where the Rustler is buried more deeply.

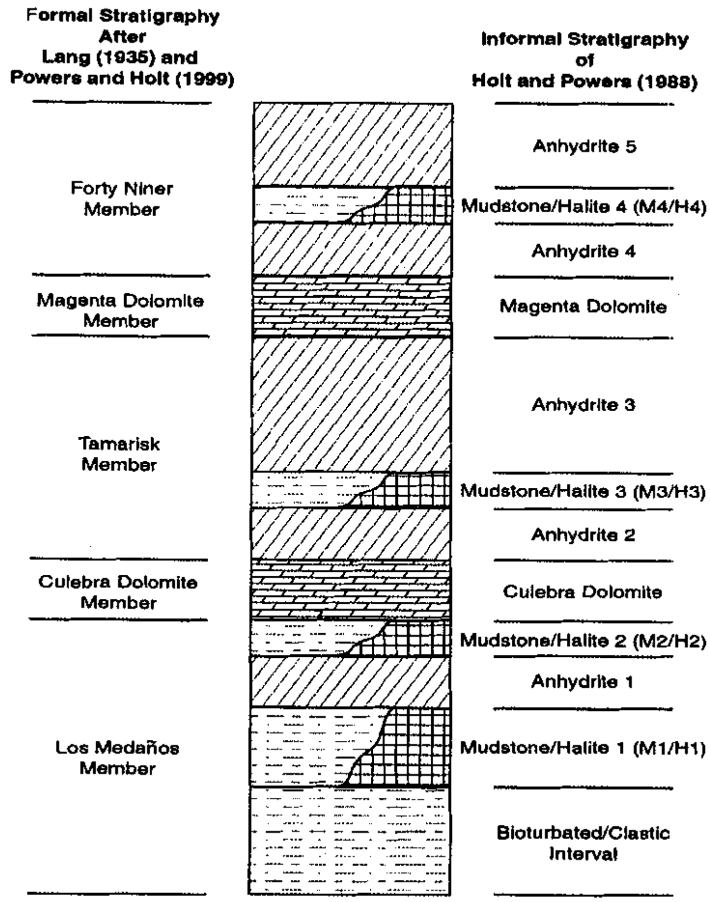

Figure 11. Stratigraphic subdivisions of the Rustler Formation.

Whereas early researchers (e.g., Snyder, 1985) interpreted the absence of halite west of these margins as evidence of dissolution, Holt and Powers (1988) interpreted it as reflecting changes in the depositional environment, not dissolution. In their model, the only place where dissolution of Rustler halite may have occurred is along the present-day margins.

The occurrence (or not) of dissolution is important because of its possible effects on the hydraulic properties of overlying units. Nash Draw, to the west of the WIPP site, is an area where dissolution of the upper Salado has occurred, resulting in subsidence and collapse of the overlying Rustler. Figure 8 shows how the eastward limit of dissolution of the upper Salado interpreted from drillhole logs coincides with the surface expression of Nash Draw. The Culebra is fractured and orders of magnitude more transmissive in Nash Draw than it is east of the WIPP site. Presumably, dissolution of halite from Rustler units would also result in increased transmissivity in the overlying dolomites.

Culebra transmissivity varies over three orders of magnitude on the WIPP site. If this variation is not caused by dissolution of Rustler halite, what is its source? According to Holt (1997), the spatial distribution of Culebra transmissivity is largely a function of a series of deterministic geologic controls, including Culebra overburden thickness, dissolution of the upper Salado Formation (already discussed), and the occurrence of halite in units above or below the Culebra.

Overburden thickness is a metric for two different controls on Culebra transmissivity. First, fracture apertures tend to decrease with increasing overburden thickness, which should lead to lower transmissivity where Culebra depths are great. Second, erosion of overburden leads to stress-relief fractures, and the amount of Culebra fracturing increases as the overburden thickness decreases. Thus, generally speaking, Culebra transmissivities should increase from east to west as overburden thickness decreases.

All wells (e.g., H-12) located where halite occurs in the m2/h2 or m3/h3 intervals show low Culebra transmissivity. Transmissivity data are limited in this region, but it is unlikely that halite would survive in regions of high transmissivity because halite units are very close (several m) to the Culebra and would likely be dissolved by under-saturated Culebra waters. We therefore assume that high-transmissivity zones do not occur in regions where halite is present in the m2/h2 or m3/h3 intervals. In regions where halite is present in both the m2/h2 and m3/h3 intervals, we have no reliable estimates of Culebra transmissivity. Based upon geologic observations of halite-bound units elsewhere within the WIPP area, Holt (1997) suggests that porosity within the Culebra may contain abundant halite cements in these areas and transmissivity is correspondingly low. High-transmissivity zones within the Culebra occur between areas affected by Salado dissolution and areas where halite is present in the m2/h2 and m3/h3 intervals. In these zones, fractures are well interconnected, and fracture interconnectivity is controlled by a complicated history of fracturing with several episodes of cement precipitation and dissolution (Beauheim and Holt, 1990; Holt, 1997). No clear deterministic controls on high transmissivity have been identified in the region east of the Salado dissolution limit but west of the m2/h2 and m3/h3 halite margins, so we currently treat the distribution of high T in this region as the product of a stochastic process.

Development of a new generation of T fields based on the conceptual model presented above was begun in FY02 under Analysis Plan AP-088 (Beauheim, 2002). The approach taken in development of the new first-generation Culebra T fields involved, first, defining a statistical correlation between Culebra transmissivities inferred from tests at individual wells and the thickness of overburden, taking into account geologic factors including the occurrence of dissolution of the upper Salado Formation, the presence of halite above or below the Culebra, and position between the m2/h2 and m3/h3 halite margins and the limit of Salado dissolution (Figure 12; Holt (2002)). This correlation was then used in combination with maps of the geologic factors (which are based on data from many more boreholes than those from which Culebra T information is available) to create 100 equally likely realizations of the Culebra transmissivity distribution ("base" T fields) over the domain of interest (e.g., Figure 13).

The modeling domain consists of a rectangle 22.3 km by 30.6 km in extent. It covers an area similar to that modeled in the CCA, but is oriented with its long axis extending from north to south, parallel to the principal flow direction in the Culebra, like the model domain of LaVenue et al. (1990). The modeling is being performed using MODFLOW 2000 with a uniform grid of 50-m by 50-m elements. Heads are specified for all boundaries except on the west. The northern model boundary is slightly beyond the limit of our data, and coincides with an inferred groundwater divide. The eastern boundary lies in a region of inferred low transmissivity, where the 3D model of Corbet and Knupp (1996) indicates flow is predominantly to the west. The southern boundary is slightly beyond the limit of our data, in an area where flow is believed to be

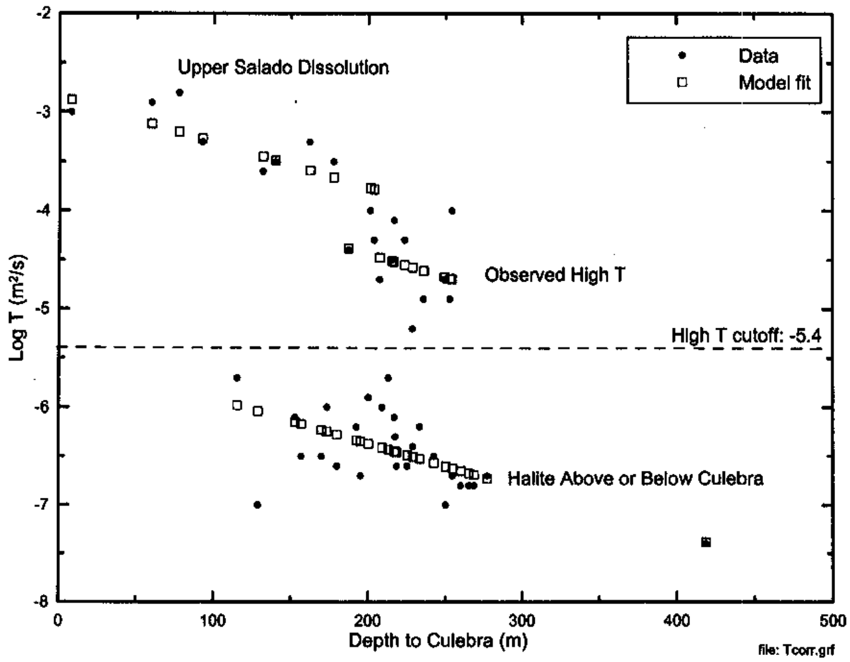

Figure 12. Correlation between Culebra T and overburden thickness for different geologic environments.

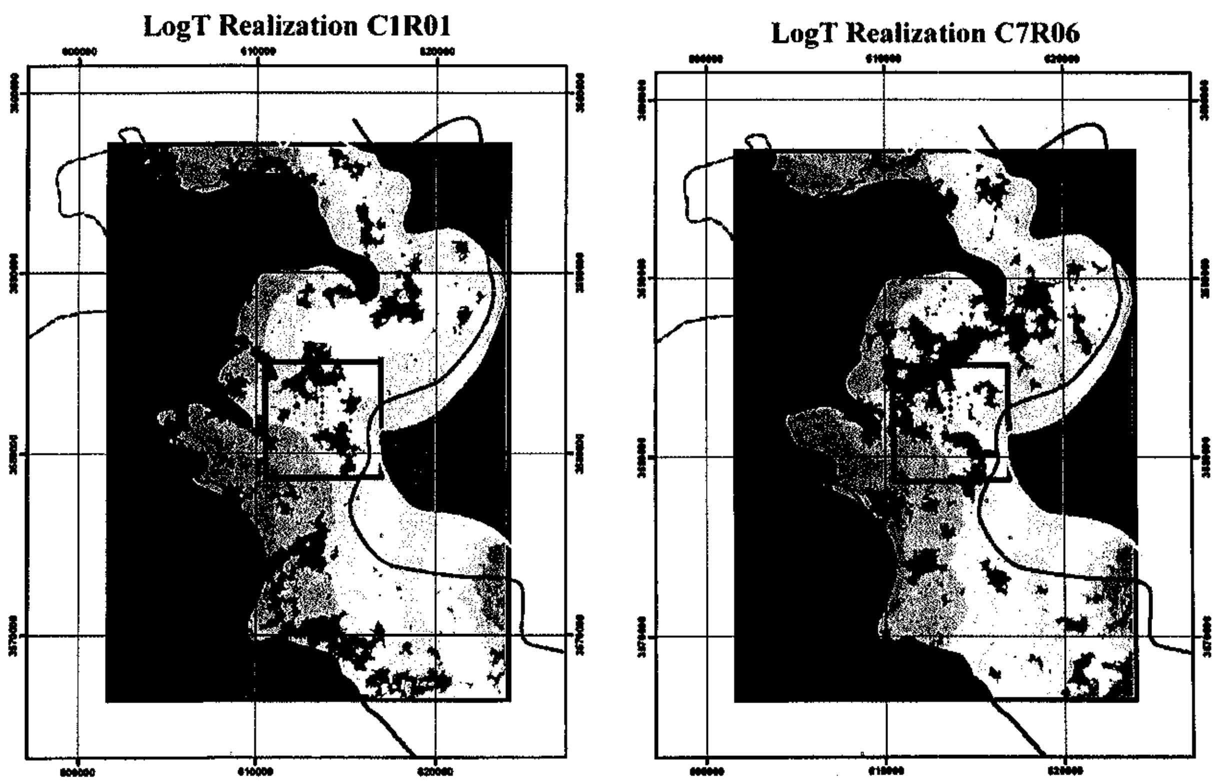

Figure 13. Example first-generation base T fields.

to the south. The western boundary of the model domain passes through Nash Draw. Groundwater is believed to flow both down the main axis of Nash Draw from northeast to southwest, and down the axis of the southern arm from northwest to southeast. Thus, flow lines along these axes are used as no-flow boundaries within the model domain (see green diagonal lines on Figure 8).

4.2 Impact Assessment

The first-generation base T fields described above are being used to evaluate the effect, if any, of simple increases in head on the inferred distribution of Culebra transmissivity. We hypothesize that while the CCA assumption of Culebra heads being in steady state may have been incorrect, this would have no effect on the calibration of the T fields. As long as the heads used for calibration were in equilibrium with the boundary conditions on the system and both were reasonably defined in the model, an appropriate representation of the Culebra T fields should have been obtained. Thus, the major objective of this activity is to develop T fields using heads from three different time periods to show whether or not the calibration is significantly affected if the equilibrium state of the overall system changes. The groundwater travel time from above the center of the WIPP disposal panels to the WIPP site boundary (accessible environment) is being used as the metric by which a "significant" change to the T-field calibration is judged.

Calibration is performed using the parameter-estimation code PEST and pilot points to modify the base T fields as little as possible while bringing simulated heads into agreement with measured heads. The base T fields have been conditioned to Culebra hydraulic heads representing equilibrium conditions at 10-year intervals (i.e., 1980, 1990, and 2000) and also to the "steady-state" heads used in the CCA, producing four sets of 100 realizations of the Culebra T field.

To determine how much effect the differences in head have on the resulting T fields, cumulative distribution functions (CDF's) of the groundwater travel times from a point above the center of the waste-disposal panels to the WIPP site boundary have been generated for each set of 100 realizations. These CDF's have been compared to a CDF generated of the travel times determined for replicate 1 of the CCA transient-calibrated T fields (Figure 14). Figure 14 shows that the travel times in the four new sets of T fields are longer than those given in the CCA. However, the new T fields have not yet been calibrated to transient heads, and the process of transient calibration has been found in the past to decrease travel times.

The next step in T-field generation is to calibrate a set of T fields to both equilibrium and transient conditions. The equilibrium conditions that will be used for this step are the 2000 heads, because those heads are closer to current conditions than either the 1980 or 1990 heads, and also produced the fastest travel times. The transient heads that will be used in the calibration represent the responses observed in various wells to the following events:

- construction of, and leakage into, the exploratory (now salt) and ventilation (now waste-handling) shafts;
- the H-3 multipad pumping test;
- the WIPP-13 multipad pumping test;
- the P-14 pumping test;

- the 1995-96 H-19 and H-11 tracer tests;
- the WQSP-1 pumping test; and
- the WQSP-2 pumping test.

Once the calibration is completed, a CDF of the travel times will be generated for comparison to the CCA replicate 1 CDF shown in Figure 14. Finally, the transient-calibrated T fields will be altered to represent the potential effects of future potash mining as was done for the CCA. Again, CDF's of travel times for the mining cases will be compared to the CDF's generated of the travel times provided by CCA replicate 1 modified for the mining scenarios. The transient-calibrated T fields will then be used for compliance calculations for the first CRA.

