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Technical Area 21 Groundwater and Vadose-Zone Monitoring Well Network Evaluation and Recommendations

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EXECUTIVE SUMMARY

This monitoring well network evaluation addresses the adequacy of the existing groundwater and vadose-zone monitoring networks for detecting the migration of known or potential contaminant sources at Technical Area 21 (TA-21) of the Los Alamos National Laboratory. The subject sources are solid waste management units (SWMUs) and areas of concern (AOCs) that consist of the material disposal areas (MDAs) at TA-21 and SWMUs and AOCs that are part of the DP Site Aggregate Area. The recommendations that derive from this evaluation are intended to capture the monitoring requirements necessary to protect groundwater and water-supply wells and to support completion of ongoing investigations and selection of corrective measures alternatives for applicable sites at TA-21. Vadose-zone monitoring near sources is incorporated as part of the network as an important means to provide near-term data concerning potential migration.

The monitoring requirements at TA-21 address two types of sources: historical releases that are known to be present in groundwater somewhat distant from TA-21 and known and potential releases in the immediate vicinity of sites at TA-21. SWMU 21-011(k), a historical industrial wastewater outfall, is considered the main TA-21 source of contaminants already present in groundwater.

Specific goals of the monitoring network include the following:

- Provide sentinel monitoring at water-supply wells for contaminants historically released from SWMU 21-011(k)
- Effectively monitor the fate and transport of contaminants historically released from TA-21 [SWMU 21-011(k)]
- Characterize and monitor groundwater in areas proximal to moderate- to high-priority TA-21 release sites on DP Mesa to support ongoing investigations and the evaluation of potential corrective measures
- Ensure that vapor-phase monitoring is adequate to characterize nature and extent and temporal variability of contaminants present in the vadose zone beneath key TA-21 contaminant sources
- Characterize and monitor vadose-zone moisture content for evaluation of potential corrective measures and long-term performance monitoring

For this evaluation, TA-21 sources are prioritized by their potential to impact groundwater. Sources ranked as having moderate to high priority either have or could have potentially released contaminants to the subsurface with chemical concentrations above risk drivers and were accompanied by large liquid drivers. A lower priority was assigned to dry sites without liquid drivers, deferred sites that are scheduled for source removal and further verification sampling, or sites that have been administratively closed. These sites are considered to have contaminants with little or no potential to migrate to groundwater and are not included as part of this evaluation. The source prioritization developed the following ranking.

- High priority: SWMU 21-011(k) and the adsorption beds and disposal shafts at MDA T
- Moderate priority: DP West, waste lines and sumps, and MDA V
- Low priority: MDA A, MDA B, MDA U, DP East, and a diesel spill

Mobile contaminants, such as tritium, nitrate, and perchlorate, released at the SWMU 21-011(k) outfall have dispersed down DP and Los Alamos Canyons by surface water and alluvial groundwater. They are present in perched-intermediate groundwater near the confluence of DP and Los Alamos Canyons (at R-6i, LAOI-3.2, and LAOI-3.2a), farther down Los Alamos Canyon (at LAOI-7 and R-9i), and beneath Mesita de Los Alamos (at TA-53i).

Contaminant concentrations are at background levels in regional groundwater monitoring wells in the near vicinity of TA-21 (e.g., R-6, R-7, and R-8) suggesting that deep infiltration through the vadose zone, including migration from perched groundwater, does not reach the regional aquifer near TA-21. The regional aquifer at TW-3 appears to be contaminated, but this may be related to well construction. Tritium and perchlorate are slightly elevated in the regional aquifer at R-9, which is located farther down Los Alamos Canyon. These far-field contaminants may have originated at SWMU 21-011(k). Water-supply wells O-1 in lower Pueblo Canyon, O-4 at the DP Canyon/Los Alamos Canyon confluence, and PM-3 in lower Sandia Canyon are potentially along the flow path. For this reason, existing monitoring wells along these flow paths and sentinel wells for O-1, O-4, and PM-3 are evaluated with respect to their ability to monitor for contaminants from SWMU 21-011(k).

Under natural conditions, slow vertical unsaturated flow and transport should occur through the tuffs that underlie DP Mesa. However, enhanced moisture migration and decreased contaminant travel times may occur beneath liquid waste disposal sites where infiltration beneath absorption beds, for example, has increased the moisture content in the underlying strata. Several of the wetter mesa-top source areas are therefore considered to have the potential to reach groundwater. Proximal regional monitoring and local vadose-zone monitoring are considered for such sources.

Based on this evaluation, existing intermediate and regional wells in the current monitoring network downgradient of TA-21 are generally performing well. With the exception of TW-3, it is recommended that monitoring of these existing wells should continue in accordance with the current Interim Facility-Wide Groundwater Monitoring Plan. A new monitoring well, TW-3r, is proposed to be a sentinel well for O-4, and it replaces the existing TW-3 that is recommended for plugging and abandonment. Existing regional monitoring wells R-35a/R-35b and R-3 act as sentinel wells for water-supply wells PM-3 and O-1, respectively.

Two new regional groundwater monitoring wells closer to the moderate- and high-priority mesa-top sources at TA-21 are recommended to augment the existing well network in order to detect potential contaminants. The proposed wells, termed MW-14 and MW-10 in this report, will be located approximately 100 m north and 110 m east, respectively, of the center of MDA T and will detect contaminants within 5 yr of their entering the regional aquifer with greater than 95% detection efficiency. The intent of the new wells is to provide data sufficient to support corrective measure evaluations at TA-21, especially MDA T. Vadose-zone moisture-monitoring wells are recommended near the disposal shafts at MDA T because enhanced residual moisture beneath the MDA T adsorption beds could potentially mobilize contaminants at the site. Observations of moisture movement as a proxy for contaminant migration are recommended. Finally, this evaluation recommends that a vapor-monitoring well be installed near the former wastewater treatment plant east of MDA T to augment monitoring of volatile organic compound and tritium vapors in the vadose zone and to fill a data gap near the east end of MDA T.

Monitoring is deferred for other TA-21 sites that are considered low priority in this evaluation. The need for additional monitoring at these low-priority sites will be assessed after ongoing investigations and/or cleanup are completed and verification sampling has been performed. Additionally, the need for an upgradient baseline well will be reexamined after monitoring data from the two new downgradient monitoring wells are evaluated.

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Acronyms and Abbreviations

AOC	area of concern
bgs	below ground surface
CHFR	cased-hole formation resistivity
CME	corrective measures evaluation
COPC	chemical of potential concern
D&D	decontamination and decommissioning
DO	dissolved oxygen
DOE	U.S. Department of Energy
DRO	diesel range organic
ECS	elemental capture spectroscopy
ELAN	Elemental Log Analysis
FMI	Formation Micro-Imager
HSA	hollow-stem auger
HSWA	Hazardous and Solid Waste Amendments of 1984
I.D.	inside diameter
IFGMP	2009 Interim Facility-Wide Groundwater Monitoring Plan
LANL or the Laboratory	Los Alamos National Laboratory
MDA	material disposal area
MP	multiple port
n/a	not applicable
NGS	natural gamma spectrometry
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxygen-reduction potential

OWR	Omega West Reactor
PVC	polyvinyl chloride
RWSA	retrievable waste storage area
SWMU	solid waste management unit
TA	technical area
TD	total depth
TKN	total Kjeldahl nitrogen
TLD	Triple Litho-Density Detector
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSTA	Tritium Systems Test Assembly
UTL	upper tolerance limit
VOC	volatile organic compound
WWTP	wastewater treatment plant

1.0 INTRODUCTION

This monitoring well network evaluation for Technical Area 21 (TA-21) at the Los Alamos National Laboratory (LANL or the Laboratory) is being conducted pursuant to a requirement set forth by the New Mexico Environment Department's (NMED's) "Approval with Modifications, Phase III Investigation Report for Material Disposal Area T, at Technical Area 21, Revision 1" dated February 4, 2010 (NMED 2010, 108767).

This evaluation addresses the adequacy of the existing groundwater and vadose-zone monitoring networks for detecting known or potential contaminant sources at TA-21 to support ongoing investigations and pending corrective measures implemented under the Compliance Order on Consent (Consent Order). The subject sources are solid waste management units (SWMUs) and areas of concern (AOCs) that consist of the material disposal areas (MDAs) at TA-21 and SWMUs and AOCs that are part of the DP Site Aggregate Area (see Figure 1.0-1). The recommendations that derive from this evaluation are intended to capture the monitoring requirements to support completion of ongoing investigations and selection of corrective measures alternatives for applicable sites at TA-21.

A previous network evaluation was conducted in 2008 for the Los Alamos and Pueblo Canyon watershed that addressed potential sources throughout the watershed (LANL 2008, 101330). That evaluation focused on monitoring of the perched-intermediate groundwater and the regional aquifer. It included sources at TA-21, but used somewhat different objectives and was less detailed with respect to the TA-21 sources than this evaluation. Additionally, this evaluation includes assessment of characterization and monitoring gaps for the vadose zone beneath the most significant SWMUs and AOCs at TA-21 based on information obtained during ongoing Consent Order investigations. Vadose-zone characterization and monitoring is complete or underway at TA-21 for several of the MDAs.

Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy policy.

2.0 MONITORING OBJECTIVES AND EVALUATION APPROACH

The purpose of this report is to evaluate the existing groundwater and vadose-zone monitoring networks that support investigations and potential corrective measures for SWMUs and AOCs at TA-21. As described in section 3 of this report, the monitoring needs to address historical releases that are known to be present in groundwater somewhat distant from TA-21 proper, and potential releases in the immediate vicinity of sites at TA-21. The specific objectives are described below.

Objective #1, Provide Sentinel Monitoring at Water-Supply Wells for Contaminants Dispersed along DP Canyon from SWMU 21-011(k)

This objective specifically addresses monitoring of contaminants that are associated with historical liquid effluent releases from SWMU 21-011(k) into DP Canyon. These contaminants were dispersed downcanyon by surficial processes before infiltrating the vadose zone at locations distant from the original outfall. To address this objective, the groundwater network should include sentinel wells located near water-supply wells that are potentially downgradient of TA-21, particularly in areas where contaminants are known to be present in perched-intermediate groundwater and potentially present in regional groundwater. Discussions in section 3 of this report describe the conceptual model for the nature and extent of groundwater contamination associated with the SWMU 21-011(k) source. The key water-supply wells along or potentially downgradient of the flow path include O-1 in lower Pueblo Canyon, O-4 at the

DP Canyon/Los Alamos Canyon confluence, and PM-3 in lower Sandia Canyon. The wide spatial distribution of these monitoring points reflects known and potential complexities of flow path(s), especially in the vadose zone. The basis for considering these water-supply wells for the SWMU 21-011(k) source is presented in section 3 of this report.

This objective focuses mainly on existing regional wells located adjacent to the three water-supply wells. The physical and geochemical attributes of the sentinel wells for each of these water-supply wells are discussed in Appendixes A and B. Section 4 of this report summarizes the information from Appendixes A and B into a table that presents the ability of the existing wells to provide adequate sentinel groundwater monitoring.

Objective #2, Effectively Monitor the Fate and Transport of Contaminants Historically Released from TA-21 [SWMU 21-011(k)]

This objective is focused on monitoring the fate and transport of the contamination historically released as liquid effluent from SWMU 21-011(k) in areas downgradient of DP Mesa. It is similar to objective #1 above, but emphasizes the effectiveness of existing intermediate and regional monitoring wells that define or characterize the pathways and fate of these contaminants. The conceptual model in section 3 describes the pathways for groundwater and associated contaminants initially discharged from SWMU 21-011(k) that are now present in perched-intermediate and regional groundwaters along the flow path.

This objective also focuses on existing monitoring wells, but includes both intermediate and regional aquifer wells. The physical and geochemical attributes of the monitoring wells are included in Appendixes A and B and summarized in section 4.