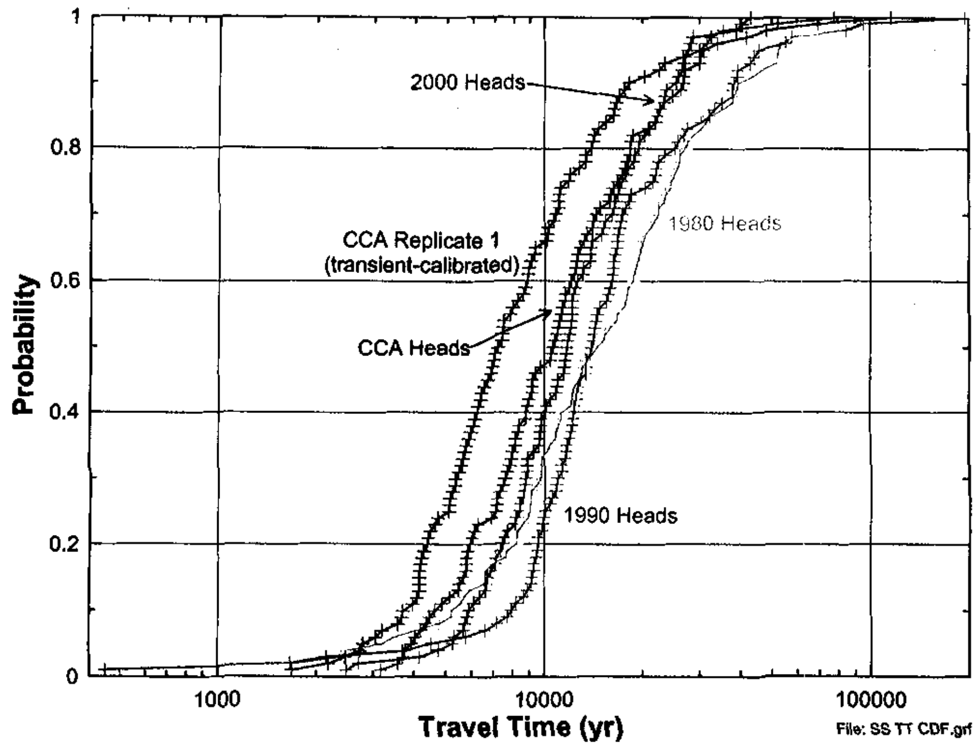

Figure 14. Comparison of travel time CDF's.

4.3 Preliminary Scenario Evaluation

The 100 transient-calibrated Culebra T-field realizations discussed above are being developed using the Culebra conceptual model of Holt and Powers described above, and include the two inferred re-entrants of upper Salado dissolution as high-transmissivity features. These T fields do not, of course, include any of the specific well information to be obtained during the FY03-09 field activities. Because the available data surrounding the WIPP site are so sparse, the 100 T fields include a range of possible T distributions in areas to be investigated under this program. For instance, some of the T-field realizations include high-T connections between the northern and southern Salado dissolution re-entrants, and some do not. Some have direct high-T connections between H-6 and Nash Draw to the northwest, and some do not. By modeling the same scenarios with T fields having significantly different characteristics, we can determine how important those characteristics are in affecting the simulated water-level responses. These

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simulations will help define the objectives to be met by the three multipad pumping tests planned.

The preliminary scenario modeling will examine the following possible conditions:

1. Various amounts of leakage from the Mississippi East tailings pile entering the Culebra directly;
2. Various amounts of leakage from the Dewey Lake and/or Magenta entering the Culebra through specific suspected leaky boreholes north of the WIPP site, both individually and collectively; and
3. Various amounts of leakage entering the Culebra from different injection-well or plugged and abandoned well locations southeast of the WIPP site.

The simulated water-level changes resulting from these scenarios will be compared to the observed water-level changes to identify the combinations of leakage amounts, leakage locations, and T fields that most closely reproduce the observed responses. This information can then be used to locate new wells in the most important and sensitive areas.

In addition, particle tracking will be used to determine what effects the two dissolution re-entrants from Nash Draw that have been included in the first-generation T fields have on flow directions in the Culebra under the scenarios described above. For this evaluation, simulated particles will be released into the Culebra at all points (tailings pile, boreholes) where leakage into the Culebra is simulated, and their movement through the model domain will be tracked. If desired, particles can also be released at points on the upstream model boundaries or within the model domain to help in defining flow directions.

4.4 Enhanced Conceptual Model and Second-Generation T Fields

The field activities described in Section 5 are intended to verify aspects of the conceptual model discussed in Section 4.1, provide information on Culebra transmissivity and flow dimension at numerous new locations, provide information on Culebra head at key locations, and provide transient head responses over large areas that can be used for model calibration. This information will be used with the results of the preliminary scenario evaluation discussed in Section 4.3 to develop an enhanced conceptual model of Culebra hydrology and create a second generation of new T fields. We expect that modeling with the second-generation T fields will be able to replicate the water-level changes that have occurred over the past 25 years, and provide reasonable predictions of future water-level changes under different future scenarios. The second-generation T fields may be created using a different model from MODFLOW 2000 (e.g., a finite-element model) that can incorporate such things as variable-density fluid, particularly if modeling changes in water quality (e.g., transport of potash effluent) is found to be important.

4.5 Magenta Model

Existing information on Magenta transmissivity and head will be combined with new data from wells and tests described in Section 5 to develop a model of groundwater flow in the Magenta in the vicinity of WIPP. A Magenta model is needed for two reasons: to help determine if Magenta water-level changes have the same source(s) as Culebra water-level changes, and to be able to model the effects of interconnecting the Culebra and Magenta through leaking boreholes. The Magenta does not exhibit the same variability in transmissivity as the Culebra, nor has hydraulically significant fracturing been observed in the Magenta outside of Nash Draw. Therefore, we assume that data from fewer wells will be needed to develop a Magenta model than for a Culebra model. No decision has yet been made as to what computer code to use for the Magenta model. A wide range of fluid densities is observed in the Magenta (Mercer, 1983), which may necessitate the selection of a code capable of incorporating variable-density fluid.

4.6 Compliance Model for Second CRA

The scenario modeling performed with the second-generation Culebra T fields and the Magenta model will be used to determine the type of model needed for future compliance calculations. For instance, if interconnections between the Culebra and Magenta are found to be important in determining head levels and changes in the Culebra, a 3D model of Rustler hydrology may be needed to model radionuclide transport under different future scenarios. Alternatively, if the Culebra and Magenta are found to act independently of one another, a 2D Culebra model incorporating vertical leakage in key locations may be adequate. Whatever decision is made about the type of model to be used in future compliance calculations, an independent peer review of that decision and the associated conceptual and numerical models will be required.

5. Description of Field Activities

A variety of field activities are planned to address the issues discussed in Section 3 and provide data needed for the modeling activities discussed in Section 4. To the extent possible, the activities represent an integrated approach to addressing all of the issues simultaneously, rather than a piecemeal approach that addresses each issue individually. The principal components of the field activities are drilling and logging of new and replacement wells, testing in individual wells, large-scale testing involving many wells, recompletion of existing wells, and plugging and abandonment of old wells. In addition, we anticipate that various ancillary activities will be necessary to collect information to support scenario evaluation and conceptual model development. The planned schedule for the field activities, as well as for the modeling activities, is described in Section 6. The activities described below represent our best current estimate of the work that will be needed. Clearly, the activities conducted in FY04 and later years are necessarily contingent on the results of previous years' field and modeling activities. As described in Section 11, a meeting of all parties involved in the hydrology program will be held annually to evaluate progress to date and develop final plans for the coming year.

5.1 New and Replacement Wells

Twelve locations have been identified where data from new wells are needed. These locations are designated with "SNL-#" labels in this document. Some of these wells are expected to provide information directly relevant to the scenarios under consideration, while others will provide information needed to support our conceptual and numerical models. In addition, a long-term Culebra monitoring network consisting of fiberglass-cased wells at potentially 21 locations has been designed to provide the data needed for compliance with the requirements of the WIPP HWFP. These wells will replace the existing network of steel-cased wells that are deteriorating and in need of plugging and abandonment. The 21 locations for the long-term monitoring network are designated with "WTS-#" labels. Well locations have been optimized so that five wells can serve as both SNL and WTS wells, reducing the total to 28 locations. Preliminary locations for the wells are shown in Figure 8. However, the final number and locations of the WTS wells will be optimized based on the modeling described in Section 4. Seven other existing well locations outside the extent of the HWFP network have been identified that will likely require replacement wells in the future to continue to provide data needed for Culebra modeling. New Magenta wells will be installed at six of the SNL- and WTS-designated locations to provide data needed for scenario evaluation and modeling. Five Dewey Lake wells are planned for locations north of the WIPP site where Dewey Lake water is encountered while drilling the Culebra wells. The justifications for the 12 SNL locations are given below, followed by the justifications for the WTS locations and the "far-field" replacement locations. Table 1 shows the roles to be played by each of the wells. The sequencing of drilling and testing in the new wells is described and explained in Section 6.

5.1.1 SNL Well Justifications

SNL-1: Both Culebra and Magenta, and possibly Dewey Lake, wells will be drilled at the SNL-1 location, which is due south of the Mississippi East tailings pile (see Figure 8). These wells will be close enough to the tailings pile to provide a good measure of how much leakage of disposed water has increased heads in the Rustler. In addition, analyses of water samples collected from these wells should show whether or not the potash mining effluent is entering the Rustler members. This is also a location surrounded by potentially leaking potash holes (see Figure 7). The purposes of the SNL-1 wells are fourfold:

1. determine hydraulic heads immediately downgradient of the Mississippi East tailings pile;
2. determine the transmissivity of the Rustler members where water may be entering the system;
3. determine if water-bearing horizons above the Rustler exist at this location; and
4. determine, from water-quality analyses, if potash mining effluent is entering the Rustler members, and what the characteristics of that water are (e.g., solute concentrations, redox potential, etc.).

This information is critical in modeling the effects of the tailings pile on heads at the WIPP site.

SNL-2/WTS-1: Both Culebra and Magenta (and possibly Dewey Lake) wells will be drilled at the SNL-2 location, which is due northwest of H-6 on the Livingston Ridge surface next to Nash Draw and slightly east of the inferred margin of upper Salado dissolution (see Figure 8). This location is west of the m1/h1 halite margin, and wells drilled west of this margin have shown high Culebra transmissivity (e.g., H-6). H-6 is a location where Culebra and Magenta heads are similar and rising at equal rates (Figure 3) even though we have abundant evidence that the Culebra and Magenta are not hydraulically connected at that location. Heads at H-6 are also rising faster than at most other locations. The SNL-2 location is also surrounded by a cluster of oil wells. The purposes of the SNL-2 wells are:

1. determine if dissolution of the upper Salado is extending beneath Livingston Ridge at this location;
2. determine whether hydraulic properties are consistent with dissolution propagating from Nash Draw to the southeast toward the WIPP site;
3. determine how well-connected the Culebra and Magenta are upgradient of the WIPP site on the edge of Nash Draw;
4. determine if flow at this location is toward, or away from, the WIPP site; and
5. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-5) to provide transient data for calibration of the Culebra model north of the WIPP site.

In addition, a Culebra well at the SNL-2 location will provide needed information to help define the direction and rate of groundwater flow across the WIPP site, which is required for annual HWFP reporting to NMED (hence the parallel designation WTS-1).

Table 1. Roles Served by Planned Wells.

Well	Addresses leakage from tailings pile	Addresses high-T conduits	Addresses leaking boreholes	Addresses Salado dissolution	Provides model boundary condition information	Provides other information needed for modeling	Provides information supporting conceptual model	Provides information on flow across WIPP site
SNL-1	X		X					
SNL-2/ WTS-1		X	X	X				
SNL-3		X	X	X				
SNL-4		X		X				X
SNL-5			X			X		
SNL-6					X		X	
SNL-7		X		X			X	
SNL-8/ WTS-8			X				X	
SNL-9/ WTS-2		X		X		X		
SNL-10/ WTS-5						X	X	X
SNL-11	X		X			X		
SNL-12/ WTS-10			X	X		X		
WTS-3						X	X	
WTS-4			X	X		X		X
WTS-6				X		X		
WTS-7			X			X		
WTS-9						X	X	
WTS-11						X		X
WTS-12						X		X
WTS-13						X		X

Well	Addresses leakage from tailings pile	Addresses high-T conduits	Addresses leaking boreholes	Addresses Salado dissolution	Provides model boundary condition information	Provides other information needed for modeling	Provides information supporting conceptual model	Provides information on flow across WIPP site
WTS-14						X		X
WTS-15						X		X
WTS-16						X		X
WTS-17						X		X
WTS-18			X			X		
WTS-19						X		X
WTS-20						X		
WTS-21						X		
AEC-7					X			
H-9					X			
H-10					X			
WIPP-25		X				X		
WIPP-26						X		
WIPP-27					X			
WIPP-28	X		X		X			

SNL-3: This Culebra well is to be located in the northern re-entrant of inferred dissolution extending to the southeast from Nash Draw (see Figure 8). If present, this dissolution re-entrant may short-circuit the long recharge path assumed for the Culebra in the CCA, and allow anthropogenically induced changes in the flow regime in Nash Draw to affect the Culebra (and Magenta) at the WIPP site. Alternatively, it could act as a drain on the unfractured, low-transmissivity Culebra lying to the east. This area has also been recently targeted for oil exploration. Logs were obtained from as many of these wells as possible to help optimize the location of SNL-3. Specifically, the logs were used to identify the boundaries of the dissolution re-entrant so that SNL-3 could be located as centrally within the re-entrant as possible. Six primary purposes will be served by SNL-3:

1. determine if dissolution of the upper Salado has in fact occurred at this location;
2. determine if the inferred dissolution of the upper Salado has resulted in increased Culebra transmissivity;
3. determine if the flow dimension inferred from a pumping test is consistent with a bounded, linear feature, or indicates connection with a larger volume of the Culebra;
4. determine if shallow (e.g., Dewey Lake) water is present above the Magenta that could be leaking into the Culebra and Magenta through poorly plugged boreholes;
5. determine the direction of flow at this location; and
6. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-5) to provide transient data for calibration of the Culebra model north of the WIPP site.

If water is found in the Dewey Lake, a Dewey Lake well may also be installed at the SNL-3 location.

SNL-4: This Culebra well is to be located along the western WIPP site boundary down the axis, but beyond the inferred extent, of the southern re-entrant of inferred upper Salado dissolution (see Figure 8). This location is west of the m1/h1 halite margin, and all wells drilled west of this margin to date have shown high Culebra transmissivity (e.g., H-6). If high Culebra T is present, the southern dissolution re-entrant may short-circuit the long recharge path assumed for the Culebra in the CCA, and allow anthropogenically induced changes in the flow regime in Nash Draw to affect the Culebra (and Magenta) at the WIPP site. Alternatively, and particularly under the mining scenarios considered for the CCA, if high transmissivity crosses the western site boundary and flow is from east to west, this area could act as a rapid off-site pathway from the center of the site. The primary purposes to be served by SNL-4 are:

1. determine if dissolution of the upper Salado extends to the WIPP site boundary;
2. determine if the increased transmissivity present above the area of dissolution extends to the WIPP site;
3. determine the direction of flow at this location; and
4. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-9) to provide transient data for calibration of the Culebra model on the west side of the WIPP site

SNL-5: Both Culebra and Magenta (and Dewey Lake if water is present at that horizon) wells will be installed at this location midway between existing wells DOE-2 and WIPP-30, north of the WIPP site (see Figure 8). This location is critical in understanding the distribution of Culebra transmissivity north of the WIPP site, along one of the two possible pathways for water from the Mississippi East tailings pile to be influencing heads at WIPP. DOE-2 lies in a high-transmissivity region of the Culebra, while WIPP-30 lies in a low-transmissivity region. However, WIPP-30 responds strongly to pumping at wells in the northern portion of the WIPP site, indicating a good hydraulic connection that is inconsistent with an extensive region of low transmissivity. SNL-5 will also be in an area near many oil, gas, and potash holes, which could potentially be serving as conduits for leakage. The primary purposes to be served by SNL-5 are:

1. provide transmissivity data in a key area north of the WIPP site;
2. determine vertical head gradients north of the WIPP site; and
3. provide a location for a large-scale (multipad) pumping test to provide transient data for calibration of the Culebra model north of the WIPP site

SNL-6: A Culebra well will be installed at this location near the northeastern boundary of the Culebra flow model (see Figure 8). This location is critical in establishing accurate model boundary conditions that will allow us to assess the effects of potential vertical-leakage pathways to the Culebra (either the Mississippi East tailings pile or leaky boreholes). Without accurate boundary conditions, we cannot use a model to determine if vertical leakage is, or is not, needed to explain observed water-level rises. The primary purposes to be served by SNL-6 are:

1. provide needed boundary conditions (both head and transmissivity) for the northeastern area of the Culebra flow model; and
2. confirm the hypothesis in our conceptual hydrogeologic model that Culebra transmissivity is low in this region between the m2/h2 and m3/h3 halite margins.

SNL-7: This location is between the old WIPP-33 location and the western WIPP site boundary. WIPP-33 was located in a depression in which all surface water drains vertically downward. The borehole encountered cavernous porosity (karst) in the Magenta, but not Culebra. If present, karst could provide a connection between the Culebra and Magenta, explaining the similarity in Culebra and Magenta heads at the nearby H-6 hydropad. If cavernous porosity is encountered in the Rustler in this hole, the hole will be deepened to MB103 (or other suitable marker bed) to determine if dissolution has affected the Salado at this location. A well at the SNL-7 location will serve the following purposes:

1. determine the presence or absence of karst and Salado dissolution east of WIPP-33 toward the WIPP site;
2. provide information on vertical hydraulic gradients within the Rustler; and
3. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-9) to provide transient data for calibration of the Culebra model on the west side of the WIPP site.

If water is found in the Dewey Lake, a Dewey Lake well may also be installed at the SNL-7 location.

SNL-8/WTS-8: A Culebra well will be installed at this location on the old P-20 drilling pad, east of the northern portion of the WIPP site (see Figure 8). This location is slightly west of the m3/h3 halite margin. Our conceptual hydrogeologic model hypothesizes that dissolution of Rustler halite (and associated effects on Culebra transmissivity) may have occurred near the present-day margins. Some wells drilled near this margin (e.g., H-11, DOE-1) have shown high Culebra transmissivity, but others have not (e.g., H-15). A Culebra well at the SNL-8 location will serve the following purposes:

1. confirm the assumed low Culebra transmissivity east of the WIPP site; and
2. provide information on Culebra heads in an area with many nearby oil and gas wells.

In addition, a Culebra well at the SNL-8 location will provide needed information to help define the direction and rate of groundwater flow across the WIPP site, which is required for annual HWFP reporting to NMED (hence the parallel designation WTS-8).

SNL-9/WTS-2: Both Culebra and Magenta (and possibly Dewey Lake) wells will be installed at this location in the southern re-entrant of inferred dissolution extending to the southeast from Nash Draw (see Figure 8), approximately one mile west of the western WIPP site boundary near the location of the old P-14 monitoring well, which had to be plugged and abandoned. If present, this dissolution re-entrant may allow anthropogenically induced changes in the flow regime in Nash Draw to affect the Culebra and Magenta at the WIPP site. Wells at the SNL-9 location will serve six primary purposes:

1. confirm that dissolution of the upper Salado has in fact occurred at this location;
2. confirm that the high transmissivity measured at P-14 is characteristic of the Culebra within this dissolution re-entrant;
3. determine if the flow dimension inferred from a pumping test is consistent with a bounded, linear feature, or indicates connection with a larger volume of the Culebra;
4. determine how well-connected the Culebra and Magenta are within this dissolution re-entrant;
5. determine the direction of flow at this location; and
6. provide a pumping location for a large-scale (multipad) test to provide transient data for calibration of the Culebra model on the west side of the WIPP site.

In addition, a well at the SNL-9 location will provide needed information to help define the direction and rate of Culebra groundwater flow across the WIPP site, which is required for annual HWFP reporting to NMED (hence the parallel designation WTS-2).

SNL-10/WTS-5: A Culebra well will be installed at this location in the west-central portion of the WIPP site near the m1/h1 halite margin (see Figure 8). The effect, if any, of this halite margin on Culebra transmissivities is unclear. A well in this location will help define the boundary between the high Culebra transmissivities at wells such as P-14 and WQSP-1 and the low transmissivities at wells such as H-2 and H-14. A well at the SNL-10 location will serve the following purposes:

1. provide transmissivity data in an area of the Culebra model domain where data are currently lacking;
2. provide data to define better the location of the m1/h1 halite margin and its effect on Culebra transmissivity; and
3. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-9) to provide transient data for calibration of the Culebra model on the west side of the WIPP site.

In addition, a well at the SNL-10 location will provide needed information to help define the direction and rate of Culebra groundwater flow across the WIPP site, which is required for annual HWFP reporting to NMED (hence the parallel designation WTS-5). Putting a well at this location obviates the need to install a replacement well on the H-2 hydropad when the last Culebra well there has to be plugged and abandoned.

SNL-11: This location is on the Livingston Ridge surface just south of the inferred Salado dissolution margin north of the WIPP site (see Figure 8). This location is a likely entry point for water in the northern portion of Nash Draw, which may originate from the Mississippi East tailings pile, to flow under the Livingston Ridge surface toward the WIPP site. Head and transmissivity information from this location will be important in modeling the effects of the Mississippi East tailings pile on groundwater at the WIPP site. A Culebra well at the SNL-11 location will serve four primary purposes:

1. determine if dissolution of the upper Salado is extending beneath Livingston Ridge at this location;
2. provide head and transmissivity data needed for modeling Culebra water-level-rise scenarios;
3. determine the direction of flow at this location; and
4. provide a monitoring location for a large-scale (multipad) pumping test (centered at SNL-5) to provide transient data for calibration of the Culebra model north of the WIPP site.

If water is found in the Dewey Lake, a Dewey Lake well may also be installed at the SNL-11 location.

SNL-12/WTS-10: A Culebra well will be installed south of the WIPP site in an area where there has been extensive drilling for oil and gas (see Figures 6 and 8). This is an area where our Culebra flow models always indicate the Culebra must have high transmissivity, but no wells have been available to confirm this. It is also an area through which the water-level changes observed most markedly at H-9 propagate to the southern WIPP wells. Logs were obtained from new oil wells and potash holes in this region to help optimize the location of SNL-12. Specifically, the logs were used to identify any features that may be related to high transmissivity, especially potential dissolution of the upper Salado, to maximize the probability that SNL-12 will be located in a high-T zone. The data do not indicate local re-entrants along the Salado dissolution margin. The location was chosen to sample an area where Salado may not be dissolved, but Culebra T is likely to be high. A well at the SNL-12 location will:

1. confirm that the high transmissivity south of the site indicated by our models exists;
2. determine if dissolution of the upper Salado has occurred in this area;
3. determine if the dimensionality of flow (inferred from a pumping test) indicates that the high transmissivity is channelized (focused) or is widely distributed (diffuse);
4. provide another monitoring point to help determine the source and/or cause of the water-level changes regularly observed at H-9;
5. provide information on Culebra heads in an area with many nearby oil and gas wells; and
6. provide a pumping location for a large-scale (multipad) test to provide transient data for calibration of the Culebra model south of the WIPP site.

In addition, a well at the SNL-12 location will provide needed information to help define the direction and rate of Culebra groundwater flow across the WIPP site, which is required for annual HWFP reporting to NMED (hence the parallel designation WTS-10).

5.1.2 WTS Well Justifications

The general purpose of the WTS-designated wells is to replace the existing monitoring network of decaying steel-cased wells with a comprehensive, regularly spaced distribution of fiberglass-cased wells to allow determination of the direction and velocity of Culebra groundwater flow across the WIPP site. Insofar as possible, this well network will make use of existing well pads to minimize construction costs. Fourteen of the wells proposed herein will either be direct replacements of current steel-cased wells when they are plugged and abandoned, or will go on existing pads built for exploratory boreholes. However, before currently existing wells are replaced, a modeling evaluation of the continued need for a well in that location will be performed. Of the remaining seven WTS-designated wells, four will also be SNL-designated wells, so only three pads may have to be constructed solely for the monitoring program. All of the proposed WTS-designated well locations are shown in Figure 8.

The factors considered in selecting preliminary well locations for the long-term monitoring network included:

1. Replace existing wells only in locations that provide key water-level data to allow continued definition of flow rate and direction for HWFP compliance.

2. Provide data coverage at the same basic spatial level that our regulators used to make initial permitting and certification decisions.

3. Replace and be representative of locations now served by two or more wells in the same general vicinity, thus reducing the number of wells in the network and the associated costs to drill and monitor.

4. Allow better definition of area flow directions.

5. Provide necessary data to address the Culebra water-level change issues now and to provide optimal locations for future water-level monitoring for HWFP compliance.

6. Be representative of and provide data points in the different areas of the Culebra exhibiting large variability in formation transmissivity and water chemistry.

7. Support the needs of PA modeling of the groundwater flow system.

8. Concentrate locations within and around the 16 square mile land withdrawal boundary to allow better definition of flow rate and direction around the facility (HWFP), but also provide some far-field information to support modeling and confirm regional groundwater flow characteristics.

The role played by each individual well is discussed below.

WTS-1/SNL-2: This well coincides with SNL-2 and provides a monitoring location northwest of the WIPP site within a cluster of oil wells.

WTS-2/SNL-9: This well represents a replacement for plugged and abandoned well P-14 west of the WIPP site, and coincides with SNL-9.

WTS-3: This Culebra well will replace plugged and abandoned well P-18 east of the WIPP site, and provide needed information on transmissivity east of the m4/h4 halite margin. A Magenta well will also be installed at this location to provide information on Magenta head and transmissivity east of the site needed for modeling.

WTS-4: This well will replace plugged and abandoned well P-15 in the southwest corner of the WIPP site. This corner of the WIPP site is surrounded by recently drilled oil and gas wells.

WTS-5/SNL-10: This well coincides with SNL-10 and will be installed one mile west of the center of the WIPP site. Putting a well at this location obviates the need to install a replacement well on the H-2 hydropad when the last Culebra well there has to be plugged and abandoned.

WTS-6: This Culebra well will provide a new monitoring location southwest of the WIPP site, and provide transmissivity data near the Salado dissolution margin. A Magenta well will also be installed at this location to provide information on Magenta head and transmissivity southwest of the site needed for modeling.

WTS-7: This Culebra well will provide a new monitoring location northeast of the WIPP site in an area of extensive drilling for oil and gas. This well will help to confirm the conceptual model assumption of low Culebra transmissivity east of the WIPP site. If water is found in the Dewey Lake, a Dewey Lake well may also be installed at the WTS-7 location.

WTS-8/SNL-8: This well coincides with SNL-8 and will be installed on the old P-20 pad east of the northern portion of the WIPP site in an area with extensive drilling for oil and gas. This well will help to confirm the conceptual model assumption of low Culebra transmissivity east of the WIPP site.

WTS-9: This well will provide a new monitoring location southeast of the WIPP site, and help to confirm the conceptual model assumption of low Culebra transmissivity east of the WIPP site.

WTS-10/SNL-12: This well coincides with SNL-12 and will provide a monitoring location south of the WIPP site, approximately mirroring the WTS-20 location north of the site. This is also an area of extensive drilling for oil and gas.

WTS-11: This well will replace P-17, but will be installed on the old P-8 pad slightly north of P-17, where it will mirror the WTS-12 location on the northern WIPP site boundary and provide transmissivity information from a new location.

WTS-12: This well will replace DOE-2 on the northern WIPP site boundary.

WTS-13: This well will replace H-15 in the east-central portion of the WIPP site.

WTS-14: This well will replace H-3 south of the waste panels.

WTS-15: This well will replace H-5 in the northeast corner of the WIPP site.

WTS-16: This well will replace H-6 in the northwest corner of the WIPP site.

WTS-17: This single well will replace wells WIPP-12, WIPP-19, WIPP-21, and WIPP-22 due north of the repository.

WTS-18: This well will replace WIPP-30 due north of the WIPP site, mirroring WTS-10 to the south.

WTS-19: This well will replace H-11 in the southeastern portion of the WIPP site.

WTS-20: This well will replace H-7 southwest of the WIPP site.

WTS-21: This well will replace H-17 south of the eastern portion of the WIPP site.

5.1.3 Far-Field Well Justifications

Data from seven locations several miles from the WIPP site are used in Culebra flow modeling for definition of boundary conditions and other properties within the model domain. At one of these locations (WIPP-28), the original steel-cased well has already had to be plugged and abandoned and needs to be replaced with a fiberglass-cased well. At another location (H-9), we are uncertain whether the existing well, currently completed to the Magenta, can also provide Culebra data. The wells at the other five locations will also need to be replaced in time to continue to provide data needed for modeling. These wells are all shown in Figure 8.

AEC-7: This well provides head information needed to define the boundary condition along the northern and central portion of the eastern model boundary.

H-9: This well provides head information needed to define the boundary condition on the southern side of the model domain.

H-10: This well provides head information needed to define the boundary condition along the southern portion of the eastern model boundary.

WIPP-25: This well provides necessary head information in Nash Draw west of the WIPP site.

WIPP-26: This well provides necessary head information in Nash Draw west of the WIPP site.

WIPP-27: This well provides head information needed to define the boundary conditions in the northwestern portion of the model domain.

WIPP-28: This well provides head information near the northern model boundary, and may also provide information on the effects of the Mississippi East tailings pile on heads nearby in Nash Draw. This location is also near many potentially leaking potash holes (see Figure 8).

5.1.4 Culebra Wells Not Scheduled for Replacement

No replacement wells are currently being contemplated for existing Culebra wells H-4, H-12, DOE-1, ERDA-9, WIPP-13, and WIPP-29, wells that have been turned over to area ranchers (D-268 and H-8b), or former Culebra wells that have been recompleted to other units (CB-1, H-14, H-18, and WIPP-18). Should future testing, modeling, or monitoring activities show a continued need for wells at these locations, replacement wells could be installed. As noted above, H-2, P-14, and P-17 will not be replaced at their current locations but at nearby locations where new data will be useful. Also, a single well (WTS-17) will take the place of existing wells WIPP-12, WIPP-19, WIPP-21, and WIPP-22.

5.1.5 New and Replacement Magenta Wells

New Magenta wells are planned for the six locations shown in Figure 15. The Magenta wells are intended to serve three primary purposes:

- Provide head information to determine vertical hydraulic gradients and connectivity;
- Provide information needed for numerical modeling (e.g., boundary conditions, T, head); and
- Provide data needed to calibrate a model and evaluate scenarios.

The need to replace existing steel-cased Magenta wells when they must be plugged and abandoned has not been established at this time. However, given the role played by the Magenta in some of the scenarios related to water-level changes, continued monitoring of the Magenta may be found to be a key to the understanding of Culebra monitoring data. One component of this hydrology program is an independent peer review in 2007 of the new conceptual and numerical hydrogeologic models we have developed. We anticipate that one result of that peer review will be a clear decision on the need for continued Magenta monitoring. Consequently, we defer any decisions on replacement of steel-cased Magenta wells until that time.