Objective #3, Characterize and Monitor Groundwater in Areas Proximal to Moderate- to High-Priority TA-21 Release Sites on DP Mesa to Support Ongoing Investigations and the Evaluation of Potential Corrective Measures

This objective evaluates potential locations for new groundwater monitoring wells to adequately support ongoing investigations at applicable TA-21 sources that have the potential to impact perched-intermediate or regional aquifer groundwater near the source. The intent of the new wells is to provide data sufficient to support corrective measure evaluations (CMEs) at TA-21, especially MDA T. The performance objective for these wells is a 95% probability of detecting groundwater contaminants that might already exist or could arrive in the future from any of the applicable sources. The goal is to detect contamination at the new monitoring locations within 5 yr of arrival into the regional aquifer. This time frame is chosen so that sufficient groundwater data are available to support CMEs of the various source areas.

This objective is addressed by first assessing which sites at TA-21 require groundwater monitoring because of the nature of contaminants and potential release mechanisms. The ranking of these sites is presented in section 3 of this report. The number and locations of new wells is derived from a hydrologic and modeling analysis conducted in Appendix C. New wells are identified to detect existing or potential regional groundwater impacts in areas immediately adjacent to moderate- to high-priority TA-21 sites. This approach uses a groundwater transport model that places hypothetical contaminants in the regional groundwater beneath the moderate- to high-priority source areas described in section 3 and predicts the dispersion of hypothetical plumes. Variations in the parameters that govern transport are treated probabilistically, yielding a description of possible transport pathways. The results of these simulations are then analyzed to help site potential wells.

Objective #4, Ensure that Vapor-Phase Monitoring is Adequate to Characterize Nature and Extent and Temporal Variability of Contaminants Present in the Vadose Zone Beneath Key TA-21 Contaminant Sources

This objective is focused on evaluating potential data gaps in vadose-zone characterization and monitoring of vapor-phase volatile organic compounds (VOCs) and tritium at applicable sites. This assessment is limited to sites that are under active investigation and defers those sites at TA-21 that are pending cleanup activities and confirmation sampling. Appendix A summarizes the current vapor-monitoring network at TA-21. A summary discussion of sites at TA-21 that may require further vadose-zone characterization because of outstanding questions regarding nature and extent of vapors is in section 3 of this report. Recommendations are presented in section 5.

Objective #5, Characterize and Monitor Vadose-Zone Moisture Content for Evaluation of Potential Corrective Measures and Long-Term Performance Monitoring

This objective is focused on the TA-21 sites that have contaminant inventory that may remain in place and where pore-water contents are higher than background levels and, subsequently, may facilitate migration. The assessment will identify the sites that presently warrant further characterization of vadose-zone moisture. This assessment is limited to sites that are under active investigation and defers those sites at TA-21 that are pending cleanup activities and confirmation sampling. This objective is addressed in section 3 of this report and derives from the ranking of sites and the nature of sources that may remain in place.

3.0 CONCEPTUAL MODELS FOR DP CANYON AND DP MESA

This section is an overview of the principal sources of contamination at TA-21 and of the Laboratory’s current conceptual models for the fate and transport of those contaminants in the subsurface beneath DP Canyon and DP Mesa. Environmental investigations conducted have led to sufficient understanding of contaminant distributions in the subsurface beneath these two areas to develop conceptual models for the fate and transport of contaminants and to subsequently conduct an evaluation of the monitoring network with respect to contaminants released from or disposed at TA-21. The contaminant sources are described and then ranked relative to their potential for impacting groundwater in section 3.1. Then, separate conceptual models are developed for DP Canyon and DP Mesa, as illustrated in Figures 3.0-1 through 3.0-5, because the extent of contaminant migration differs substantially between these two locations, as described in section 3.2. Development of the DP Canyon hydrologic conceptual model is based on water-level observations and sediment, surface water, and alluvial water contaminant distributions that were presented in detail in the “Los Alamos and Pueblo Canyons Investigation Report” (LANL 2004, 087390) and the “Los Alamos and Pueblo Canyons Groundwater Monitoring Well Network Evaluation and Recommendations, Revision 1” (LANL 2008, 101330). Development of the conceptual model for DP Mesa is based on hydrologic and geochemical data from site investigations and periodic monitoring conducted at TA-21 mesa-top SWMUs and AOCs (e.g., LANL 2006, 094151; LANL 2006, 092589; LANL 2009, 108012; LANL 2010, 109082).

Several outfalls and overflow from MDA V released effluent from the south side of TA-21 to Los Alamos Canyon. However, sediment, surface water, and alluvial groundwater concentrations presented in the “Los Alamos and Pueblo Canyons Investigation Report” showed that these sources had minimal impact on contaminant distributions in Los Alamos Canyon (LANL 2004, 087390). For this reason, Los Alamos Canyon sources from TA-21 are not discussed, and the conceptual model for the canyon is only discussed for the areas at and below the confluence with DP Canyon where contaminants from TA-21 are present.

3.1 Contaminant Sources

The TA-21 contaminant sources, in terms of their potential to impact groundwater, and the justification for the ranking of each source are summarized in Table 3.1-1 and shown in Figures 1.0-1 and 3.0-1. These sources include SWMU 21-011(k), MDAs, underground industrial waste lines and sumps [Consolidated Unit 21-022(b)-99], and buildings at DP East and DP West. The MDAs at TA-21 include MDA A, MDA B, MDA T, MDA U, and MDA V (Figure 1.0-1). These MDAs either currently contain or formerly contained legacy wastes in adsorption beds, pits, shafts, and trenches that were dug into the mesa top. Most sites are stabilized with temporary crushed tuff or asphalt covers.

For this evaluation, the sources are prioritized by their potential to impact groundwater. The sources and the justification for their priority level are discussed below. Sources ranked as having moderate to high priority either have released or could potentially have released contaminants to the subsurface with chemical concentrations above risk drivers and were accompanied by large liquid drivers. These include effluent releases to adsorption beds, disposal shafts, or outfalls as well as potentially leaky pipes, drainlines, or sumps. A lower priority was assigned based on one or more of the following criteria: dry sites without liquid drivers, deferred sites that are scheduled for source removal and further verification sampling, or sites that have been administratively closed. The conceptual models presented in section 3.2 will further clarify why liquid drivers are important when ranking the sources for their potential to impact groundwater.

The moderate- to high-priority sources at TA-21 are the most important locations to characterize and monitor for groundwater protection, and they are the focus of this network evaluation. Because historical contaminant releases from the SWMU 21-011(k) former outfall have resulted in off-site migration of contaminants, the network includes monitoring of groundwater in downgradient monitoring wells and in sentinel wells protecting municipal supply wells (objectives #1 and #2 in section 2). Proximal monitoring of the vadose zone and groundwater near moderate- and high-priority sources on DP Mesa is needed to provide timely detection of groundwater impacts near mesa-top release sites (objectives #3, #4, and #5 in section 2). Installation of additional wells to monitor regional groundwater proximal to these sources is discussed in Appendix C. Potential breakthrough locations for these sources are shown in Figure 3.0-1.

For completeness, lower-priority sources at TA-21 are also described below, but these sites are considered to present little or no threat to groundwater and are not included as part of the network evaluation assessment. The lower-priority sites may be reconsidered for additional monitoring in the future if confirmation sampling beneath sites undergoing remediation indicates that contaminant migration beneath these sites could impact groundwater.

3.1.1 High-Priority DP Canyon Sources (important for off-site groundwater monitoring – objectives #1 and #2 in section 2)

SWMU 21-011(k) (Figure 1.0-1) is ranked as a high priority because large volumes of wastewater were released at the outfall (over 50 million gal. total [Birdsell et al. 2006, 094399]), and associated contaminants have migrated down DP Canyon over a kilometer from the discharge point. The SWMU 21-011(k) former outfall discharged treated industrial liquid waste and is the largest volume source of contaminants released to DP Canyon. The outfall was active between 1952 and 1986 (LANL 1991, 007529; LANL 1995, 052350). Plutonium, uranium, cesium, and strontium are important radionuclide contaminants discharged from this outfall, but these are predominantly retained in sediment and in surface and alluvial waters (LANL 2004, 087390). Mobile constituents discharged at SWMU 21-011(k) that have contaminated deeper groundwater include tritium, perchlorate, nitrate, and possibly 1,4-dioxane (Birdsell et al. 2006, 094399). Some or all of these contaminants have been observed in alluvial wells in DP and Los Alamos Canyons and in downgradient intermediate wells R-6i, LAOI-3.2, LAOI-3.2(a), LAOI-7, R-9i, and TA-53i (see Appendix B). Monitoring requirements for contaminants from SWMU 21-011(k) are described in objectives #1 and #2 of section 2 and relate to monitoring of constituents that have already traveled far afield (secondary source in the environment) rather than from the original source. Although strontium-90 and cesium-137 from SWMU 21-011(k) have not been consistently detected in deeper groundwater to date, they are included in the analysis in Appendix B because they represent the more mobile of the radionuclides associated with the former outfall.

3.1.2 Moderate- to High-Priority DP Mesa Sources (important for proximal vadose zone and groundwater monitoring – objectives #3, #4, and #5 in section 2)

3.1.2.1 MDA T

MDA T [Consolidated Unit 21-016(a)-99] consists of four inactive absorption beds, disposal shafts, buried sumps and pipelines, the former retrievable waste storage area (RWSA), and a former wastewater treatment plant (WWTP). It is located on the mesa top (Figure 1.0-1). Contaminants at the site include plutonium, americium, uranium, and mixed fission products. Nitrate, perchlorate, and some VOCs are also present.

For MDA T, the adsorption beds and shafts together are ranked as a high-priority source because a significant radionuclide inventory of several thousand curies (Rogers 1977, 005707) was disposed of at the site, and former liquid discharges could enhance contaminant migration. Untreated liquid waste from uranium- and plutonium-processing laboratories was released to the absorption beds from 1945 to 1952. After 1952, treated radioactive liquid wastes were still infrequently released to the absorption beds until 1967. Approximately 18 million gal. of wastewater was discharged to the MDA T absorption beds (LANL 2004, 085641). The shafts received wastes containing americium-241, plutonium-239/-240, and other mixed fission products mixed with Portland cement, and some shafts received unspecified volumes of wash water. The former RWSA is not considered a threat to groundwater because the source was removed, and no evidence of a release was noted during removal.

Ongoing investigations at MDA T show that moisture contents and concentrations of tritium, nitrate, and perchlorate within the mesa remain elevated above background to depths of approximately 350 ft below ground surface (bgs) (LANL 2006, 094151). Vapor-phase VOCs and tritium are also detected in five vapor monitoring wells (21-25262, 21-25264, 21-603058, 21-603069, 21-607955; Figure 1.0-1) to depths of approximately 300 to 500 ft bgs, respectively (LANL 2010, 108529). Currently, both primary sources (those remaining in the disposal units—the adsorption beds and shafts) and secondary sources (contaminants beneath the disposal units that have migrated into the unsaturated zone) are present. Elevated subsurface moisture may continue to redistribute and subsequently transport contaminants to greater depths.

3.1.2.2 DP West

The DP West facilities are ranked at moderate priority because of their long history of operations and because leaks in underground piping are known to have occurred. DP West facilities include buildings 21-002, 21-005, and 21-150 and former buildings 21-003 and 21-004. These decommissioned buildings were used primarily for purification, reduction, and recovery of plutonium, uranium, and americium and research on tritium, stable and rare isotopes, and mixed fission products. Buildings 21-003 and 21-004 were demolished in the mid-1990s; the rest will be demolished in 2010 and 2011 as part of TA-21 decontamination and decommissioning (D&D). Consolidated Unit 21-006(c)-99, also located within DP West, included underground seepage pits, a drainline, and an outfall from one of the seepage pits; it was removed in 2008. Although monitoring consideration for these facilities could be deferred until cleanup activities are completed, they are included in the network assessment because known leaks into the subsurface at these facilities may represent a secondary source. Contaminant concentrations were potentially high because the wastes were untreated. Released liquid volumes are assumed to be less than what was discharged at SWMU 21-011(k) or at MDA T, but sampling following D&D will provide data to check this assumption. Potential contaminants include nitrate, perchlorate, plutonium, uranium, americium, and metals.