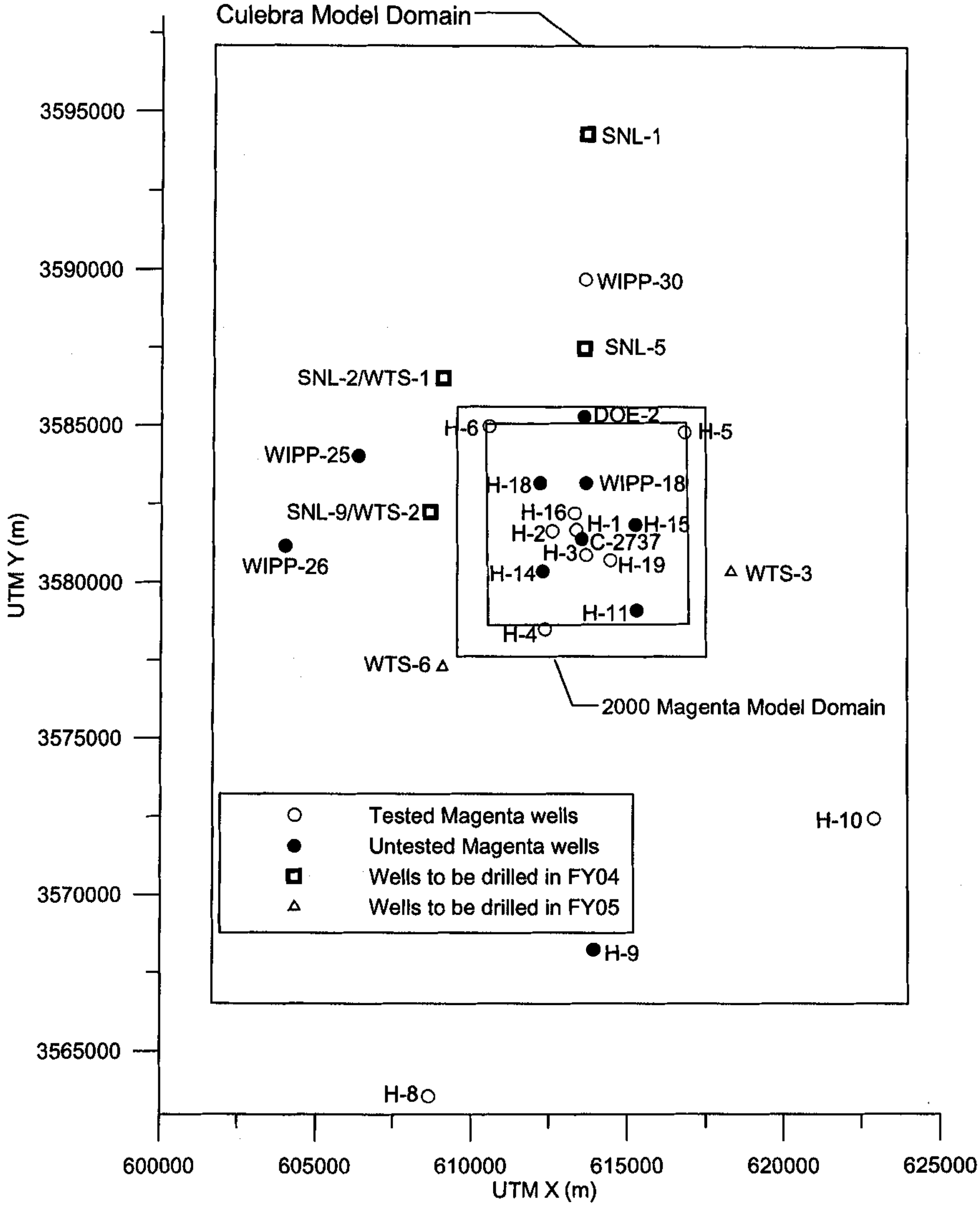

Figure 15. Existing and planned Magenta wells.

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5.1.6 Dewey Lake Wells

A total of five new Dewey Lake wells are proposed for this program to provide information on the position and hydraulic properties of a water-table aquifer that could be a potential source of recharge to the Culebra and Magenta through leaking boreholes. Dewey Lake wells will only be installed at locations where water is found in a permeable section of the Dewey Lake. These locations cannot be known in advance, but only identified while drilling Culebra wells at various locations. Thus, at a location where a Dewey Lake well may be desired, a decision to drill a Dewey Lake well or not will be made based on the findings in the Culebra well at that location. As shown on Figure 16, eight candidate locations have been established for Dewey Lake wells. If more than five of them could support such a well, the preliminary priority for locations is as follows:

1. SNL-1
2. SNL-3
3. SNL-2/WTS-1
4. SNL-5
5. SNL-7
6. SNL-11
7. SNL-9/WTS-2
8. WTS-7

The locations are ranked in terms of the potential for Dewey Lake water, if present, to affect Rustler heads. Three factors contribute to this potential: the presence of nearby boreholes (or other potential vertical pathways), the existence of high Culebra transmissivity, and a northern location. High Culebra transmissivity is important to allow enough Dewey Lake water to enter the unit to affect heads over a wide area. Thus, if the Culebra T at SNL-11 is found to be much higher than that at SNL-5, those two locations might change places on the priority list. A northern location is important for leakage to be able to affect heads at northern wells such as H-6, DOE-2, and WIPP-30. Thus, while the presence of Dewey Lake water is expected at southern locations such as WTS-4, 6, and 11, only locations from the southern dissolution re-entrant to the north are considered for potential wells.

5.2 Well Recompletions

At the present time, Bell Canyon water levels are being monitored in two wells: Cabin Baby (CB)-1 near the southern WIPP boundary and AEC-8 northeast of the site (see Figure 1). Bell Canyon water levels have been monitored in CB-1 since 1999 through tubing attached to a production-injection packer (PIP) set in the lower Castile Formation. CB-1 is cased only from ground surface to 650 ft, a few feet above the top of the Salado. The BLM has requested that the well be cased through the evaporite section (Salado and Castile Formations). Accordingly, we plan to remove all packers and tubing from CB-1, clean the hole to its total depth of 4291 ft, and set and cement a casing string into the upper Bell Canyon so that the well can serve as a single-completion Bell Canyon monitoring well on the south side of the WIPP site.

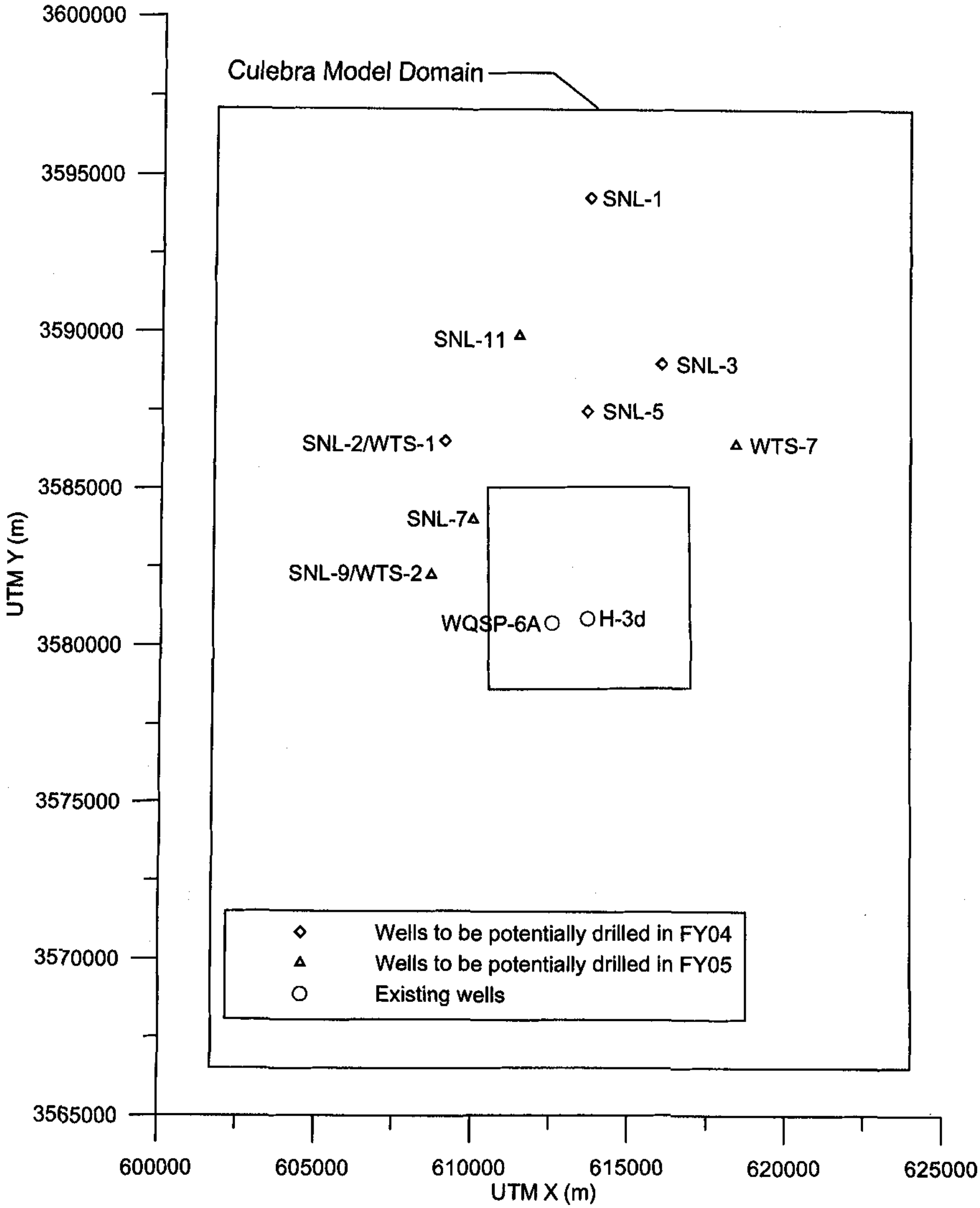

Figure 16. Existing and potential Dewey Lake wells.

Bell Canyon water levels have been monitored in AEC-8 since 1978. Water levels in AEC-8 have been rising since 1993 (Figure 17) for an unknown reason. AEC-8 contains two casing strings, an 8.625-inch string that extends from ground surface to 874 ft, and a 5.5-inch string that extends from ground surface to the total well depth of 4907 ft. The annulus between these two casing strings is not cemented above a depth of 840 ft. The inner casing string is perforated to two intervals in the Bell Canyon. The outer casing string was once perforated to the Culebra interval, but those perforations were later squeezed shut with cement. We suspect that water from an unknown source has entered the annulus between the casing strings, corroded a hole(s) through the inner casing string, and is now leaking into the inner casing, causing the water level to rise. Rather than attempt to repair AEC-8, we plan to plug and abandon it and convert DOE-2, located near the center of the northern WIPP boundary, to a single-completion Bell Canyon well.

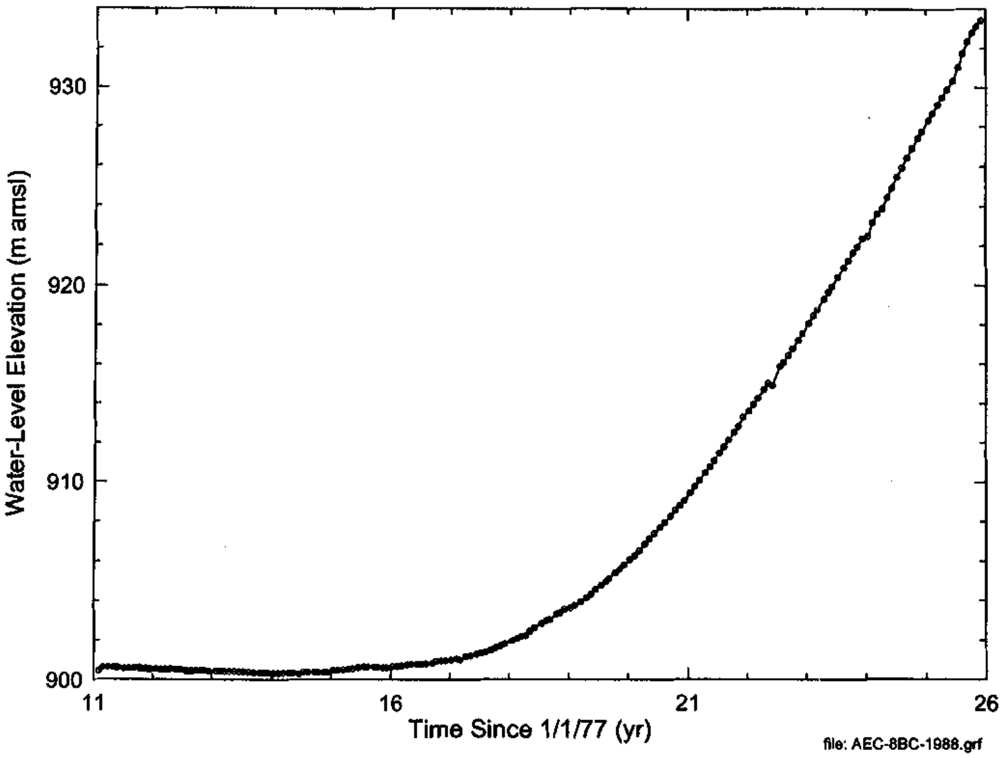

Figure 17. Rising water levels in Bell Canyon well AEC-8.

DOE-2 was drilled to a depth of 4325 ft in the Bell Canyon, and cased to 1009 ft, in the upper Salado. The casing is perforated to the Magenta and Culebra, and the well is currently being used as a Magenta observation well. We plan to remove all packers and tubing from DOE-2, clean the hole to its total depth, and set and cement a casing string into the upper Bell Canyon so that the well can serve as a single-completion Bell Canyon monitoring well on the north side of the WIPP site.

In 1995, seven fiberglass-cased wells were completed to the Culebra on the H-19 hydropad. Because we no longer need seven Culebra wells at this location, one of the wells will be plugged with cement from total depth up into the casing 10-20 ft below the Magenta. The Magenta interval will then be perforated, providing us with a Magenta well at that location. Other wells on the pad could be similarly recompleted to the Dewey Lake or other horizons, if necessary.

Well H-3d (originally designated H-3b4) was drilled into the lower anhydrite of the Forty-niner Member of the Rustler Formation in 1987. The well was intended to provide a fourth Culebra well on the H-3 hydropad for a proposed sorbing-tracer test that never occurred. The original plan was to stop drilling temporarily in the lower Forty-niner, monitor the Forty-niner claystone and Dewey Lake for several months, and then resume drilling and complete the well to the Culebra. The well was never deepened, and consequently never cased, because the sorbing-tracer test was not approved. The well can easily be re-entered in the future, cleaned, deepened if necessary, and completed to whatever interval is desired using fiberglass casing.

Well H-16 was drilled in 1987 and instrumented with a five-packer tool to allow monitoring of all members of the Rustler Formation during drilling of the Air-Intake Shaft. One transducer (for the Forty-niner) appears to have failed, but the remaining four transducers are still functioning and all five packers are holding pressure. We anticipate that one or more packers will fail at some time in the future, at which point the tool string will need to be removed to prevent commingling of water from different units. Seven-inch steel casing is cemented to a depth of 469 ft in the lower Dewey Lake, and a 6.125-inch open hole continues to a depth of 850.9 ft in the upper Salado. Whenever the tool string is removed, the hole can be re-entered and completed to whichever Rustler member is desired using fiberglass casing.

5.3 Testing Activities

A variety of testing and sampling activities will be performed in different wells as this program advances. Table 2 shows the types of tests currently anticipated to be performed in each new well. In addition to tests in the new wells discussed above, some existing wells are currently awaiting testing. Seven Culebra wells have been recompleted to the Magenta in recent years (DOE-2, H-9c, H-11b2, H-14, H-15, H-18, and WIPP-18). Testing of the Magenta in these wells will be performed under Test Plan TP 00-03 (Chace, 2002). Well C-2737, a dual Culebra-Magenta completion, is also yet to be tested. C-2737 will be tested under Test Plan TP 03-01 (Chace, 2003).

5.3.1 Single-Well Hydraulic Tests

Hydraulic tests will be performed in all wells installed at new locations, and existing untested wells, to provide estimates of transmissivity and flow dimension. The type of hydraulic test performed will be dependent on the flow rate that is found to be sustainable during development of the well: a pumping test will be performed if the well is capable of producing a sustained one gallon per minute (gpm), and two slug tests will be performed if the well cannot sustain 1 gpm. Generally speaking, pumping tests are anticipated for most Culebra wells and all Dewey Lake wells; slug tests are anticipated for most Magenta wells and some Culebra wells (see Table 2). Based on experience gained from performing dozens of pumping tests in the Culebra, we estimate that a typical pumping duration will be 100 hours (4 days). The actual duration of an individual test will be determined by real-time analysis of the data collected as the test proceeds using the well-test-interpretation code nSIGHTS (n-dimensional Statistical Inverse Graphical Hydraulic Test Simulator). Pumping will be stopped when the nSIGHTS analysis indicates that

Table 2. Testing to Be Performed in New/Replacement Wells.

Well	4-day Pumping Test	Slug Tests	Multipad Pumping Test	Scanning Colloidal Borescope Logging	Testing Not Needed—Replacement Well
SNL-1	C, M?, DL?	M?		C, M	
SNL-2/WTS-1	C, M?, DL?	M?		C, M	
SNL-3	C, DL?			C	
SNL-4	C?	C?			
SNL-5	DL?	M	C?		
SNL-6		C			
SNL-7	C, DL?			C	
SNL-8/WTS-8		C			
SNL-9/WTS-2	M?, DL?	M?	C	C	
SNL-10/WTS-5	C?	C?			
SNL-11	C, DL?			C	
SNL-12/WTS-10	C		C?	C?	
WTS-3		C, M			
WTS-4					C
WTS-6	C, M?	M?			
WTS-7	DL?	C			
WTS-9		C			
WTS-11	C?	C?			
WTS-12					C
WTS-13					C
WTS-14					C
WTS-15					C
WTS-16					C
WTS-17		C			
WTS-18					C
WTS-19					C
WTS-20					C
WTS-21					C
AEC-7R					C
H-9R					C
H-10R					C
WIPP-25R	C				
WIPP-26R	C				
WIPP-27R					C
WIPP-28R	C				

C=Culebra well
M=Magenta well
DL=Dewey Lake well

adequate data have been collected to quantify transmissivity and the dimensionality of flow (e.g., radial, linear), and that continuing the test will not significantly improve our estimation of those parameters. Water-level/pressure recovery will be monitored for at least twice the duration of the pumping period, and longer if conditions allow. During pumping tests, Trolls (self-contained monitoring gages) will be installed in nearby wells (if any) to monitor possible responses. Slug tests will be performed using two different initial slug magnitudes. An individual slug test may take several days to a week to complete. In cases of extremely low transmissivity, slug tests may be converted to drillstem tests while the testing is in progress.

5.3.2 Multipad Pumping Tests

Large-scale (multipad) pumping tests of the Culebra are planned for three locations to provide transient response data needed for flow-model calibration. Multipad pumping tests typically involve pumping for a month or longer at one location while monitoring responses at surrounding observation wells up to several miles away. Such tests have been performed in the past within the WIPP site boundaries at the H-3, H-11, H-19, and WIPP-13 locations, greatly facilitating model calibration in the affected areas where observation wells were present. The new wells to be installed provide the opportunity to extend the increased model-calibration capability provided by multipad tests to the regions surrounding the WIPP site, which is needed to improve our understanding of how hydraulic stresses originating off-site propagate to the wells on the WIPP site. In particular, one of the primary objectives of the multipad tests will be to determine the presence or absence of high-transmissivity connections between known areas of high T, such as between H-6 and P-14, and between H-11 and H-9. These types of features are important because, if present, they provide pathways for water from Nash Draw to flow under the Livingston Ridge surface or, if absent, they prevent that flow so that the only effect of increased heads in Nash Draw is to decrease the east-to-west gradient in the Culebra, causing heads to rise. Multipad tests will be performed north, south, and west of the WIPP site. (Transmissivity is too low east of the site to sustain the necessary pumping for a multipad test, and our conceptual model assumes the Culebra does not show the heterogeneity in this region that multipad tests are designed to address. The individual well tests at the new wells east of the site should be sufficient to confirm this assumption.)

Well SNL-9/WTS-2 will be the pumping well for the western multipad test, with observation wells as shown in Figure 18. Provided that it is able to produce at least approximately 5 gpm, SNL-5 will be the pumping well for the northern multipad test, with observation wells as shown in Figure 19. If SNL-5 does not have the needed pumping capacity, SNL-11, SNL-3, and WTS-12 (in that order) will be considered as potential fallback pumping wells for the test. The pumping well for the southern multipad test will prospectively be SNL-12/WTS-10, with observation wells as shown in Figure 20. Should SNL-12/WTS-10 not have the required pumping capacity, WTS-11 and WTS-6 (in that order) will be considered as fallback pumping locations.

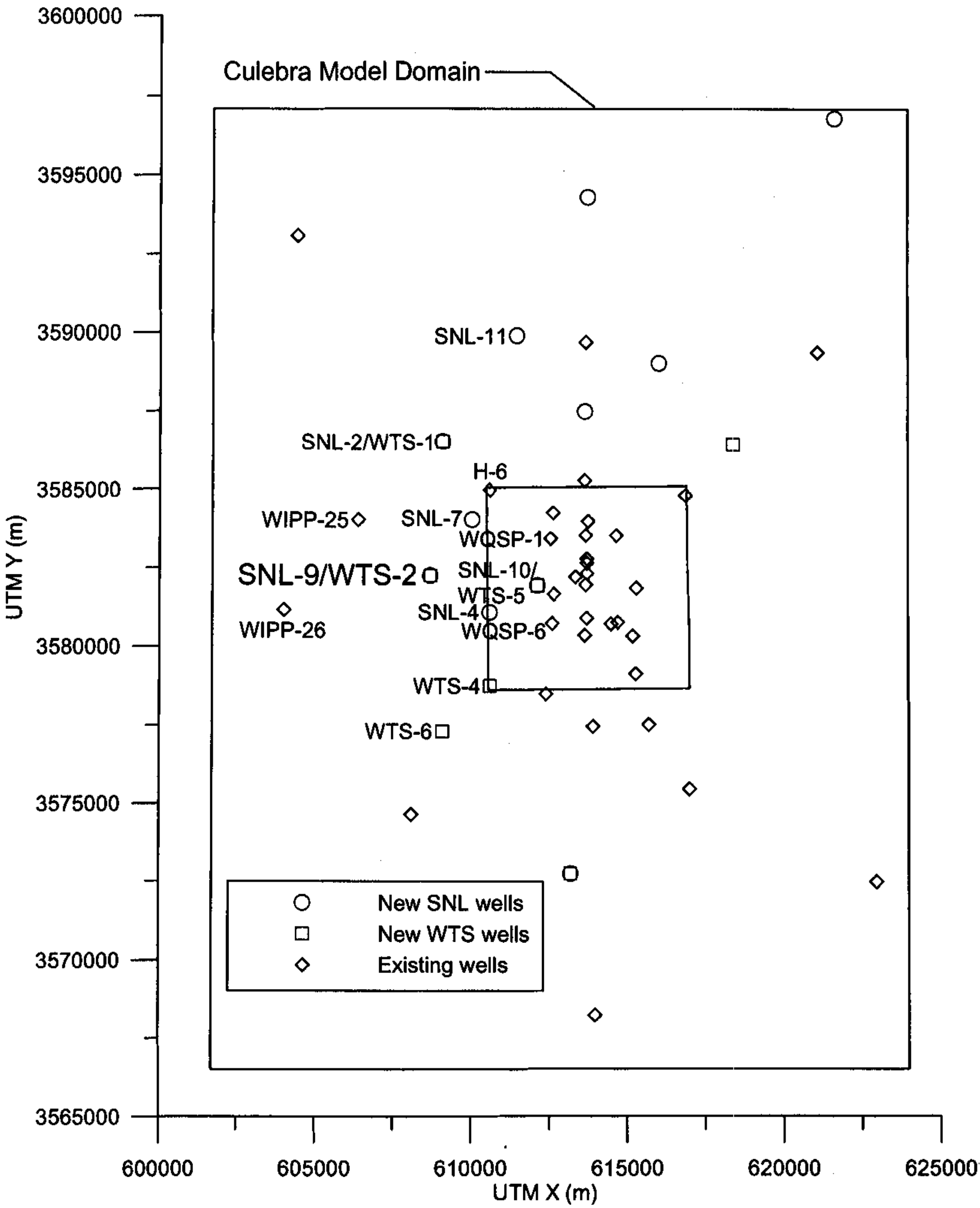

Figure 18. Pumping well and principal observation wells for western multipad pumping test.

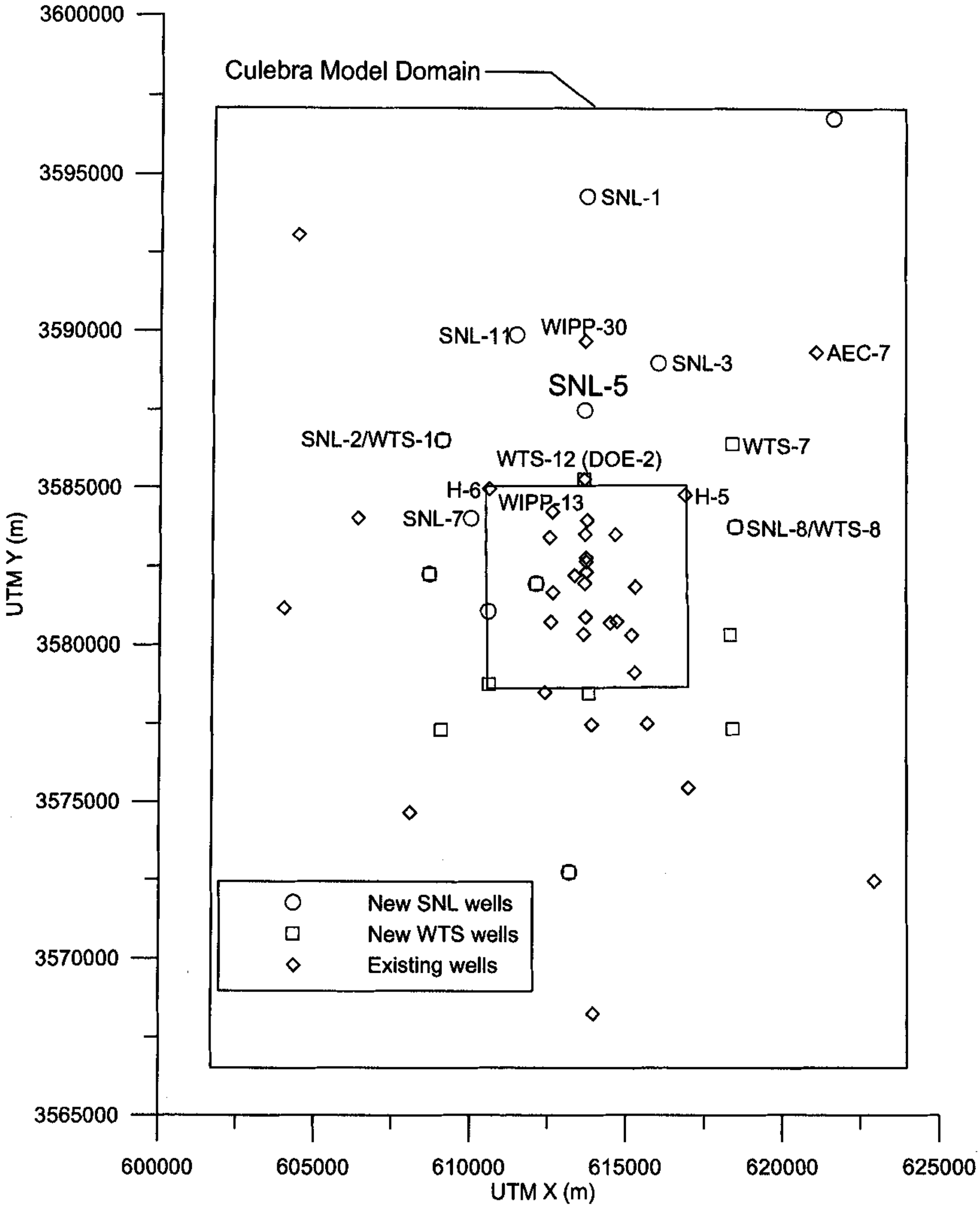

Figure 19. Pumping well and principal observation wells for northern multipad pumping test.

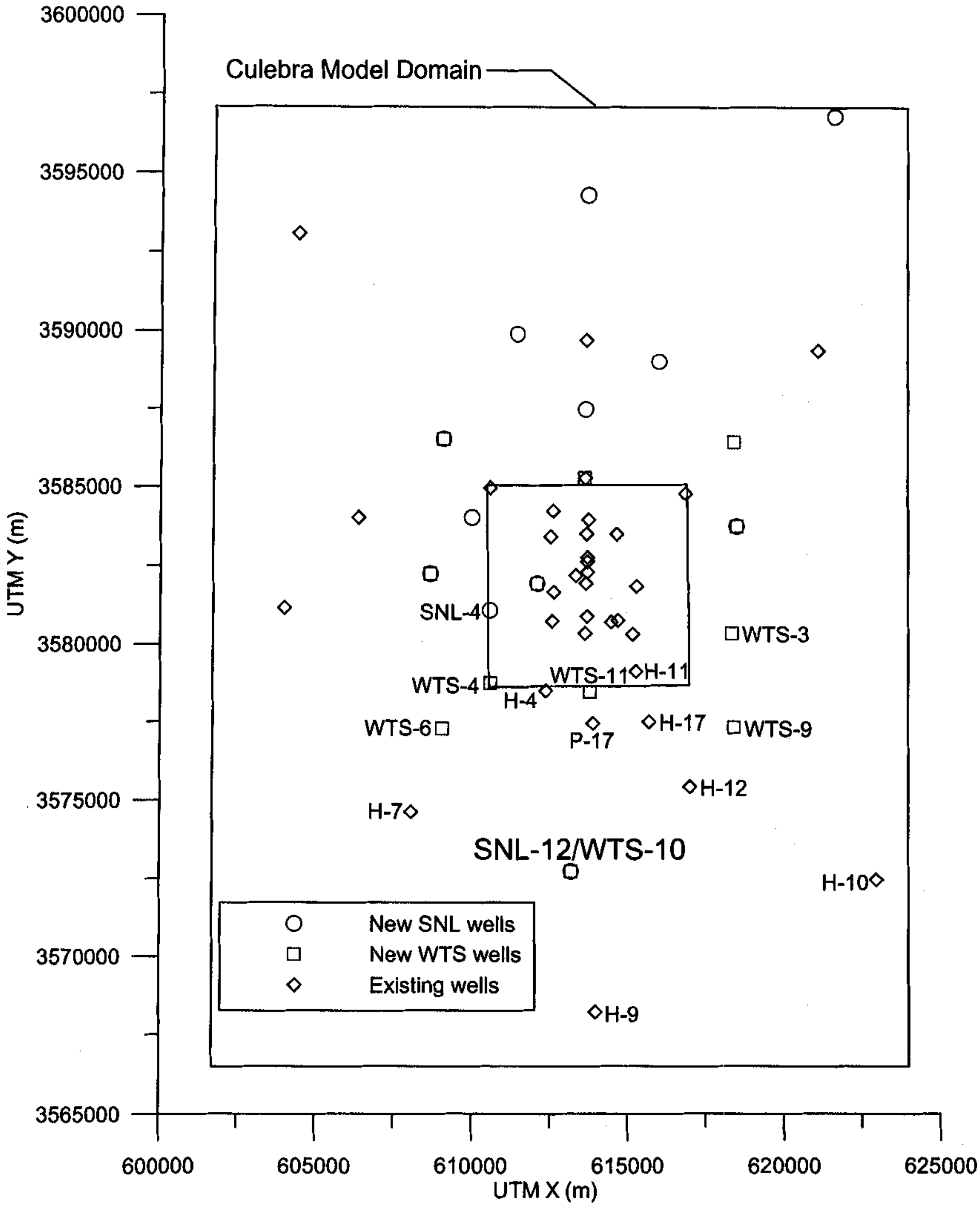

Figure 20. Pumping well and principal observation wells for southern multipad pumping test.