3.1.2.3 Waste Lines and Sumps

Consolidated Unit 21-022(b)-99 is ranked at moderate priority because of its long history of operations (1945–1986) and because leaks into the subsurface are known to have occurred. Consolidated Unit 21-022(b)-99 consists of waste lines and their associated underground, plutonium-bearing, liquid waste sumps (Figure 1.0-1). The lines and sumps received liquid wastes from DP West that were piped to MDA T for disposal, or later to buildings 21-035 or 21-257 for treatment. The pipes remain in place, but will be excavated as corrective actions continue at TA-21. Leaks to soil were evident when the sumps were removed. Although monitoring consideration for these facilities could be deferred until cleanup activities are completed, they are included in the network assessment because known leaks into the subsurface at these facilities may represent a secondary source. Concentrations from these facilities and waste lines were potentially high because the wastes were untreated. Liquid volumes are assumed to be less than what was discharged at SWMU 21-011(k) or at MDA T, but again, sampling following cleanup will test this assumption. Potential contaminants are nitrate, perchlorate, plutonium, uranium, americium, and metals.

3.1.2.4 MDA V

MDA V [Consolidated Unit 21-018(a)-99; see Figure 1.0-1] is ranked as a moderate-priority site because it received approximately 40 million gal. of wastewater, and subsurface tritium is present. MDA V received liquid waste effluent from a former laundry facility for radioactive clothing and included three adsorption beds on the south side of DP Mesa that sometimes overflowed into Los Alamos Canyon. The site was used between 1945 and 1961. Historical documents show that radioactive strontium, plutonium, and uranium were released to the absorption beds. However, the three absorption beds and underlying soils were removed and cleaned to residential standards, and these radionuclides are no longer considered chemicals of potential concern (COPCs). Therefore, although elevated moisture is present in the subsurface, the current contaminant source is sufficiently small that this site is not considered a threat to groundwater with the potential exception of tritium. There is a secondary source of tritium present in subsurface pore gas. Monitoring of tritium vapor is currently conducted at vapor-monitoring well 21-24524, (Appendix A, section A-2.0), which extends to a depth of 721 ft bgs at the site; results show decreasing trends with depth below approximately 330 ft bgs (LANL 2009, 108134).

3.1.3 Lower Priority DP Mesa Sources (not considered for additional monitoring at this time)

The following sources are considered to be lower-priority sources with respect to their potential to impact groundwater. All of the lower-priority sources are located on DP Mesa.

3.1.3.1 MDA A

MDA A (SWMU 21-014; see Figure 1.0-1) is ranked as a low-priority site because there was no significant liquid disposal to mobilize contaminants, the waste will be removed, and further consideration of monitoring is deferred until post-rehabilitation sampling is completed. MDA A is a disposal facility that was used intermittently from 1945 to 1946 and from 1969 to 1977 to dispose of radioactively contaminated solid and liquid waste, debris from D&D activities, and radioactive liquid generated at TA-21. It consists of two buried storage tanks (known as the General’s Tanks) and three disposal pits. The pits contain mostly solid waste. The General's Tanks were filled in the mid-1940s with liquids contaminated with plutonium and americium from plutonium-processing operations. From 1975 to 1983, the liquid was decanted from the tanks and processed at building 21-257. Sludge remains in the tanks, but environmental sampling indicates that the tanks have not leaked. Contaminants in the pits and tanks include plutonium, americium, and uranium. Nitrate, perchlorate, and tritium may also be present. Source removal, characterization, and restoration of MDA A are planned.

3.1.3.2 MDA B

MDA B (SWMU 21-015; see Figure 1.0-1) is ranked as a low-priority site because there was no significant liquid disposal to mobilize contaminants, the waste will be removed, and further consideration of monitoring is deferred until post-rehabilitation sampling is completed. MDA B was a common disposal area for radioactive waste generated at the Laboratory that operated from 1945 until 1948. Comprehensive information is not available, but the site is thought to contain approximately 10 pits, including one hazardous-materials pit. About 90% of the wastes received at MDA B consisted of laboratory waste (e.g., radioactively contaminated paper, rags, rubber gloves, and other trash). Potential contaminants include radionuclides and chemicals. Source material at MDA B is currently planned for removal, and further characterization and restoration activities will follow source removal.

3.1.3.3 MDA U

MDA U [Consolidated Unit 21-017(a)-99; see Figure 1.0-1] is considered a low-priority site because remediation and stabilization activities have left it clean to industrial standards. MDA U consists of two former absorption beds, an associated former distribution box, and a sump used to collect wastewater. It operated from 1948 to 1968 as a subsurface disposal site for radioactively contaminated liquid wastes. It also received process cooling-water effluent from the Tritium Systems Test Assembly (TSTA) cooling tower until sometime after 1976. In 1985, the distribution box and piping, as well as contaminated material from the adsorption beds, were removed, and the site was stabilized (LANL 2006, 092589).

3.1.3.4 DP East

DP East facilities (Figure 1.0-1) are ranked as a low-priority site because there was no significant liquid disposal to mobilize contaminants, the facilities will be removed, and further consideration of monitoring is deferred until post-rehabilitation sampling is completed. DP East facilities include buildings 21-152, 21-155, and 21-209. These buildings were used for a variety of projects including the Rover Project (nuclear rocket propulsion systems) and the TSTA project (tritium processing for fusion reactor research). Potential contaminants from these facilities include uranium, actinium, and tritium, but no leaks from the site have been observed. These facilities will be demolished in 2010 and 2011 as part of TA-21 D&D activities.

3.1.3.5 Diesel Spill

The TA-21 diesel spill site (Figure 1.0-1) is ranked as a low priority. Site assessments were conducted in 2002 and 2003 for a fuel-oil leak into the subsurface surrounding the underground pipelines connected to an aboveground diesel tank at TA-21. The February 2003 risk-based corrective action Tier I evaluation demonstrated that the maximum concentrations of the constituents of concern (i.e., benzene, toluene, ethyl benzene, xylenes, and polycyclic aromatic hydrocarbon compounds such as naphthalene) were below Tier I soil risk-based screening levels protective of groundwater. A 2009 investigation further characterized the site and found a similar extent of contamination of total petroleum hydrocarbon (TPH) diesel range organics (DRO), indicating that the nature and extent had been defined and that little or no further migration has occurred (LANL 2010, 109082).

3.2 Hydrology and Contaminant Transport in DP Canyon

A conceptual hydrogeologic cross-section for DP Canyon is shown in Figure 3.0-2, with its location shown in Figure 3.0-1. DP Canyon is a small tributary to Los Alamos Canyon on the north side of DP Mesa. It is classified as a dry canyon, as described by Birdsell et al. (2005, 092048) based on its small drainage area and low-elevation headwaters. However, it previously received effluent discharges from SWMU 21-011(k), and it currently receives enhanced urban surface runoff from paved parking lots and roadways from the townsite. These anthropogenic water sources have enhanced surface water flow in the canyon, both during and after releases from the former outfall, and have contributed to more persistent alluvial groundwater beneath parts of the canyon floor.

Surface water is ephemeral and generally occurs during runoff associated with thunderstorms and snowmelt. The portion of DP Canyon north of TA-21 is characterized by a broad flat canyon floor with a drainage system incised into the canyon-floor alluvium. Alluvial deposits are thin (approximately 2 m [6 ft]) and are periodically recharged by surface water flows that reach this part of the canyon. Surface water infiltrates into the canyon bottom alluvial sediments until its downward movement is impeded by zones of lower permeability, usually weathered tuff at the top of Qbt 2, forming a perched alluvial aquifer. Welded tuffs of Tshirege Member, unit Qbt 2, underlying the stream channel are relatively impermeable and limit the amount of infiltration below the alluvium. Despite the episodic nature of surface water flow and thin nature of the alluvial deposits, transducer readings at alluvial well LAUZ-1 indicate that the alluvium in this part of the canyon was continuously saturated from January 2008 through January 2010 (Koch and Schmeer 2010, 108926), suggesting the underlying welded tuffs are an effective aquitard that prevent deeper infiltration.

LADP-4, located on the south slope of DP Canyon beneath the SWMU 21-011(k) former outfall, penetrated a thick sequence of Bandelier Tuff (approximately 173 m [567 ft]) before reaching a total depth of 244 m [800 ft]) in the Puye Formation. Vadose-zone core samples from LADP-4 were dry relative to those collected in Los Alamos Canyon (see Appendix D, LANL 2008, 101330), and no perched groundwater was encountered over the total depth of 800 ft bgs, suggesting infiltration rates are currently likely to be low. Robinson et al. (2005, 091682) ran numerical simulations and found that an infiltration rate of 1 mm/yr adequately fit moisture data at LADP-4, as opposed to infiltration rates of 200 mm/yr and larger being required to fit moisture data in Los Alamos Canyon proper, such as at LADP-3 and LAOI(a)-1.1.

Adsorbing contaminants released from the former outfall have adhered to sediments and have not traveled as far afield as the mobile constituents; most are found much closer to the outfall and migrate with sediment following storms (Figure 3.0-2). A voluntary corrective action successfully removed contaminated soil on the hillslope below the former outfall to levels appropriate for trail-user land-use and extended backyard scenarios. Some accumulation of radionuclides adsorbed on sediments is present at the confluence of DP Canyon with Los Alamos Canyon (LANL 2004, 087390).

Some of the mobile contaminants released to DP Canyon from the SWMU 21-011(k) former outfall traveled downcanyon with surface water or alluvial groundwater before infiltrating the underlying bedrock tuffs between DP Spring and the confluence with Los Alamos Canyon. East of well LADP-5, DP Canyon develops a well-defined inner channel that becomes narrow, steep, and deeply incised as it cuts through welded tuffs of Qbt 2. The thickness of alluvium decreases in this part of the canyon because the stream channel is periodically scoured down to bedrock by storm runoff. Little infiltration is expected to occur in this portion of the canyon. From DP Spring to the confluence with Los Alamos Canyon, the tuff bedrock beneath the stream becomes progressively less welded and more permeable, and the canyon-bottom alluvium thickens. The canyon floor remains relatively narrow until it widens at the mouth of DP Canyon.

The lower reach of DP Canyon is the likely infiltration location for mobile contaminants such as tritium, nitrate, and perchlorate that are observed in perched groundwater at R-6i, LAOI-3.2, and LAOI-3.2a (see Appendixes B and D). Infiltration at the confluence with DP Canyon (near wells LAOI-3.2/LAOI-3.2a) may be further enhanced by surface water runoff and alluvial groundwater in Los Alamos Canyon, contributing to the deeper, perched-intermediate zones observed beneath the confluence of the two canyons (Figure 3.0-2). The zones of perched-intermediate groundwater occur within the Guaje Pumice Bed and the underlying Puye Formation near the confluence of the two canyons (Figures 3.0-2 through 3.0-5). Near TA-21, saturated thicknesses for these groundwater bodies range from about 9 ft at LADP-3 to more than 31 ft at LAOI-3.2a. Appendix D describes the occurrences for perched-intermediate groundwater in detail. The perched zones are probably recharged by percolation of alluvial groundwater through the underlying bedrock units before perching on top of low-permeability perching layers found at the base of the Guaje Pumice Bed and within the Puye Formation.

It appears that an important control on perched-intermediate groundwater flow in the vicinity of TA-21 is the contact between the Guaje Pumice Bed and the underlying Puye Formation. Structure contours indicate that the downdip direction for the base of the Guaje Pumice Bed is towards the south, southeast, and southwest in the vicinity of TA-21 (Figure D-1). The control exerted on groundwater flow by the Guaje Pumice Bed suggests that perched groundwater beneath Los Alamos Canyon should move generally southward away from TA-21. This conclusion is supported by observations that deep boreholes at MDA V (21-02523 and 21-24524), at MDA T (21-25262 and 21-607955), and at LADP-4 and LADP-5 did not encounter perched groundwater in the Guaje Pumice Bed or the underlying Puye Formation.