5.3.3 Scanning Colloidal Borescope Logging

Direct measurement of the direction of groundwater flow is needed in the inferred Salado dissolution re-entrants, near the Mississippi East tailings pile, and on the edge of Nash Draw. Therefore, after SNL-1, 2, 3, 7, 9, and 11 have recovered from well development or pumping tests, the screened intervals of both the Culebra and Magenta (if present) wells will be logged using the scanning colloidal borescope. The scanning colloidal borescope images colloidal-size particles moving with the water through the wellbore, and tracks their motion to determine the direction and velocity of groundwater flow. In SNL-3 and 9, this will provide direct indications of whether the dissolution re-entrants serve as sources of fluid to the WIPP site, or as sinks for fluids coming from the east and north. In all cases, the information will be useful in flow model calibration.

5.3.4 Water-Quality Sampling

Water-quality sampling will be performed in all wells to provide baseline information and allow us to make inferences about water origins and flow paths. Water samples will be collected at the end of well-development activities for those wells at which pumping tests do not appear to be feasible, or for replacement wells where hydraulic testing is not necessary. During the pumping tests at the other wells, water-quality parameters such as electrical conductivity, temperature, specific gravity, and pH will be collected no less frequently than every six hours. Prior to turning off the pump, samples will be collected for laboratory analysis of major ion concentrations. At a minimum, analyses will be performed of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, and HCO_3^{-} concentrations. Age-dating may also be performed on Dewey Lake water samples.

5.4 Plugging and Abandonment

Plugging and abandonment of old wells is carried out in consultation with the New Mexico Office of the State Engineer (OSE). An ultrasonic imaging (USI) log is performed to provide information on the condition of the well casing and the cement bond between the casing and borehole wall. Where the casing is in relatively good condition and a good cement bond exists, the OSE is generally willing to allow us to cement the well inside the casing from total depth to land surface. If voids are present in the cement behind the casing, the casing may need to be perforated at that horizon so that cement can be squeezed behind the casing. If the cement bond is extremely poor, some or all of the casing may need to be removed before the well is cemented. All decisions on how a specific well will be P&A'ed must be approved by the OSE.

Many Culebra wells are cased only to the lower Tamarisk, and are open holes through the Culebra. Particular care will be taken at locations where the Culebra is known to have high transmissivity to ensure that the cement used to plug the well does not migrate through the formation. This will involve filling the open, Culebra part of the hole with cement dumped from a bailer. Once the cement level extends into the casing, the casing can be cemented to the surface from the bottom up.

Plugging and abandonment of wells at locations that we wish to keep in the monitoring network will, insofar as possible, be performed after the replacement wells have been installed at those locations. At those locations where no replacement wells are envisaged, P&A may occur whenever no need for future monitoring at that location (such as during a multipad pumping test) is foreseen.

5.5 Ancillary Activities

As the work outlined in this plan proceeds, we anticipate that a variety of ancillary activities will be needed to resolve specific questions that arise, and to provide information needed for development of conceptual models. These activities might include such things as:

- mapping of subsidence-induced fractures that might allow vertical leakage;
- air photo analysis of fracture and vegetation patterns;
- studies of vegetative cover that might be related to fracturing or other places where water might be concentrated;
- isotope and other geochemistry studies to characterize groundwaters;
- core studies; and
- geophysical well log studies to relate log signatures to hydraulic properties and/or geologic facies.

Test Plans will be written to support any such ancillary activities that are found to be necessary.

6. Schedule of Activities

Both modeling and field activities are scheduled so that specific results are available for the first and second CRA's. The modeling impact assessment described in Section 4.2 must be completed in FY03 so that the new T fields are available for inclusion in the first CRA, which is to be submitted to EPA in November 2003. The field activities involving new wells must be completed no later than early FY06 so that the models requiring data from those activities can be developed and included in a peer review to be conducted in FY07. No information collected after FY07 can be included in the second CRA. As discussed above, the activities and schedule described below represent our best current estimate of the work that will be needed. Clearly, the activities conducted in FY04 and later years are necessarily contingent on the results of previous years' field and modeling activities. As described in Section 11, a meeting of all parties involved in the hydrology program will be held annually to evaluate progress to date and develop final plans for the coming year.

6.1 Drilling, Testing, and Modeling Schedule

Drilling and multipad testing activities will be sequenced to make optimum use of time. For the SNL wells, first priority is given to those locations from which key information supporting (or refuting) our working hypotheses will be obtained, followed by wells needed for specific testing purposes and those providing data needed for modeling. For the WTS wells, first priority is given to those new locations that will support the water-level-change investigations, followed by new locations that will provide data needed for modeling, and finally by replacement of existing wells. We intend to use all existing wells as long as possible while we focus on collecting data from new well locations. The drilling sequence given in Table 3 and described below represents the optimum program in which all permits are easily obtained, all sites are accessible, all new wells meet our expectations, no existing wells fail and need immediate plugging and abandonment, etc. In the event that unexpected or unforeseen conditions arise (see Section 6.3), the schedule and sequence of activities will be modified as appropriate.

6.1.1 FY03

The wells to be drilled in FY03 will be those that address the water-level-change scenarios north of the site (SNL-1, 2, 3, and 9), high Culebra transmissivity south of the site (SNL-12), and WTS-4 to fill the gap that has existed in the monitoring network since P-15 had to be plugged and abandoned (Table 3). Installation of SNL-1, 2, 3, and 9 is essential early in the program to provide confirmation that our working hypotheses are in fact feasible. Should these wells fail to confirm our hypotheses, we would need to develop alternative hypotheses and means of testing them in the subsequent years. The SNL-12 well is needed to determine if high Culebra transmissivity, possibly caused by dissolution of the upper Salado, is present south of the site that might act as a drain on, and thereby accelerate, flow through the site. A well at the P-15/WTS-4 location is needed at all times for the annual determination of groundwater flow direction across the WIPP site required by the HWFP.

Testing in FY03 will consist of hydraulic tests in the newly drilled wells, the existing re-completed Magenta wells, and existing dual-completion well C-2737. Test analysis will be initiated while tests are in progress, and will be completed shortly after the tests are terminated.

Table 3. Sequence in Which Wells Will Be Drilled.

Drilling Sequence	Year		Drilling Sequence	Year
SNL-2/WTS-1 (C)	FY03		WTS-13 (C)	FY06
SNL-3 (C)	FY03		WTS-14 (C)	FY06
SNL-1 (C)	FY03		WTS-15 (C)	FY06
SNL-9/WTS-2 (C)	FY03		WIPP-25R (C)	FY06
WTS-4(C)	FY03		WTS-16 (C)	FY07
SNL-12/WTS-10 (C)	FY03		WTS-17 (C)	FY07
SNL-4 (C)	FY04		WTS-18 (C)	FY07
SNL-7 (C)	FY04		WTS-19 (C)	FY07
SNL-10/WTS-5 (C)	FY04		WIPP-26R (C)	FY07
SNL-5 (C)	FY04		WTS-20 (C)	FY08
WTS-6 (C)	FY04		WTS-21 (C)	FY08
SNL-11 (C)	FY04		AEC-7R (C)	FY08
WTS-7 (C)	FY04		H-10R (C)	FY09
SNL-6 (C)	FY04		H-9R (C)	FY09
SNL-1 (M)	FY04		WIPP-27R (C)	FY09
SNL-1? (DL)	FY04			
SNL-2 (M)	FY04			
SNL-2 or 3? (DL)	FY04			
SNL-9 (M)	FY04			
SNL-5 (M)	FY04			
SNL-5 or 11? (DL)	FY04			
WTS-9 (C)	FY05			
WTS-3 (C)	FY05			
WTS-11 (C)	FY05			
SNL-8/WTS-8 (C)	FY05			
WTS-12 (C)	FY05			
WIPP-28R (C)	FY05			
WTS-6 (M)	FY05			
WTS-3 (M)	FY05			
SNL-7 or 9? (DL)	FY05			
WTS-7? (DL)	FY05			

C=Culebra well
M=Magenta well
DL=Dewey Lake well

Logging with the scanning colloidal borescope may be performed in some wells in FY03, or may be deferred until the last of the wells to be logged are completed in FY04.

Modeling in FY03 will focus first on completing the impact assessment discussed in Section 4.2 and developing the T fields to be used in the first CRA. The preliminary scenario evaluation (Section 4.3) will then be initiated, as well as preliminary development of the Magenta conceptual model (Section 4.5) as Magenta test data become available.

6.1.2 FY04

Drilling in FY04 will focus first on the observation wells needed to conduct the western multipad pumping test planned for late FY04 (SNL-4, 7, 10, and 11 and WTS-6), then on wells needed for the northern multipad pumping test planned for early FY05 (SNL-5 and WTS-7), and finally on SNL-6 which is needed to begin developing a baseline of head data for the northeastern corner of the Culebra model domain. Magenta and Dewey Lake wells will generally be drilled after the Culebra wells scheduled for each year are completed. The western multipad pumping test will be performed after all of the principal Culebra observation wells shown in Figure 10 have been installed and tested, and water levels have stabilized. Drilling of WTS-7 and SNL-6 can occur during the western multipad test without affecting that test.

The modeling assessment of the water-level-change scenarios will continue, using recently obtained information to focus the simulations. Development of the Magenta numerical model will begin in FY04.

6.1.3 FY05

Drilling in FY05 will focus first on the Culebra observation wells needed for the southern multipad pumping test planned for late FY05 (WTS-3, 9, and 11), followed by the replacement of plugged and abandoned well WIPP-28, then on the remaining new well east of the site (SNL-8/WTS-8), and finally on WTS-12, the replacement well for DOE-2. The latter three wells can be drilled during the southern multipad test without affecting that test. Magenta and Dewey Lake wells will be drilled after the Culebra wells are completed. Well CB-1 will be cleaned out to total depth and then cased through the evaporite section to provide a single-completion Bell Canyon well near the southern boundary of the WIPP site.

The northern multipad test will be performed early in FY05 after the observation wells it shares with the western multipad test (compare Figures 18 and 19) have recovered (or established consistent trends). The southern multipad test will be performed in late FY05 after all of the wells shown in Figure 20 have been installed and tested and water levels have stabilized.

Assembly of the databases for the second-generation Culebra T fields will begin in FY05 as more and more new data become available. The correlation between Culebra T and thickness of overburden and other geologic factors will be re-evaluated using the new data in preparation for generating new T fields. This will contribute to the development and beginning documentation of the enhanced conceptual model for site hydrogeology.

Development of the Magenta model will be completed as the final Magenta data become available, and simulations of Magenta water-level changes (scenario modeling) will be performed.

6.1.4 FY06

Drilling in FY06 will involve replacing steel-cased wells (e.g., WIPP-25, H-3, H-5, H-15) in need of plugging and abandonment. The order of replacement may be different from that shown in Table 3 if wells fail before their replacement is scheduled. Well DOE-2 will be cleaned out to total depth and then cased through the evaporite section to provide a single-completion Bell Canyon well on the northern boundary of the WIPP site.

Development and documentation of the enhanced conceptual model for site hydrogeology will be completed in FY06, and the second-generation T fields will be developed. The results of the scenario modeling performed using the first-generation T fields and the Magenta model will be used to guide a decision on a 2D or 3D approach to the new compliance model. Work on the new compliance model will begin.

6.1.5 FY07

Drilling in FY07 will continue the process of replacing steel-cased wells at the locations desired for the long-term monitoring network, including the far-field wells. Ten steel-cased Culebra wells and one deep well will be plugged and abandoned.

The new compliance model will be completed, and both the new conceptual and numerical models will be peer reviewed. Based on the conclusions of the peer review, a decision will be reached on the need to replace steel-cased Magenta wells for long-term monitoring.

6.1.6 FY08-09

Drilling in FY08 and FY09 will continue and complete the process of replacing steel-cased Culebra wells at the locations desired for the long-term monitoring network, including the far-field wells. If replacement Magenta wells are decided to be necessary in FY07, drilling of those wells will occur. Plugging and abandonment of the last steel-cased wells will be completed during this period.

Compliance modeling will be performed for the second CRA in FY08, and the CRA will be submitted to EPA in early FY09.

6.2 Plugging and Abandonment Sequence

Plugging and abandonment of steel-cased wells is not scheduled to begin until FY05, when five Culebra wells and one deeper well will be P&A'ed. In subsequent years, 10 Culebra (or Magenta) wells and one deeper well will be P&A'ed annually until all steel-cased wells have been eliminated. The program will start with redundant wells, i.e., those completed to the same interval as another well on the same pad, and progress to those wells in the worst condition. Well condition is not simply a function of age, but is also affected by the salinity of the water in a particular well, the quality of the cement job, the quality of the surrounding rock, and other factors. Well condition will be assessed using USI logs or other techniques to identify those wells most in need of P&A each year.

6.3 Decision Points

As discussed above, the drilling, testing, and P&A sequences just described assume that all new wells meet our expectations, no existing wells fail and need immediate plugging and abandonment, etc. In the event that unexpected or unforeseen conditions arise, the schedule and sequence of activities will be modified as appropriate. A number of decision points can be foreseen, depending on the conditions actually encountered.

Wells SNL-1, 3, 9, and 12 have been located with clear expectations that they will encounter conditions and properties that help explain the changes in Rustler water levels. SNL-1 is expected to show high Magenta and Culebra heads, possibly equal, as a result of leakage from the Mississippi East tailings pile. SNL-3 and SNL-9 are expected to show high Culebra T resulting from dissolution of the upper Salado. SNL-12 is expected to show the high Culebra T predicted by all Culebra flow models since the late 1980's. In contrast, SNL-6 and SNL-8 are expected to show low Culebra T. If the expected conditions and properties are not found at these locations, our conceptualization of the system, and our strategy for characterizing it, may have to change.

If the expected conditions of high heads are not found at SNL-1, we may have to shift our focus from the area south of the Mississippi East tailings pile to the area to the west. Instead of water flowing directly south from the pile, it could be following a path of least resistance into Nash Draw to the southwest. In that case, replacing WIPP-28 (already plugged and abandoned; replacement scheduled for FY05) could become more important to provide a measure of the heads in the upper part of Nash Draw.

High Culebra T might not be found at SNL-3 either because no dissolution of the upper Salado has actually occurred at that location or because not enough dissolution has occurred to affect the transmissivity of the Culebra. In either case, low Culebra T at SNL-3 would increase the importance of a well at the SNL-11 location to determine if any high T pathway exists south from the Mississippi East tailings pile to the WIPP site.

Given that high Culebra T has already been observed at P-14, only a few hundred meters from the SNL-9/WTS-2 location, low T at that location would be completely unexpected. Nevertheless, if low T were found, it would suggest that a continuous dissolution re-entrant does not extend from Nash Draw to P-14 and beyond. It would also complicate the western multipad pumping test, as an alternative pumping location would have to be identified.

If high Culebra T is not found at the SNL-12 location, we would have to re-evaluate the lines of geologic evidence that led us to site the well where we did, evaluate whether the information gained from drilling the hole allowed us to make a better prediction of where high T could be found, and decide if drilling another hole to try to find it was worthwhile.

Because of the depth to Culebra at SNL-6 and SNL-8, transmissivities are expected to be low at those locations. However, those locations are also near to and on the western side of the m3/h3 halite margin, where dissolution is possible and high T has been found in other wells (e.g., H-11). If high T were to be found at SNL-6 and/or SNL-8, we would have to re-evaluate our conceptual understanding of flow east of WIPP. We would also need to perform a long enough pumping test to determine if high-T connections existed to nearby wells.

Depending on what is found at the SNL-7 location, we may or may not need to perform drilling and/or testing beyond what is currently planned. If no evidence of the cavernous porosity encountered in the Rustler at WIPP-33 is seen at SNL-7, then no additional work would be expected. If cavernous porosity is encountered at SNL-7, however, we would have to evaluate whether or not an additional hole should be drilled to the east on the WIPP site.

The general expectations we have of the conditions to be encountered at each new well location, and possible actions to be taken if those expectations are not met, are summarized in Table 4.

Table 4. Expectations and Contingent Actions for New Wells.

Well	Expectations	Possible Actions if Expectations Not Met
SNL-1	• high, similar heads in Culebra and Magenta • geochemical evidence of potash brine • moderate to high Culebra T	• replace WIPP-28 sooner than planned (FY05)
SNL-2/ WTS-1	• moderate to high Culebra T • possible fracturing parallel to Nash Draw • possible dissolution of upper Salado	• combine with information from SNL-11 to revise conceptual model regarding transition from Nash Draw to Livingston Ridge
SNL-3	• dissolution of upper Salado • high Culebra T • subradial flow dimension • flow direction parallel to dissolution re-entrant	• increases importance of SNL-5 and SNL-11 in understanding flow north of the site • shifts more focus on cause of water-level rise to Nash Draw
SNL-4	• no dissolution of upper Salado • low to moderate Culebra T	• characterize connectivity with H-2 and WQSP-6 • select location for new well to define eastward limit of high T
SNL-5	• few—generally a characterization hole • Culebra T could be low to moderately high	• very high T ($>10^{-4}$ m^2/s) or intense fracturing could lead to decision to deepen hole into upper Salado, alter conceptual model of Salado dissolution
SNL-6	• low Culebra T	• establish connectivity with SNL-1 and SNL-3 • consider additional well to the southwest between the m2/h2 and m3/h3 halite margins
SNL-7	• moderately high Culebra T similar to that at H-6 • possible cavernous porosity in Rustler	• if cavernous porosity is encountered, site additional well to the east to define eastern limit
SNL-8/ WTS-8	• low Culebra T	• establish connectivity with H-15, WQSP-4, and DOE-1 • site additional well to the southwest on the western side of the m3/h3 halite margin
SNL-9/ WTS-2	• upper Salado dissolution • high Culebra T similar to that at P-14 • subradial flow dimension • flow direction parallel to dissolution re-entrant	• revise conceptual model • consider additional well

SNL-10/ WTS-5	• few—generally a characterization hole • Culebra T could be low to moderately high	If T is high: • characterize connectivity with H-2, WQSP-1, and WQSP-6 • consider need for new well to define eastern limit of high T
SNL-11	• moderate to high Culebra T • possible fracturing parallel to Nash Draw • possible dissolution of upper Salado	• combine with information from SNL-2 to revise conceptual model regarding transition from Nash Draw to Livingston Ridge
SNL-12/ WTS-10	• moderate to high Culebra T • possible dissolution of upper Salado	• reconsider geologic data and determine location for possible additional well
WTS-6	• dissolution of upper Salado • high Culebra T	• reconsider geologic data and revise conceptual model
WTS-7	• low Culebra T	• reconsider geologic data and revise conceptual model
WTS-9	• low Culebra T • halite in (some) Culebra pores	• reconsider geologic data and revise conceptual model

7. Well Construction Activities

Field operations for construction of the wells discussed herein involves site preparation, drilling and coring, well completion, well development, and logging. WTS and its contractors will be responsible for all well construction activities and will be supported by SNL through technical consultation and monitoring of existing wells located near the new wells being drilled.

7.1 Site Preparation

The principal activities involved in site preparation include access road construction, pad construction, mud pit construction/lining, augering the initial section of each hole, and installation of surface conductor casing. Heavy equipment will be used to extract, haul, place, grade, and compact material to provide a stable surface for drilling activities. Heavy equipment will also be used to dig a pit to hold cuttings and drilling fluid, if used. The pits will be lined appropriately during construction. An auger rig will be used to drill an 18-inch hole to an approximate depth of 30 ft. Steel surface casing (13.625-inch) will be set and cemented in this hole with approximately 2 ft extending above ground surface. The surface casing will provide protection for the fiberglass well casing against damage from external sources. A minimum 3-ft by 3-ft concrete pad will be placed around the surface casing contoured to slope slightly down and away from the casing to provide storm drainage away from the surface casing.

7.2 Well Drilling and Coring

Drilling activities will begin with detailed inspection of the rig by WTS to ensure that safety and environmental requirements are met. The rig will be set up and ancillary equipment (compressors, etc.) put in place before drilling begins. As the hole is drilled, the cuttings and cores will be described, and any samples for testing will be prepared and shipped. On-site personnel will be responsible for measuring all drill pipe, bits, subs, core barrels, etc. required to ensure accurate depth control while drilling.

The Culebra wells are to be drilled using compressed air as the circulation medium. If water is encountered above the Rustler Formation, the well will be deepened by approximately 30 feet past the point of the encounter, and drilling will stop for the day while water levels are monitored. If feasible, an estimate of the production capacity of the water-bearing zone will be obtained by air-lifting the fluid from the well. A water sample for water-quality analysis will be collected before air-lifting ceases. Drilling may resume the following day. If hole conditions require changing to a fluid-based system, Culebra brine from a nearby well or fresh water may be used. If brine is used, careful records shall be kept of the amount lost to the well on a daily basis. The water level in the hole will be measured at the beginning and end of each drilling shift. Except as noted below, at all new well locations, 4-inch core will be taken over the entire Magenta interval (approximately 30 ft), and from the lower part of the upper Tamarisk anhydrite to approximately 20 ft below the base of the Culebra (an interval of approximately 70 ft). The wells will be reamed to a diameter of 12.25 inches, except for SNL-9/WTS-2 which will be reamed to a diameter of 14.75 inches. The anticipated total depths of the Culebra wells are shown in Table 5.

Table 5. Anticipated Total Depths of Proposed Wells.

Location	Culebra Well Depth (ft)	Magenta Well Depth (ft)	Dewey Lake Well Depth (ft)
SNL-1	670	550	??
SNL-2/WTS-1	820*	410	??
SNL-3	940*		??
SNL-4	850*		
SNL-5	840	730	??
SNL-6	1505		
SNL-7	890*		??
SNL-8/WTS-8	1000		
SNL-9/WTS-2	860*	500	175
SNL-10/WTS-5	695		
SNL-11	580		??
SNL-12/WTS-10	920*		
WTS-3	960	750	
WTS-4	565*		
WTS-6	600*	275	
WTS-7	875		??
WTS-9	960		
WTS-11	610		
WTS-12	865		
WTS-13	905		
WTS-14	720		
WTS-15	940		
WTS-16	645		
WTS-17	800		
WTS-18	675		
WTS-19	775		
WTS-20	295		
WTS-21	750		
AEC-7R	910		
H-9R	695		
H-10R	1405		
WIPP-25R	490		
WIPP-26R	230		
WIPP-27R	340		
WIPP-28R	465		

*depth to MB103

Dissolution of the upper Salado Formation will be studied in up to eight drilling locations: SNL-2, 3, 4, 7, 9, and 12 and WTS-4 and 6. At these selected locations, the boreholes that will become the Culebra wells will be cored from the lower part of the upper Tamarisk anhydrite to the halite beds of the upper Salado (approximately 175 ft), and then will be rotary drilled through Marker Bed (MB) 103. If MB100, 101, or 102 are well defined, the on-site geologist together with the Lead Hydrologist and Field Operations Lead may terminate drilling at any one of these marker beds. If MB103 is disturbed by deeper dissolution, the borehole may need to be deepened by an estimated additional 100 ft by rotary drilling through MB109 or other suitable stratigraphic marker bed as determined by the on-site geologist in consultation with the Lead Hydrologist and Field Operations Lead. This decision is most likely for four holes (SNL-2, SNL-3, SNL-11, and SNL-12) where the uppermost Salado may have been dissolved to greater depths, obscuring the upper Salado stratigraphic record. After all desired core and geophysical logs have been collected from the upper Salado, the holes will be plugged with cement back to a depth approximately 20 ft below the base of the Culebra before the upper part of the hole is reamed to its final diameter.

Available information is adequate to justify coring the upper Salado in holes SNL-2, SNL-3, and SNL-9. WTS-4 will provide reference data from a location where dissolution of the upper Salado is not believed to have occurred. With respect to SNL-4 and SNL-7, however, decisions to continue the holes beyond the Culebra will depend on information obtained as this program progresses. Because the purpose of coring the upper Salado in SNL-4 would be to determine if the dissolution found in SNL-9 extended to the SNL-4 location, that coring will occur only if dissolution of the upper Salado is conclusively found at SNL-9. The purpose of SNL-7 is to determine whether or not the cavernous porosity found in the Rustler at WIPP-33 continues to the east. If cavernous porosity is found at SNL-7, and if (unlike WIPP-33) it extends as deep as the Culebra, the hole will be continued through MB103 to determine if any dissolution of the upper Salado has occurred. Similarly, if conditions encountered while drilling any other borehole for this program (outside of Nash Draw) indicate the potential for dissolution of the upper Salado, drilling will continue through MB103.

The Magenta wells will have configurations similar to that of the Culebra wells. The wells will be drilled using compressed air as the circulation medium, although fresh water (not Culebra brine) can be used if required. The wells will be drilled to a depth approximately 20 feet below the base of the Magenta, and then reamed to a diameter of 12.25 inches. No coring will be performed, as all necessary core will have been obtained from the Culebra wells at those locations. The anticipated total depths of the Magenta wells are shown in Table 5.

The Dewey Lake wells will also have configurations similar to that of the Culebra wells. The wells will be drilled using compressed air as the circulation medium, although fresh water (not Culebra brine) can be used if required. The wells will be drilled to a depth of 10-20 feet below the cement change on which water appears to be perched (if any), and then reamed to a diameter of 12.25 inches. If no cement change is present, the on-site geologist will determine the total depth to be drilled based on examination of the core recovered. Four-inch core will be taken from a point 10 ft above the water level established for the Dewey Lake when drilling the Culebra well at that location to the total depth. Total depths of most of the potential Dewey Lake wells cannot be estimated in advance.

Core handling, logging, and storage are the responsibility of WTS. Core measurement, labeling, and description will be performed in accordance with WIPP Procedure 07-502. As cores are recovered, they will be logged and samples will be selected, preserved, and transported for laboratory analysis (if any time- or condition-dependent analyses are to be performed). Samples for laboratory analysis will be preserved and transported following ASTM guidelines established according to ASTM Designation D 5079-02 *Standard Practices for Preserving and Transporting Rock Core Samples*. The remaining core will be stored in the WIPP Core Storage Library as material not requiring time- or environmentally-sensitive analysis. All WIPP core will be stored, handled, and distributed following WIPP Procedure 07-EU3504. The core material will be retained indefinitely in the WIPP Core Storage Library; this retention period may be reviewed periodically and at the conclusion of these investigations. The *Integrated Sample Control Plan* (WP 02-EM.02) broadly describes requirements for controlling and handling samples from WIPP investigations.

Only Teflon-based pipe and casing lubricants will be used during well drilling and construction. No additives to the circulation system (e.g., foam, organics, clay) will be allowed without prior written authorization from the Lead Hydrologist.

7.3 Logging

Open-hole geophysical logging will be performed after each Culebra hole is drilled to total depth and reamed, but before the casing and well screen are installed. Wells drilled into the upper Salado will be logged prior to reaming, and caliper logging will be repeated after reaming. The suite of logs to be run in all wells includes: natural gamma, resistivity (induction if the well is not fluid-filled), neutron, density, and caliper. These logs will be used to confirm stratigraphic contact depths determined from core, and will aid in selecting final casing and screening depths. In addition, a high-resolution microresistivity log (e.g., FMI, FMS, EMI) will be run in the SNL-2 Culebra well to determine its effectiveness at identifying fractures and their orientations. If successful, a microresistivity log may be run in other holes. In the Magenta and Dewey Lake wells, only natural gamma and caliper logs are planned, although resistivity (or induction) and neutron logs could be required in Dewey Lake wells to resolve uncertainty about the zone of saturation. After well completion, an acoustic cement-bond log may be run to provide a baseline of cement conditions behind the well casing. The logger must provide all logs in both paper and digital form.

7.4 Well Completion

Well-completion activities will begin with WTS and SNL consultation to determine the casing and screen placement, as well as the depths for annulus fill. The casing string, with screens, will be made up and placed in the hole and depths verified by on-site personnel. The annulus fill depths (see below) will be verified by on-site personnel as the drilling contractor completes each phase.

Five-inch (or 5.5-inch) outside diameter (O.D.) fiberglass casing and well screen will be installed in all wells except for Culebra well SNL-9/WTS-2, in which 9-inch O.D. fiberglass casing and well screen will be installed (because of the anticipated need for a high-capacity 6-inch pump in this well). The well screen will have 0.020-inch slots and cover the interval from one foot above to one foot below the completion horizon (i.e., Culebra, Magenta, or zone of saturation in Dewey Lake). Blank casing will continue below the screen to the total depth of the hole. A sand pack will be placed around the screen, from total depth to approximately five feet above the top of the completion horizon. In no case can the sand pack in a Culebra well extend into the Tamarisk claystone (m3/h3) interval. If halite is encountered in the mudstone (m2/h2) below the Culebra, the annulus from approximately 1-3 feet below the Culebra to total depth (TD) will be cemented. At least five feet of bentonite will be placed on top of the sand pack, and the remainder of the annulus between the fiberglass casing and the borehole wall will be filled with cement.

7.5 Well Development

Following completion of a well, the well may be developed using compressed air to lift the fluid out of the well. Regardless of whether or not the well is first developed by air-lifting, a submersible pump will be set in the well in the tailpipe below the screen and the well shall be pumped for a minimum of twelve hours. Pumping may be performed at different rates, with or without recovery periods in between. Well-development pumping will not cease until the water being produced appears clean and a sustainable pumping rate has been determined.

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8. Roles, Responsibilities, and Work Breakdown Structure

The activities described in this plan will be performed under the auspices of the IGWT. Roles and responsibilities of IGWT members are generally defined in the *Strategic Plan For Groundwater Monitoring at the Waste Isolation Pilot Plant* (DOE, 2003). The functional organization for the WIPP Integrated Groundwater Hydrology Program is presented in Figure 21. This program is managed by E.B. Nuckols, DOE Hydrology Program Manager. In this capacity, the DOE lead provides for final work authorization through formal plan approval processes. Formal plan or work authorization entails DOE plan review, comments, comment resolution, and written authorization to proceed for all activities. Deviations from approved plans are captured in a formal baseline change order control process in which written authorization to proceed will be obtained prior to commencing a changed work scope. Disagreements among program participants will be discussed and resolved at monthly progress meetings (see Section 11), with final decision authority resting with E.B. Nuckols.

The program is an integrated approach that incorporates execution of program tasks by SNL and WTS. SNL is the Scientific Advisor on hydrology for the WIPP while WTS provides operations support. SNL has designated Rick Beauheim as the Lead Hydrologist for the program. The Lead Hydrologist is the primary technical advisor for all groundwater investigations. WTS has designated Ron Richardson as their Field Operations Lead for the program. In this capacity, the Field Operations Lead will coordinate and integrate the field operations interface with the Lead Hydrologist and other functional groups in the program and the WIPP organization (e.g., regulatory compliance, NEPA, etc.). The work and other activities performed by SNL and WTS will be governed by the Quality Assurance programs of their respective organizations.