In contrast to the apparent lack of perched-intermediate groundwater beneath DP Mesa, well TA-53i encountered perched groundwater beneath Mesita de Los Alamos south of Los Alamos Canyon. As illustrated in Figures 3.0-3 and 3.0-4, the major cation and anion chemistry of water in TA-53i has a higher ionic strength than perched-intermediate groundwater in upper reaches of Los Alamos Canyon at LAOI(a)-1.1 and LADP-3. However, the water chemistry at TA-53i closely matches the chemistry of perched-intermediate groundwater near the mouth of DP Canyon (R-6i and LAOI-3.2/LAOI-3.2a), supporting the conclusion that the perched groundwater originating near the Los Alamos Canyon/DP Canyon confluence has a southerly or southwesterly component of flow (LANL 2009, 107453). The southerly or southwesterly flow of perched-intermediate groundwater in this area may be controlled in part by the Guaje Pumice Bed which dips toward the southwest (Figure D-1). Figure 3.0-4 presents a cross-section to illustrate a conceptual model for potential mixing of perched-intermediate groundwater beneath Los Alamos and DP Canyons and Mesita de Los Alamos based on mean values of major ion groundwater chemistry and rock type. Figure 3.0-3 shows the same information in map view. Stiff diagrams illustrate the relative concentrations of major cations (sodium, calcium, magnesium, and potassium) to major anions (chloride, bicarbonate, sulfate, and bromide) at each location (see legend, Figures 3.0-3 and 3.0-4). The stiff diagrams are also color-coded to indicate the geologic unit in which they occur. The conceptual model figure depicts potential mixing of perched-intermediate groundwater caused by lateral, generally southward, flow along perching layers at the base of the Guaje Pumice Bed and within the underlying Puye Formation.

In addition to major ion chemistry, contaminant signatures also indicate that waters originating from SWMU 21-011(k) have spread to perched-intermediate groundwater located beneath DP and Los Alamos Canyons at wells R-6i, LAOI-3.2/LAOI-3.2a, LAOI-7, and R-9i and beneath Mesita de Los Alamos at TA-53i. Historical releases from the Omega West Reactor (OWR) may also contribute to contaminants, especially tritium, observed at some of these wells.

Contaminant concentrations are at background levels in regional groundwater monitoring wells in the near vicinity of TA-21 (e.g., R-6, R-7, and R-8) suggesting that deep infiltration through the vadose zone, including from perched groundwater, does not reach the regional aquifer near TA-21. TW-3 appears to be contaminated in the regional aquifer, but this may be more related to well construction than to deep transport in this area based on the other nearby uncontaminated wells (see Appendix A). Therefore, contaminant transport (for mobile species) in this part of the canyon is illustrated in Figure 3.0-2 by the zone that extends into the vadose zone, including the perched-intermediate zones, but does not reach the regional aquifer. Tritium and perchlorate are slightly elevated in the regional aquifer at R-9, which is located farther down Los Alamos Canyon (Appendix B). These far-field contaminants may have originated at SWMU 21-011(k), with some contributions of tritium from the OWR. The conceptual transport model is that these contaminants were transported by surface water and alluvial groundwater down DP and Los Alamos Canyons to the area east of well LAOI-7 before infiltrating the canyon floor where alluvium directly overlies Cerros del Rio basalt. Infiltration is probably enhanced in this area where surface water and saturated alluvium drains into the extensive network of open fractures in the Cerros del Rio basalt immediately below the canyon floor.

To summarize, any groundwater impacts related to the SWMU 21-011(k) former outfall will likely be observed far afield from the original outfall location. The former outfall was the original (primary) source of most contaminants to DP Canyon. However, that primary source is now considered low priority for impacting groundwater because releases from the former outfall ceased in 1985, hillslope contamination below the outfall has been remediated, adsorbing contaminants are located in canyon sediments, and mobile constituents have moved downcanyon. Far-field contamination observed in alluvial and perched-intermediate groundwater, and to a limited extent, the regional aquifer, shows that a secondary source related to the outfall exists. The secondary source is observed in lower Los Alamos Canyon and laterally to the south beneath Mesita de Los Alamos (e.g., at well TA-53i) indicating that contaminants may arrive at the regional aquifer to the east and southeast of DP Canyon. Water-supply wells O-1 in lower Pueblo Canyon, O-4 at the DP Canyon/Los Alamos Canyon confluence, and PM-3 in lower Sandia Canyon could potentially be affected by contaminants arriving along these flow paths.

3.3 Hydrology and Contaminant Transport at DP Mesa

Under natural conditions, DP Mesa fits the “Dry and Disturbed Mesa Conceptual Model” for the Pajarito Plateau as defined by Birdsell et al. (2005, 092048). It is a dry finger mesa; the hydrologic conditions on the surface and within such dry mesas generally lead to slow unsaturated flow and transport. Dry mesas shed precipitation as surface runoff to the surrounding canyons such that most deep infiltration occurs episodically following snowmelt, and even then much of the water is lost through evapotranspiration. As a result, annual net infiltration rates for dry mesas are less than 10 mm/yr and are more often estimated to be on the order of 1 mm/yr or less (Kwicklis et al. 2005, 090069). Because dry mesas are generally composed of nonwelded to moderately welded unsaturated tuffs with low water content, water flow is matrix-dominated rather than fracture-dominated. Travel times for contaminants migrating through dry mesas to the regional aquifer are expected to be several hundred to thousands of years (Nylander et al. 2003, 076059.49; Birdsell et al. 2005, 092048). However, much of DP Mesa is disturbed by development and former liquid waste disposal. Enhanced moisture migration and decreased contaminant travel times are expected beneath liquid waste disposal sites where infiltration beneath absorption beds increased the moisture content in the underlying tuffs. A conceptual hydrogeologic cross-section for DP Mesa near MDA T is shown in Figure 3.0-5, with its location shown in Figure 3.0-1. The figure depicts observed enhanced moisture and contaminant migration beneath MDA T because of historical wastewater releases to the adsorption beds. Despite potential enhanced transport associated with anthropogenic water sources on DP Mesa, transport through the mesa top toward the regional aquifer should lag behind transport toward the regional aquifer from outfall releases through canyons and perched zones.

MDAs A and B were predominantly dry disposal sites. Little transport beneath these sites should have occurred. Similarly, the DP East facility did not dispose liquid waste on-site, and no leaks from underground pipes have been observed. Contaminant sources will be removed from these three sites, further decreasing the possibility they could impact groundwater. MDA T, MDA U, MDA V, the DP West facility, and Consolidated Unit 21-022(b)-99 are liquid waste sites where anthropogenic discharges, such as liquid waste releases to adsorption beds and building sumps or water leaks from buried pipes, caused large, temporary increases in mesa-top infiltration rates. As discussed below, moisture migration may have included components of both fracture and matrix flow during periods of liquid discharge or leaks, depending on the water volumes that were released. Now that discharges have ended, moisture migration is expected to occur as matrix flow under present-day and future conditions. Infiltration rates are expected to return to near-background levels when the mesa-top water balance returns to native conditions. However, an extended period of enhanced, downward matrix-dominated water flow will occur if vadose-zone moisture contents are elevated compared to background conditions. This is the likely case beneath the wet MDAs T, U, and V where wastewaters were discharged to adsorption beds. However, although water may continue to migrate beneath these MDAs, only MDAs T and V are ranked as moderate- to high-priority sources for their potential impact to groundwater because inventory remains in place. At DP West and Consolidated Unit 21-022(b)-99, no subsurface moisture data are available to know if or how much enhanced moisture movement will occur.

Elevated-moisture contents and above-background detections of nitrate and perchlorate are observed to depths of 350 ft bgs beneath MDA T (Figure 3.0-5). The primary sources in the shafts and adsorption beds and the secondary source present beneath the disposal units could potentially impact groundwater if they were mobilized and transported by enhanced moisture beneath the site. The mobile constituents perchlorate and nitrate are still, however, approximately 800 ft above the regional water table. Adsorbing constituents like plutonium and americium remain closer to the original source and even farther from the water table. Transport of these constituents to the regional aquifer requires that they migrate with moisture. Even with soil moisture redistribution in the unsaturated zone, travel times to the regional aquifer may be several hundreds of years or more. Observing moisture movement as a proxy for contaminant migration is recommended in section 5 of this report.

VOCs and tritium migrate in the vadose zone as vapors and in the dissolved phase. Vapor migration is dominated by vapor diffusion, and diffusion rates commonly exceed liquid transport rates at mesa-top sites at the Laboratory (Stauffer et al. 2005, 090537). Vapor-phase VOCs and tritium observed in pore gas beneath MDAs T and V likely infiltrated with wastewater when releases were occurring, but have continued to migrate in the vapor phase. This combination of transport mechanisms helps explain why VOCs and tritium are observed at deeper depths beneath MDA T than the conservative soluble species nitrate and perchlorate.

At MDA T, subsurface contaminant data from 1960, 1978, and 1996 collected beneath the adsorption beds show evidence of contaminant transport associated with fractures, while subsurface data collected in boreholes adjacent to the beds shows none (Nyhan et al. 1984, 058906; LANL 2004, 085641). However, the 1978 study, which targeted data collection in fractures beneath the adsorption beds, concluded that most fractures (8 of 10) did not enhance contaminant transport and that most contaminants were much shallower and located in the porous matrix. The two observations of transport in fractures in that investigation occurred at similar depths (less than 7 m below the ground surface) to those cited in the 1960 study, even though the four investigative boreholes drilled in 1978 extended deeper (to 30 m) (Nyhan et al. 1984, 058906). Although the 1996 data show contamination in a 20-m-deep fracture, the general assumption is that fracture transport occurred while the beds actively received liquid waste, and that the contaminants associated with the fractures are remnants of previous fracture flow episodes (LANL 2004, 085641). These data support the idea that fracture flow ceased soon after liquid mesa-top disposals stopped (Soll and Birdsell 1998, 070011).

It is likely that limited fracture transport could have also occurred and that moisture contents are elevated above background beneath the adsorption beds at MDAs U and V because waste disposal practices were similar to those used at MDA T. Also, if the liquid waste lines at TA-21 leaked during their 40-yr life span, localized subsurface transport beneath these lines may have occurred.

3.4 Regional Flow and Transport

The regional aquifer is a complex, heterogeneous system that includes unconfined (phreatic) and confined zones. The degree of hydraulic communication between these zones is thought to be spatially variable. The shallow portion of the regional aquifer (near the water table) is predominantly under phreatic (unconfined) conditions and has limited thickness (in the range of approximately 30 to 50 m [98 to 164 ft]). Groundwater flow and contaminant transport directions in this zone generally follow the gradient of the regional water table; the flow is generally east or northeastward. The direction and gradient of flow at the regional water table are predominantly controlled by areas of recharge (e.g., the Sierra de los Valles and within some Pajarito Plateau canyons) and discharge (the White Rock Canyon springs and the Rio Grande). The deep portion of the regional aquifer is predominantly under confined conditions, stressed by Pajarito Plateau water-supply pumping. The intensive pumping at the production wells has a small impact on the flow directions in the phreatic zone because of poor vertical hydraulic communication between the deep and shallow zones of the regional aquifer. The poor hydraulic communication between the phreatic and confined zones does not preclude the possibility that some downward contaminant migration may occur. Between the two zones, the hydraulic gradient has a downward vertical component because of water-supply pumping, creating the possibility that downward contaminant migration may occur along “hydraulic windows.”

The concept of a hydraulic separation of the shallow and the deep sections of the regional aquifer is supported by various field observations. Near TA-21, production well O-4 is screened in the Santa Fe Group. The screen elevation is between 5512 and 4052 ft. Miocene basalt occurs near the top of the screen between elevations of 5484 and 5292 ft and 5218 and 5174 ft, possibly providing some measure of isolation between the production zone and the phreatic zone. The water level at O-4 drops to approximately 5795 ft during pumping but quickly recovers to approximately 5820 ft; the quick recovery suggests confined aquifer conditions. R-6 is located at about 500 m west northwest from O-4. It has a 23-ft-long screen in the Puye Formation with elevations between 5791 and 5767 ft. The vertical separation of the screens of production and monitoring wells is approximately 250 ft (90 m). The pumping drawdown at R-6 caused by O-4 pumping is less than 0.1 m (Appendix C; the pumping drawdown at O-4 is 35 ft or approximately 12 m). There is also substantial contrast in the static water levels: the water level of R-6 is about 5837 ft, which is 17 ft higher than the static water level of O-4 when the well is not pumping. Similar conclusions are derived from the contrasting water-level responses observed in R-35a and R-35b during pumping of PM-3 (LANL 2007, 098129). PM-3 is screened approximately 56 to 536 m (183 to 1759 ft) below the regional water table. The water level in R-35a, which has a well screen opposite the upper part of louvers in PM-3, responds rapidly to pumping at PM-3 (as well as at O-4), whereas R-35b, which is screened near the water table, shows either no response or a very small response to water-supply pumping.

In the regional aquifer, the advective flow paths of contaminant migration may not be perpendicular to the equipotential water-table lines, i.e., parallel to the direction of the hydraulic gradients. Deviations from the flownet conformity rule may occur because of anisotropy and heterogeneity of aquifer materials. Flow- and head-gradient vectors do not coincide in an anisotropic medium when the flow gradient is not coincident with the principal directions of the permeability tensor (Freeze and Cherry 1979, 088742, Chapter 5). As a result, the anisotropy of aquifer rock units in this area may influence the flow vectors. The potential uncertainty in the advective flow paths of contaminant migration in the regional aquifer is taken into account in the network analysis presented in Appendix C.

4.0 MONITORING NETWORK ASSESSMENT

The following table summarizes the evaluation of the physical and geochemical performance of the group of wells considered for TA-21 in the context of monitoring objectives #1 and #2 described in section 2. The physical and hydrologic criteria include the effectiveness of wells and associated sampling systems to provide data to meet the objectives. Also included are reviews of factors evaluated in the context of the conceptual model and monitoring objectives, such as screen positions and screen length. A more detailed discussion of the physical and hydrologic conditions is presented in Appendix A. Geochemical criteria consider conditions within the aquifer related to drilling operations that may result in sample data that do not meet monitoring objectives, focusing on key contaminants of concern related to the SWMU 21-011(k) former outfall, specifically perchlorate, nitrate, 1,4-dioxane, tritium, strontium-90, and cesium-137. A more detailed discussion of the geochemical conditions is presented in Appendix B.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
Protection of Water-Supply Wells		
R-3 (regional)	Meets objectives for protection of O-1 near top of louvers	Not evaluated. Well currently being installed.
R-6 (regional)	Meets objectives for protection of O-4 near the water table. Well is located between TA-21 sources and O-4. Top of well screen is submerged 46 ft and primary filter pack extends 21 ft above and 29 ft below the well screen.	Meets objectives
TW-3 (regional)	Does not meet objectives. Annular seal may be inadequate and could result in leakage of surface water, alluvial groundwater, or perched-intermediate groundwater to regional groundwater along well casing. Corrosion of casing may influence chemistry of water samples.	Does not meet objectives due to evidence of corrosion
R-35a (regional)	Meets objectives for protection of PM-3 near top of louvers	Meets objectives with the possible exception of representativeness for cesium-137 data (see Appendix B)
R-35b (regional)	Meets objectives for protection of PM-3 near the water table	Meets objectives
Groundwater Monitoring in the Vicinity of TA-21		
R-7 screen 3 (regional)	Meets objectives	Effective for monitoring tritium and 1,4-dioxane, neither of which is detected in this screen. Serves as a useful baseline well for these two constituents upgradient of TA-21. Because of residual drilling effects, R-7 does not provide useful baseline data for other TA-21 COPCs.
R-8 screen 1 (regional)	Conditionally meets objectives. Clay-rich slough covers upper 80% of well screen, possibly interfering with the free flow of water through the upper part of the screen. Anomalously high water levels are associated with screen 1.	Meets objectives

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-8 screen 2 (regional)	Meets objectives. Concerns with the screen 1 interval are compensated by the performance of this screen because of the close spacing of the two screens.	Meets objectives
R-9 (regional)	Meets objectives. The water-level data are ambiguous because of completion in the Miocene basalt. However, at this location, the R-9 regional screen is in the first permeable zone beneath the water table.	Meets objectives
LAOI(a)-1.1 (intermediate)	Meets objectives	Meets objectives
LADP-3 (intermediate)	Meets objectives	Meets objectives.
LAOI-3.2 (intermediate)	Meets objectives	Meets objectives
LAOI-3.2a (intermediate)	Meets objectives	Meets objectives
TA-53i (intermediate)	Meets objectives	Meets objectives
LAOI-7 (intermediate)	Meets objectives	Meets objectives
R-6i (intermediate)	Meets objectives	Meets objectives
R-7 screen 1 (intermediate)	Meets objectives, but the screen has gone dry.	Not applicable
R-7 screen 2 (intermediate)	Not applicable—screen 2 has been dry since installation.	Not applicable
R-9i screen 1 (intermediate)	Meets objectives	Meets objectives
R-9i screen 2 (intermediate)	Meets objectives	Meets objectives
R-12 screen 1 (intermediate)	Meets objectives	Conditionally meets objectives. Minor drilling effects possibly still present from degradation of residual organic drilling products following rehabilitation activities. This condition could affect representativeness of perchlorate, nitrate, and cesium-137 data (see Appendix B). Shows decreasing trend of residual organic drilling products and reducing conditions. Good prognosis for meeting objectives.
R-12 screen 2 (intermediate)	Meets objectives	Meets objectives

5.0 RECOMMENDATIONS

The regional network assessment presented in Appendix C supports the recommendations for new groundwater monitoring wells presented in this section. In addition, section 4 identifies TW-3 as not currently meeting the physical/hydrologic and geochemical monitoring objectives. This, in turn, leads to the recommendations in this section to plug and abandon the well and to replace it.

The table below presents the recommended actions and rationale for each of the existing wells evaluated as part of the TA-21 groundwater monitoring well network evaluation. These recommendations are based on the physical, geochemical, and hydrologic factors considered in the context of monitoring objectives #1 and #2 of section 2. Following this, recommendations for installation of new wells are made to address gaps in the capability of the existing wells to fulfill objectives #3, #4, and #5 of the monitoring network.

Well Name	Recommended Action	Rationale
Protection of Water-Supply Wells		
R-3 (regional)	Monitor in accordance with the current Interim Facility-Wide Groundwater Monitoring Plan (IFGMP) (e.g., LANL 2009, 106115)	Well is a newly installed (June 2010) regional groundwater monitoring well. The well will act as a sentinel well for water-supply well O-1 for contaminants historically released from SWMU 21-011(k) into DP Canyon and that may migrate towards O-1. The well has not been completed and sampled yet, and several rounds of sample data are needed to ensure that it meets monitoring network objectives.
R-6 (regional)	Monitor in accordance with the current IFGMP	Well meets monitoring network objectives. The well will act as a sentinel well for water-supply well O-4 for contaminants historically released from SWMU 21-011(k) into DP Canyon.
R-35a (regional)	Monitor in accordance with the current IFGMP	Well meets monitoring network objectives. The well will act as a sentinel well for water-supply well PM-3 for contaminants historically released from SWMU 21-011(k) into DP Canyon and that may migrate towards PM-3 via complex vadose zone and perched-intermediate and regional groundwater pathways.
R-35b (regional)	Monitor in accordance with the current IFGMP	Well meets monitoring network objectives. The well will act as a sentinel well for water-supply well PM-3 for contaminants historically released from SWMU 21-011(k) into DP Canyon and that may migrate towards PM-3 via complex vadose zone and perched-intermediate and regional groundwater pathways.
Groundwater Monitoring in the Vicinity of TA-21		
R-7 screen 3 (regional)	Continue to monitor in accordance with the current IFGMP and collect samples if water is present	No change is necessary at this time.
R-8 screen 1 (regional)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
R-8 screen 2 (regional)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
R-9 (regional)	Monitor in accordance with the current IFGMP	Well meets monitoring network objectives.

Well Name	Recommended Action	Rationale
TW-3 (regional)	Plug and abandon well	TW-3 is recommended for plugging and abandonment because the unsealed well annulus is a potential pathway for contaminated alluvial and intermediate groundwater to reach regional groundwater. A new regional groundwater monitoring well is recommended to replace TW-3 (see text below).
LAOI(a)1.1 (intermediate)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
LADP-3 (intermediate)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
LAOI-3.2 (intermediate)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
LAOI-3.2a (intermediate)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
LAOI-7 (intermediate)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
R-6i (intermediate)	Continue to monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
R-7 screen 1 (intermediate)	Continue to monitor water levels in accordance with the current IFGMP and collect samples if water is present	No change is necessary at this time.
R-7 screen 2 (intermediate)	Continue to monitor water levels in accordance with the current IFGMP and collect samples if water is present	No change is necessary at this time.
R-9i screen 1 (intermediate)	Monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
R-9i screen 2 (intermediate)	Monitor in accordance with the current IFGMP	Well meets monitoring network objectives.
R-12 screen 1 (intermediate)	Meets objectives	Well conditionally meets monitoring network objectives. Minor drilling effects possibly still present from degradation of residual organic drilling products following rehabilitation activities. Good prognosis for meeting objectives.
R-12 screen 2 (intermediate)	Meets objectives	Well meets monitoring network objectives. Manganese-reducing conditions are present but are believed to be representative of local groundwater.

Based on the assessment above, existing wells in the current monitoring network downgradient of TA-21 are generally performing well. With the exception of TW-3, it is recommended that monitoring of these existing wells should continue in accordance with the most current IFGMP.

A new monitoring well, TW-3r, is proposed to improve the characterization and monitoring of the regional groundwater near Los Alamos County water-supply well O-4. Well TW-3r is intended to be a sentinel well for O-4, and it replaces the existing TW-3 that is recommended above for plugging and abandonment. The replacement for well TW-3 is necessary because infiltration of effluent from SWMU 21-011(k) is believed to be greatest near the confluence of DP and Los Alamos Canyons. Regional well R-6 is well positioned to act as an O-4 sentinel well for infiltration that may occur beneath DP Mesa proper, but is too far from the potential breakthrough location at the confluence. In addition to water-quality data, TW-3r should provide important water-level information to help constrain the direction of groundwater flow in this area. Data from TW-3r will also improve the understanding of potential Laboratory contaminants with respect to monitoring for O-4.

This assessment also recommends that two new regional groundwater monitoring wells closer to the moderate- and high-priority mesa-top sources at TA-21 are needed to augment the existing well network in order to detect potential contaminants in a timely manner to meet objective #3. The proposed pair of wells MW-10 and MW-14 would detect contaminants within 5 yr of entering the regional aquifer with greater than 95% detection efficiency. Groundwater moving downgradient of the potential breakthrough locations at TA-21 (Figure 3.0-1) is expected to flow along the phreatic zone of the regional aquifer towards the east or northeast based on current groundwater elevation data. The two proposed new regional groundwater wells enhance the ability of the monitoring well network to confidently detect potential contaminants at proximal locations downgradient of the moderate- to high-priority mesa-top sources at TA-21. Data derived from the wells are intended to provide groundwater data sufficient to support CMEs at TA-21, especially MDA T. Monitoring is deferred for other TA-21 sites that are considered low priority in this study; the need for additional monitoring at these low-priority sites will be assessed after ongoing investigations and/or cleanup are completed and verification sampling has been performed. An upgradient baseline well for TA-21 is not proposed at this time because monitoring data from the existing well network have not detected TA-21 contaminants in regional groundwater near TA-21. The need for an upgradient baseline well will be reexamined after monitoring data from the two new downgradient monitoring wells are evaluated.

This assessment also recommends that moisture-monitoring wells be installed near the disposal shafts at MDA T to monitor vadose-zone moisture conditions to meet objective #5. This type of monitoring is proposed at MDA T because of the large inventory of contaminants stored in the shafts and elevated residual moisture in the vadose zone resulting from infiltration beneath the MDA T adsorption beds. Elevated soil moisture in contact with the waste in the shafts and with the contaminants present in and beneath the adsorption beds is considered the predominant carrier for mobilizing and transporting soluble contaminants from the wastes buried at the site. Therefore, monitoring moisture distribution over time provides a means for assessing the potential for contaminant migration. In addition, monitoring near the source provides timely information about potential migration. The combination of moisture monitoring near the source and regional aquifer monitoring at proposed wells MW-10 and MW-14 provide a defense-in-depth program for monitoring MDA T. The moisture data also will be used to establish baseline data for moisture distributions that can be used to guide and evaluate CME remedial alternatives. Moisture monitoring is not recommended at this time for DP West, MDA V, or for the waste lines and sumps.