The hydrology program is managed through a work breakdown structure (WBS) architecture and functional organization. Table 6 identifies a preliminary WBS for the FY03-09 hydrology program. The WBS is defined by the following six upper tier WBS categories:

- Plan Development
- Contracting
- Permitting
- Drilling and Well-Completion Field Operations
- Hydraulic Testing and Analysis
- Modeling

The WBS will be fully integrated with the schedule developed for the program.

Within Table 6, each WBS element is linked to a specific individual who is responsible for execution of the WBS functions and integration of these functions with the hydrology program and other WIPP organizations. The roles and responsibilities matrix is further defined by lower tier WBS elements and will be expanded into other elements as the program is further developed.

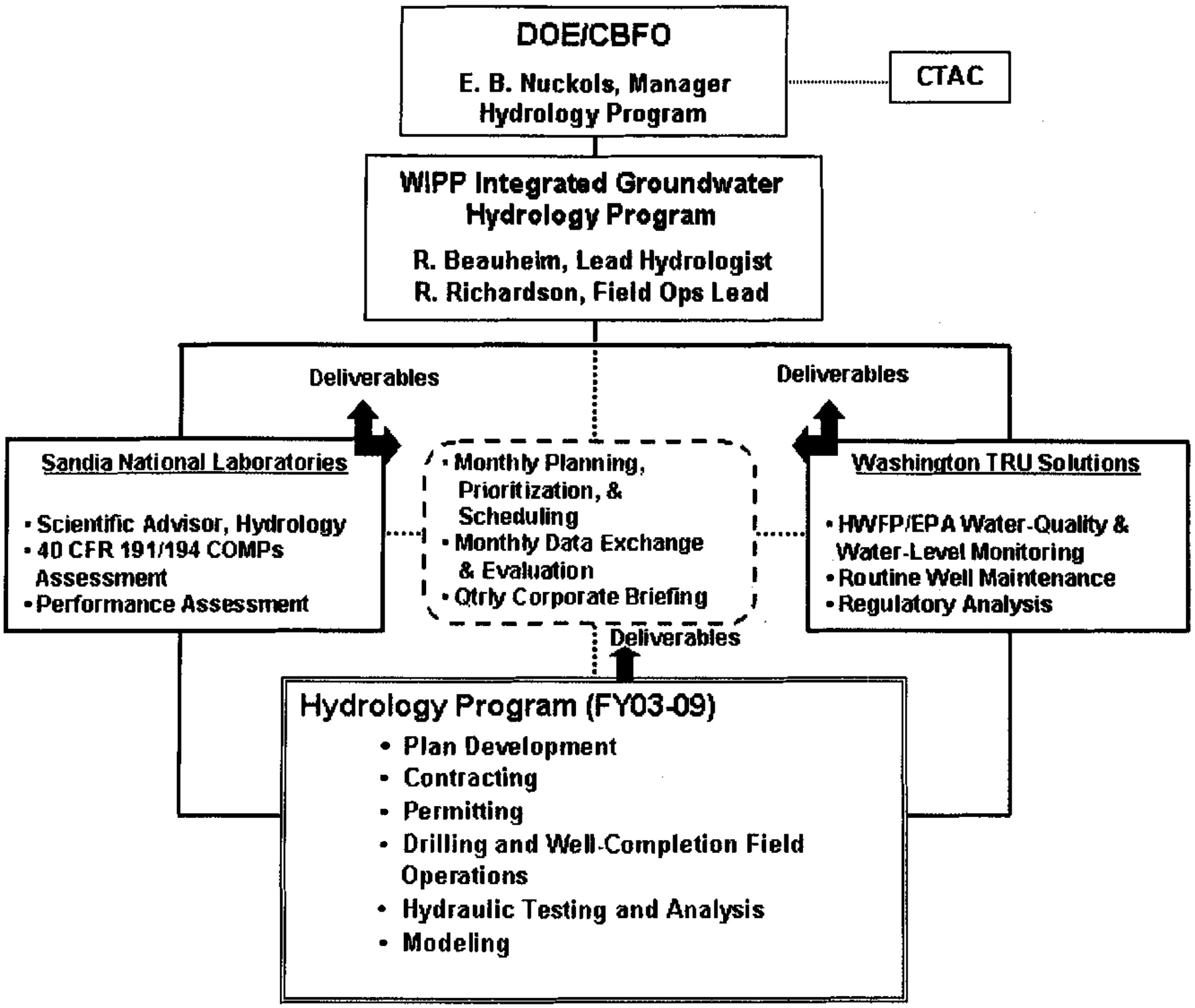

Figure 21. Organizational structure for WIPP Integrated Groundwater Hydrology Program.

Table 6. Roles and Responsibilities Matrix.

WBS	WBS Title	Responsible Person
1.0	Plan Development	R. Beauheim (SNL)/ R. Richardson (WTS)
1.1	Statements of Work for Well Drilling and Completion	R. Richardson (WTS)
1.2	Modeling Analysis Plan Development	R. Beauheim (SNL)
1.3	Field Test Plan Development	D. Chace (SNL)
2.0	Contracting	R. Richardson (WTS)/ D. Chace (SNL)
2.1	Drilling Procurement	R. Richardson (WTS)
2.2	Procurement for Hydraulic Testing Support	R. Richardson (WTS)
2.3	Equipment Procurement for Hydraulic Testing	D. Chace (SNL)
3.0	Permitting	S. Jones (WTS)
3.1	Archeological Permits	D. Lynn (WTS)
3.2	State Engineer Permits	D. Lynn (WTS)
3.3	BLM Permits/ROW's	D. Lynn (WTS)
4.0	Drilling and Well-Completion Field Operations	R. Richardson (WTS)
4.1	Site Preparation, Drilling, and Well Installation	R. Richardson (WTS)
4.2	Preparation of Basic Data Reports	R. Richardson (WTS)
5.0	Hydraulic Testing and Analysis	R. Beauheim (SNL)
5.1	Hydraulic Testing	D. Chace (SNL)
5.2	Hydraulic Testing Field Support	R. Richardson (WTS)
5.3	Hydraulic-Test Analysis	R. Roberts (SNL)
5.4	Colloidal Borescope Logging	R. Beauheim (SNL)
5.5	Reporting	D. Chace (SNL)
6.0	Modeling	R. Beauheim (SNL)
6.1	Impact Assessment	R. Beauheim (SNL)
6.2	Preliminary Scenario Modeling	R. Beauheim (SNL)
6.3	T-Field Development	R. Beauheim (SNL)
6.4	Magenta Model	J. Stein (SNL)
6.5	Final Compliance Model	R. Beauheim (SNL)
6.6	Reporting	R. Beauheim (SNL)

8.1 Plan Development

Plan development will result in Statements of Work (SOW's), Test Plans (TP's), and Analysis Plans (AP's), all of which will be approved by DOE. One SOW will be prepared by WTS with SNL consultation to govern well drilling and completion activities from FY03 through FY05. WTS will prepare at least one additional SOW to govern well drilling and completion in subsequent years. TP 03-01 (Chace, 2003) has been prepared by SNL to govern testing activities in all new wells (including C-2737). AP's will be prepared by SNL to govern modeling activities, such as preliminary scenario modeling, development of a Magenta model, development of second-generation T fields, and development of final compliance models.

The SOW's and TP's will not establish the exact scheduling for drillholes and testing activities composing the full, integrated program. Instead, the plans will provide general forecasts of activities (e.g., numbers, locations, and completion intervals of proposed wells; types of well testing and analysis for each proposed well; descriptions of proposed groundwater modeling efforts, etc) for each year of the planned FY03 – FY09 period. Activities will be scheduled for each subsequent year at the beginning of the year following review and assessment of data acquired during earlier years. This review ensures that activities scheduled for the FY are appropriate to meet the objectives of the integrated program.

8.2 Contracting

For contracting related to field activities, the SOW's descried above will form the basis for contracts with drilling companies, logging companies, etc. to provide the required services. WTS will be responsible for all contracts related to earthmoving, pad construction, drilling, geophysical logging, workover rigs, pump-setting trucks, and brine storage, hauling, and disposal.

SNL will be responsible for providing equipment required for hydraulic testing (tubing, packers, pumps, generators, data-acquisition systems, transducers, Trolls, water-quality instruments, flow meters, and flow-control devices), colloidal borescope logging, core studies (permeability, porosity, thin sections, slabbing, etc.), and water-quality analyses of final samples.

8.3 Permitting

Permitting includes filing NEPA documentation, archeological surveys, and obtaining right-of-way permits from the Bureau of Land Management or State of New Mexico and drilling and pumping permits from the Office of the State Engineer. All permitting activities will be performed by WTS, with supporting information provided by SNL as needed, and must be completed before field operations can begin.

8.4 Drilling and Well-Completion Field Operations

WTS will direct field operations associated with drilling and well completion. WTS is also responsible for all core handling, logging, and storage. An SNL representative will be available for on-site consultation during well-completion and development activities. A well-completion notification and a basic data report for each drillhole provided by WTS are the deliverables associated with this schedule element. Field operations associated with drilling are considered complete when WTS is ready to turn the well over to SNL for hydraulic testing.

8.5 Hydraulic Testing and Analysis

Hydraulic-testing operations will be led and performed by SNL, with field support (e.g., pump-setting trucks) provided by WTS as necessary. SNL will begin monitoring in new wells as soon as they are turned over by WTS, and will determine the schedule for testing based on real-time evaluation of the monitoring data. SNL will be responsible for scanning colloidal borescope logging in selected wells, and will schedule this activity around other well-testing activities. When all testing operations are completed in a well, including use of the well as a monitoring location during tests at other wells, SNL will turn the well back over to WTS for inclusion in WTS's monthly water-level-monitoring program.

Analysis of hydraulic-test data will begin while the test is in progress, and will be used to determine when the test may be terminated. The final data analysis for each well test will require one to two additional weeks following completion of the test. All hydraulic-test analysis will be performed by SNL.

8.6 Modeling

All modeling will be conducted by SNL following AP's as described in Section 8.1.

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9. Milestones

Milestones represent significant endpoints along the schedule where a task has been completed and provides important information for decision-making along the projects critical path. Milestones will be defined on an annual basis when the program for each year is approved. Milestones will be controlled through the development of a Milestone Control Log and Milestone Description Sheets (MDS's). The Milestone Control Log (MCL) will list all the controlled deliverables and products developed by the hydrology program. Those milestones that are not deliverables will be identified along the critical path of the schedule. A MDS will be developed for each milestone that describes the work to be accomplished and the product/deliverable that is to be provided on a given date. These MDS's constitute commitments that identify the completion date, milestone designation/identification, and notification of what determines milestone completion. These MDS's are commitment documents that will be signed by the DOE lead, SNL lead, and WTS lead. An example of a MDS is shown as Figure 22.

WIPP HYDROLOGY PROGRAM
MILESTONE DESCRIPTION SHEET

TITLE: Approval of Test Plan by DOE **DATE:** November 28, 2002

ASSIGNED TO: E.B. Nuckols **COMPLETION DATE:** December 15, 2002

PROGRAM WBS: 1.1 **REVISION NUMBER: 0**

MS ID: TP1-02

PREDECESSOR EVENT: Formal Review by DOE

SUCESSOR EVENT: WTS drilling Contracting (WBS 2.0)

Milestone Class:		Deliverable:	
___	Level 1 (DOE-HQ)		
___	Level 2 (DOE-CBFO, Major)	X	Report
		X	Letter
X	Level 3 (DOE-Lead)	___	Design
___	Level 4 (Internal)	___	Other (specify)

MILESTONE DESCRIPTION AND WHAT CONSTITUTES COMPLETION OF THIS COMITMENT:

The deliverable is the test plan to install four wells in FY03, perform hydraulic testing on three of the wells in FY03, perform analysis of the testing data and document the data in Basic Data Reports (Geology) and the Semi-Annual Technical Baseline Status Report (Hydrology). The test plan will be a Level 3 Milestone/ Deliverable in which a formal review, comment resolution process, and approval from the DOE is required. The approval of this test plan from the DOE represents authorization to proceed with the activities represented in the plan. The test plan will have a DOE signature block identifying approval. Completion of this commitment is defined by final signature and approval by the DOE.

WIPP HYDROLOGY PROGRAM
MILESTONE DESCRIPTION SHEET

______________________________ **DOE LEAD DATE______**
E.B. Nuckols

______________________________ **SNL LEAD DATE______**
Rick Beauheim

______________________________ **WTS LEAD DATE ______**
Ron Richardson

Figure 22. Example of a Milestone Description Sheet.

10. Deliverables

The previous section described the schedule milestones in this program. Deliverables are always milestones, but milestones are not always deliverables. Deliverables will also be defined on an annual basis as the program for each year is developed and approved. A deliverable documents an action of the DOE or contractors. For instance, the data reports identified in the schedule are deliverables to the DOE (external) and to staff of WTS (internal) summarizing the drilling field activities. Because this document does not require formal DOE review and approval, it is considered a Level 4 deliverable. Level 3 deliverables are those that are delivered to the CBFO staff and require full formal DOE review, comments, comment resolution, and approval. Level 2 deliverables are higher level summary documents typically summarizing Level 3 or 4 deliverables and are typically delivered to DOE-CBFO. Level 1 deliverables are high-level documents delivered to DOE-HQ.

The SNL Semi-Annual Technical Baseline Status Reports delivered to the DOE are non-critical-path deliverables. These are not directly associated with this program, but will be utilized to summarize hydraulic testing for the wells installed and provide status updates on modeling and ancillary activities. An example summary of some deliverables and their respective due dates is presented below:

L3 DELIVERABLES (Critical Path)

- Test Plan and Approval Letter (12/20/02)

L4 DELIVERABLES (Critical Path)

- SNL/WTS Letter Request and DOE approval for specific well installations (1/3/03)
- Basic Data Report Well 1 (5/16/03)
- Well 1 completion letter report to DOE (4/21/03)
- Basic Data Report Well 2 (6/9/03)
- Well 2 completion letter report to DOE (5/9/03)
- Basic Data Report Well 3 (6/30/03)
- Well 3 completion letter report to DOE (6/2/03)
- Completion of hydraulic testing letter report Well 1 (5/16/03)
- Completion of hydraulic testing letter report Well 2 (6/9/03)

L3 DELIVERABLES (Non-Critical Path)

- SNL Semi-Annual Status Report (1/31/03)
- SNL Semi-Annual Status Report (7/31/03)

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11. Meetings and Reporting

Monthly meetings of the IGWT will be the principal means of disseminating the results and assessing the status of the integrated WIPP hydrology program among the entire team. Disagreements among program participants will be discussed and resolved at these monthly meetings, with final decision authority resting with E.B. Nuckols, DOE Hydrology Program Manager. During field operations and testing, field personnel will commonly contact technical and program lead personnel on a daily basis to provide progress reports.

Quarterly and annual meetings will be held to provide higher level briefings to upper management, providing background and general information rather than specific test or drillhole results. In the last quarter of each fiscal year, a meeting will be held involving all personnel involved in the hydrology program to review the progress that has been made, and confirm or modify the program planned for the following year.

A variety of reports will be produced during this program. Basic Data Reports will be prepared for each new well installed. Summaries of drilling and testing activities will be included in Sandia's semi-annual status reports. One or more analysis reports will be prepared for the well testing performed in the individual new wells installed, and additional reports will be prepared for the multipad pumping tests that will be performed. Reports will also be prepared summarizing the new models developed under this program, and specific modeling results.

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