Finally, this assessment recommends that a vapor-monitoring well be installed near the former WWTP within MDA T, as was discussed in the approved Phase III investigation work plan for MDA T (LANL 2009, 105645). This well will augment the network of existing vapor-monitoring wells that define the nature and extent of VOC and tritium vapors in the vadose zone. The proposed vapor-monitoring well will fill a data gap near the east end of MDA T. This new well will be monitored in addition to the existing five vapor-monitoring wells at MDA T and one at MDA V (Appendix A, section A-2.0). The existing vapor-monitoring well located at MDA V is considered to be sufficient for monitoring tritium vapors at MDA V, and no additional vapor-monitoring wells are recommended for the site.

The existing network of perched-intermediate wells is considered adequate for groundwater monitoring in the vicinity of TA-21, and no additional perched-intermediate wells are needed. Borehole data show that perched-intermediate groundwater is not likely to occur beneath potential release sites at TA-21. In contrast, effluent releases from TA-21 outfalls and surface runoff from mesa-top drainages have resulted in the transport of contaminants into the adjacent canyons. Downcanyon transport and infiltration of contaminated water has impacted perched-intermediate groundwater beneath lower DP Canyon and

Los Alamos Canyon. The existing network of wells south of TA-21 in Los Alamos Canyon and in the vicinity of the DP and Los Alamos Canyons confluence provides sufficient monitoring of perched-intermediate groundwater in these areas.

The table below presents recommendations for installation of new wells. The recommendations are made to address gaps in the capability of the existing network to fulfill the objectives of the monitoring network.

Well Name	Recommended Action	Rationale
TW-3r	Install a two-screen replacement well for TW-3 (see table above) A specific location will be selected and presented in a well-specific work plan.	The primary purpose of this well is to be a sentinel well for water-supply well O-4. The new well will also potentially provide an important refinement of the water-table elevation and vertical hydraulic gradients; therefore, it will help constrain the groundwater flow direction. The proposed well should have two screens, one that is set near the regional water table and another that is set at an elevation that is coincident with the top of the louvers at O-4.
MW-10	Install a new single-screen regional groundwater monitoring well east of the group of moderate- to high-priority potential breakthrough locations at TA-21 The well location should be near the location identified as MW-10 in Appendix C.	Installation of this well will provide a proximal monitoring location downgradient of the most significant contaminant release sites at TA-21. Groundwater data from this well, in combination with MW-14, are intended to support CMEs at TA-21, especially MDA T. The final location for this well may be adjusted to reflect revisions to the water-table map based on data from MW-14.
MW-14	Install a new single-screen regional groundwater monitoring well northeast of the group of moderate- to high-priority potential breakthrough locations at TA-21 The well location should be near the location identified as MW-14 in Appendix C.	Installation of this well will provide a proximal monitoring location downgradient of the most significant contaminant release sites at TA-21. Groundwater data from this well, in combination with MW-10, are intended to support CMEs at TA-21, especially MDA T. This well should be drilled before MW-10 because of its higher overall detection efficiency and faster average peak arrival time than MW-10. Water-level data from MW-14 will help constrain the water table in this area.
Moisture-monitoring wells at MDA T	Install moisture-monitoring wells near the disposal shaft field at MDA T The number of wells, specific locations, slant vs. vertical boreholes, data collection approach, and number and depth of sampling ports in these wells will be presented in a well-specific work plan.	Monitor moisture beneath the disposal shaft field to address whether contaminants in shafts and beneath adsorption beds could be mobilized and transported by unsaturated flow in the vadose zone. Establish baseline data set for moisture to evaluate performance of potential remedial alternatives.
Vapor-monitoring well at MDA T	Install a vapor-monitoring well near the eastern end of MDA T.	Augment existing vapor-monitoring network for measuring VOC and tritium vapor concentrations

6.0 SCHEDULE

Upon NMED’s approval of the recommendations contained in this report, the Laboratory will submit work plan(s) for implementation of the recommended actions. Each work plan will contain specific information for each of the actions and will propose a schedule for implementation.

7.0 REFERENCES

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Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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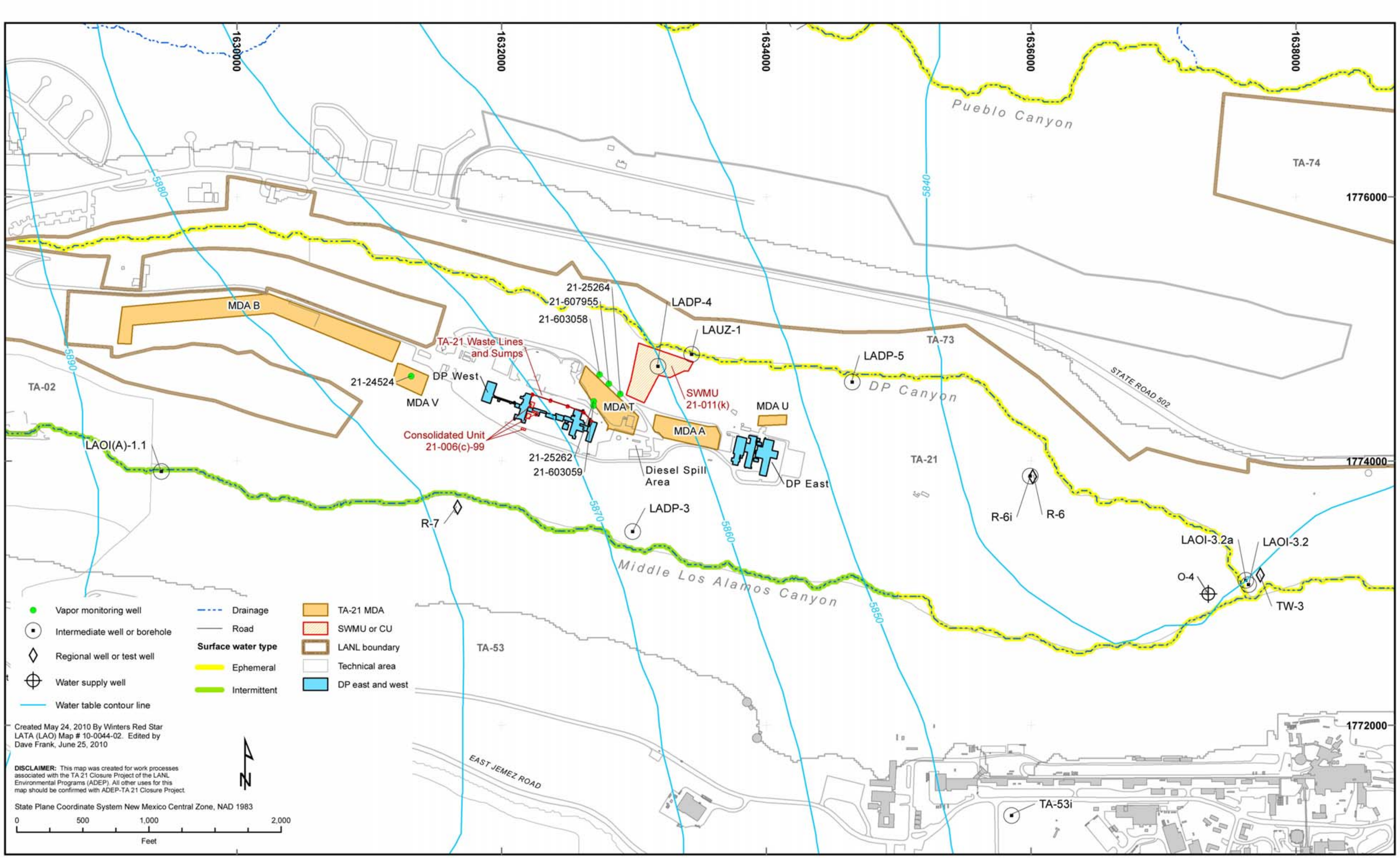


Note: Water level contours are also shown.

Figure 1.0-1 Locations of major contaminant release sites, vapor-monitoring wells, boreholes, intermediate and regional monitoring wells, and water-supply wells near TA-21

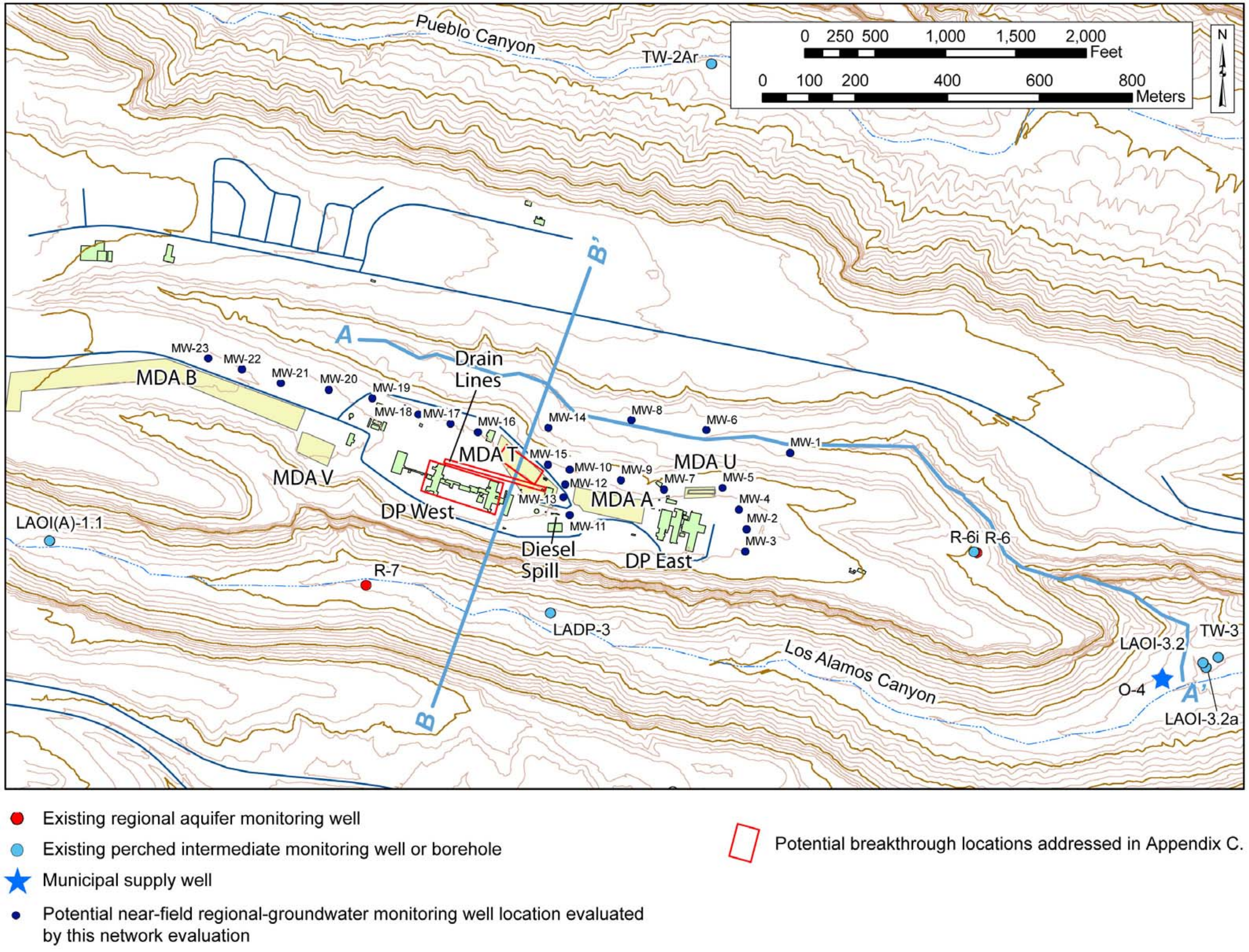
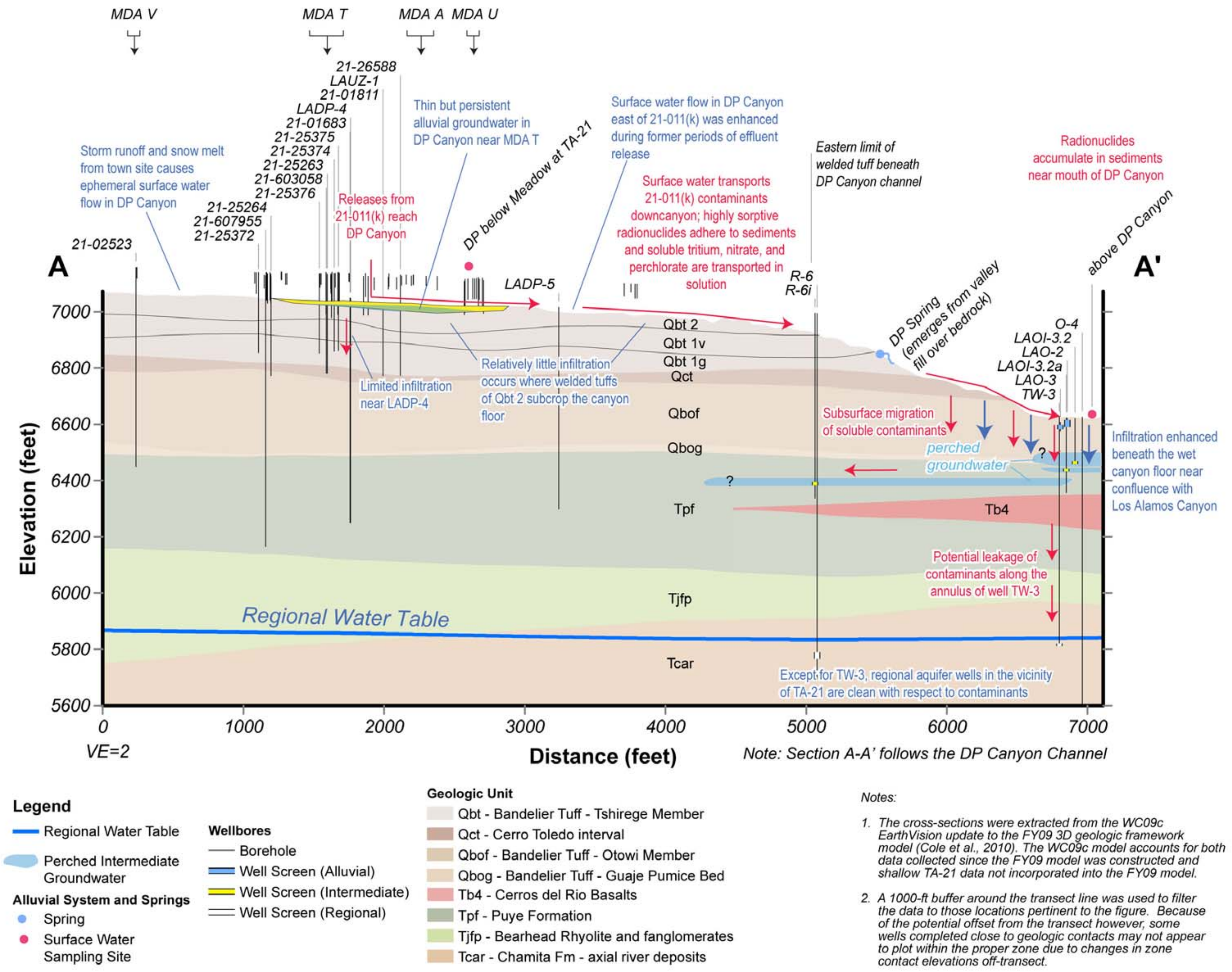


Figure 3.0-1 **Location of TA-21 showing existing monitoring locations and potential regional groundwater monitoring locations evaluated by this network evaluation**



Notes:

1. *The cross-sections were extracted from the WC09c EarthVision update to the FY09 3D geologic framework model (Cole et al., 2010). The WC09c model accounts for both data collected since the FY09 model was constructed and shallow TA-21 data not incorporated into the FY09 model.*
2. *A 1000-ft buffer around the transect line was used to filter the data to those locations pertinent to the figure. Because of the potential offset from the transect however, some wells completed close to geologic contacts may not appear to plot within the proper zone due to changes in zone contact elevations off-transect.*

Note: See Figure 3.0-1 for location of cross-section. Blue text denotes water pathways and red text denotes contaminant pathways.

Figure 3.0-2 Conceptual hydrogeologic cross-section for DP Canyon that includes potential groundwater and contaminant transport pathways

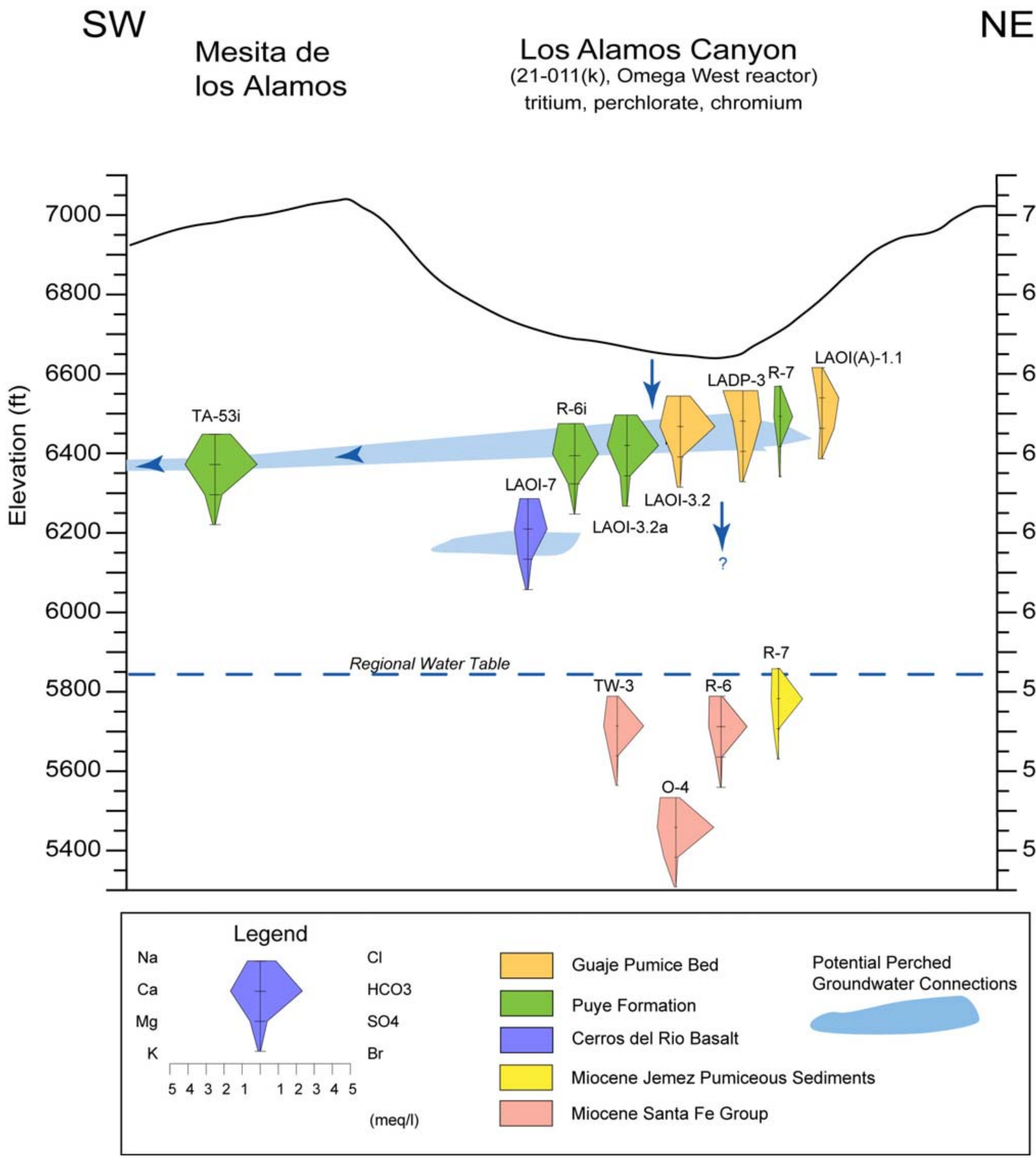


Figure 3.0-3 **Conceptual model for lateral transport and mixing of perched-intermediate and regional groundwaters near TA-21**

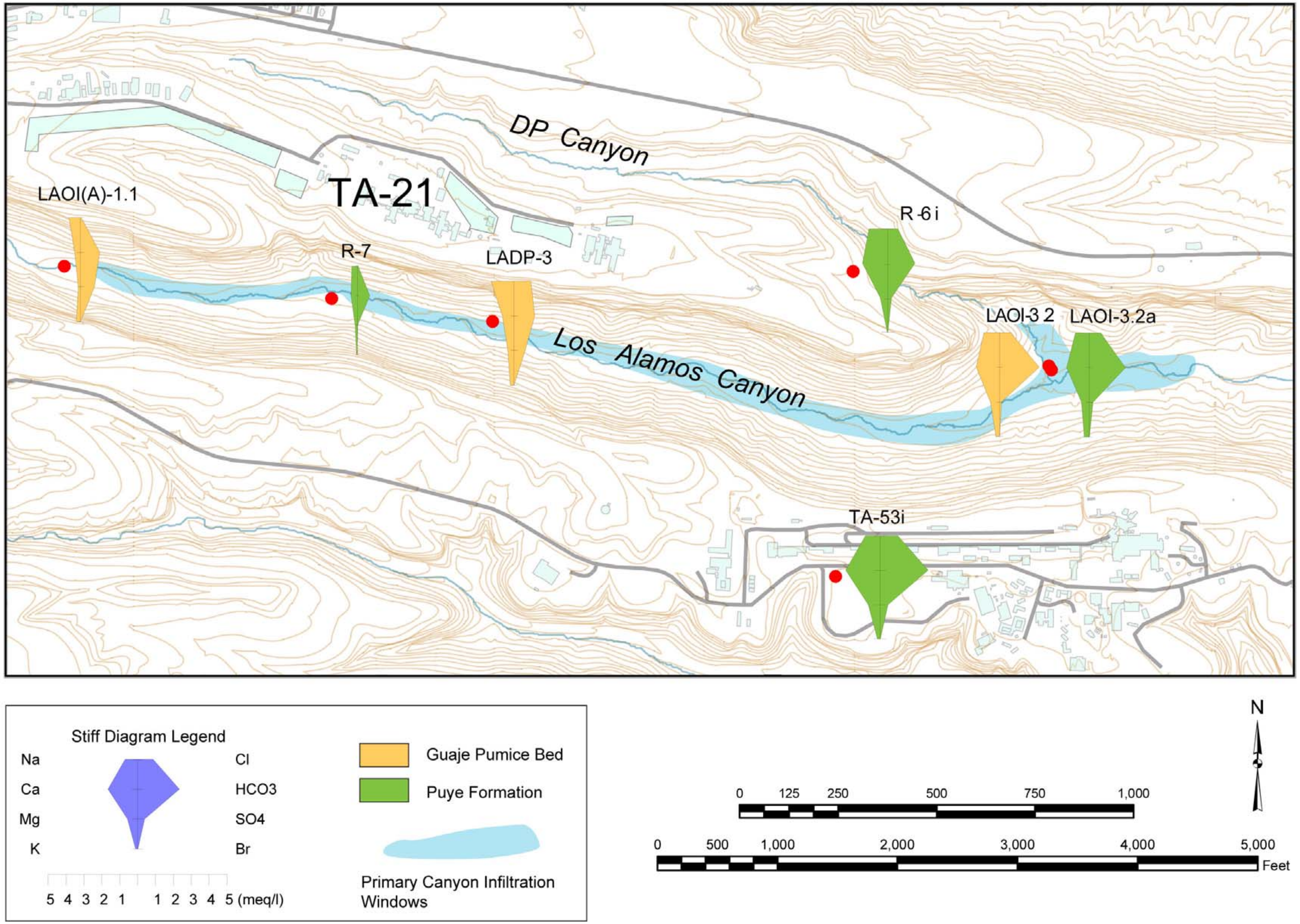
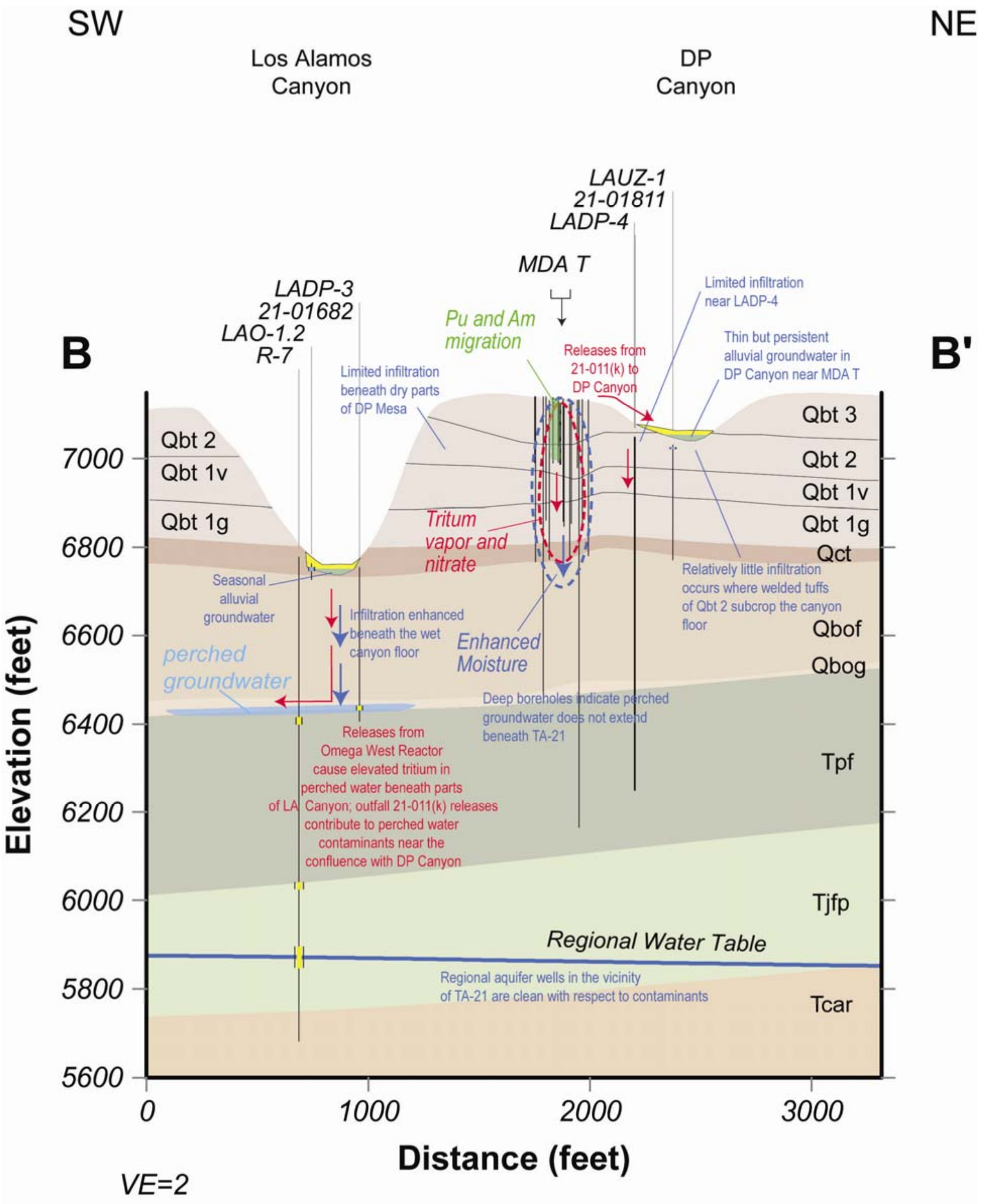


Figure 3.0-4 Major ion chemistry of perched-intermediate groundwaters near TA-21



Note: See Figure 3.0-1 for location of cross-section. Blue text denotes water pathways and red text denotes contaminant pathways.

Figure 3.0-5 **Conceptual hydrogeologic cross-section for DP Mesa at MDA T that includes potential groundwater and contaminant transport pathways**

Table 3.1-1
TA-21 Contaminant Sources and Prioritization Based on their Potential to Impact Groundwater

Potential Source	COPCs (large inventory and/or mobile)	Priority	Justification for Priority Ranking	Applicable Monitoring Objective
SWMU 21-011(k)	Plutonium, americium, strontium-90, cesium-137, tritium, perchlorate, nitrate, VOCs	High	Former liquid waste outfall discharged more than 50 million gal. into DP Canyon Primary source no longer near SWMU; source term removed Far field secondary source exists; mobile constituents (tritium, perchlorate, nitrate) observed in perched-intermediate groundwater beneath Los Alamos Canyon, DP Canyon, and Mesita de Los Alamos	1, 2
MDA T	Plutonium, americium, strontium-90, cesium-137, uranium, tritium, perchlorate, nitrate, VOCs	High	Approximately 18 million gal. untreated and treated wastewater discharged to adsorption beds; subsurface moisture contents remain high near beds and shafts Radionuclide inventory of several thousand curies VOCs and tritium present in subsurface pore gas No evidence that contaminants have reached groundwater	3, 4, 5
MDA V	Plutonium, americium, tritium, nitrate	Moderate	Approximately 40 million gal. wastewater from former laundry discharged to adsorption beds Adsorption beds and underlying soil removed; source term has been removed; site cleaned to residential standards Tritium present in subsurface pore gas; decreases to nondetect with depth below 330 ft; vapor-monitoring well 21-24524, with a total of 9 ports and a depth of 721 ft, available for tritium sampling No evidence that contaminants have reached groundwater	4
DP West	Plutonium, americium, strontium-90, cesium-137, uranium, tritium, perchlorate, nitrate, VOCs	Moderate	Leaks from pipes and sumps into the subsurface observed; volumes and duration unknown Potential for high radionuclide concentrations of untreated solutions Leaks may represent a secondary source depending on extent	3

Table 3.1-1 (continued)

Potential Source	COPCs (large inventory and/or mobile)	Priority	Justification for Priority Ranking	Applicable Monitoring Objective
Waste Lines and Sumps	Plutonium, americium, strontium-90, cesium-137, uranium, tritium, perchlorate, nitrate, VOCs	Moderate	Leaks from pipes and sumps into the subsurface observed; volumes and duration unknown Potential for high radionuclide concentrations of untreated solutions Leaks may represent a secondary source depending on extent	3
MDA A	Plutonium, americium, tritium, VOCs	Low	Dry disposal in pits and liquids disposed in tanks Liquids were removed from tanks; sampling indicates no leaks occurred Nature and extent of contamination beneath site are defined Complete source removal, characterization, and restoration to residential standards are planned	Deferred site
MDA B	Plutonium, americium, uranium, tritium, VOCs	Low	Predominantly dry disposal in pits Complete source removal, characterization, and restoration to residential standards are planned No evidence that contaminants have reached groundwater	Deferred site
MDA U	Radium and actinium, uranium, tritium, VOCs	Low	Unknown volume of liquid disposal to adsorption beds Waste lines and portion of adsorption beds have been removed; site is clean to industrial standards Nature and extent of contamination are defined	None required
DP East	Radium and actinium, tritium, uranium, nitrate	Low	Buildings; not a disposal site No subsurface characterization data	Deferred site
Diesel Fuel Spill	TPH-DRO	Low	Estimated 48,000-gal. leak of diesel fuel to subsurface Samples indicate fuel in unsaturated zone to depth of approximately 150 to 170 ft in Qbt COPCs below Tier I soil risk-based screening levels protective of groundwater	None required

Appendix A

Physical and Hydrologic Attributes of Existing Perched-Intermediate, Regional, and Vapor-Monitoring Wells

A-1.0 INTRODUCTION

This appendix describes the physical and hydrologic attributes of perched-intermediate and regional monitoring wells located around Technical Area 21. Section A-2.0 also discusses the vapor-monitoring wells located on DP Mesa.

The following abbreviations and acronyms are used throughout Appendix A.

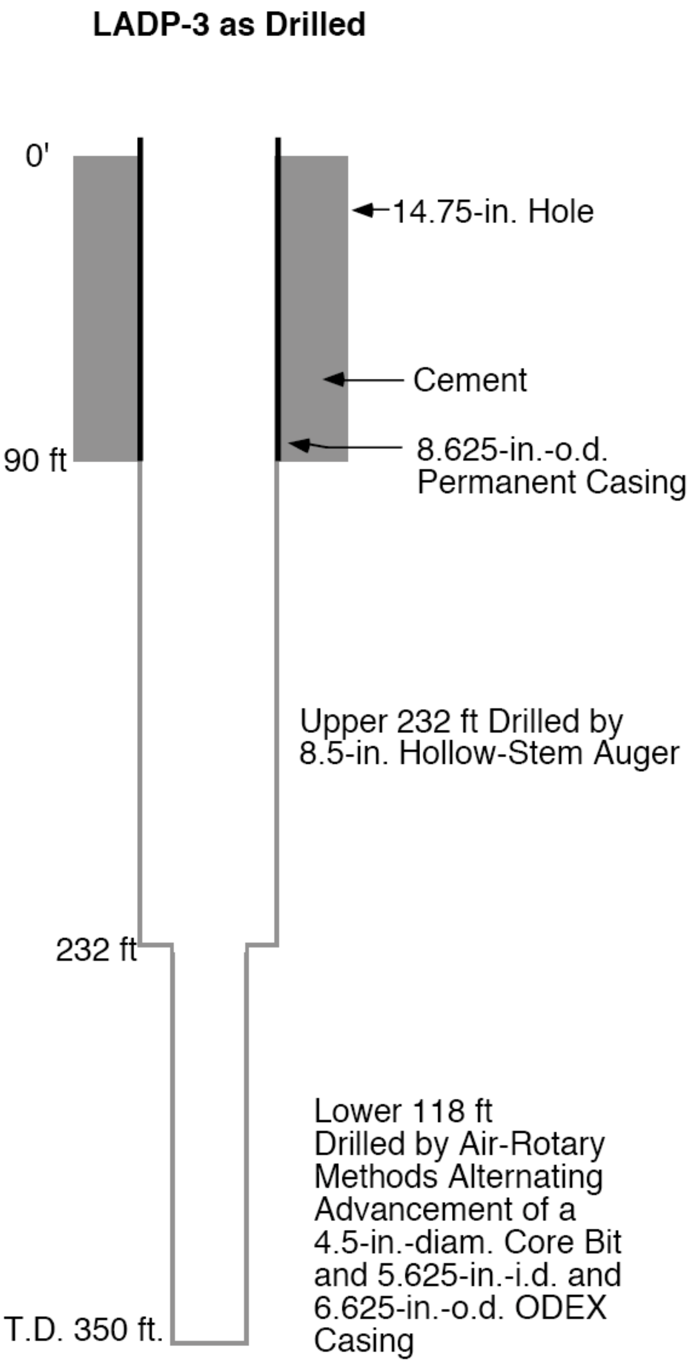
bgs	below ground surface
CHFR	cased-hole formation resistivity
ECS	elemental capture spectroscopy
ELAN	Elemental Log Analysis
FMI	Formation Micro-Imager
HSA	hollow-stem auger
HSWA	Hazardous and Solid Waste Amendments of 1984
I.D.	inside diameter
LANL or the Laboratory	Los Alamos National Laboratory
MDA	material disposal area
MP	multiple port
NGS	natural gamma spectrometry
NMED	New Mexico Environment Department
n/a	not applicable
NTU	nephelometric turbidity unit
O.D.	outside diameter
PVC	polyvinyl chloride
TA	technical area
TD	total depth
TLD	Triple Litho-Density Detector
TOC	total organic carbon

LADP-3 Well

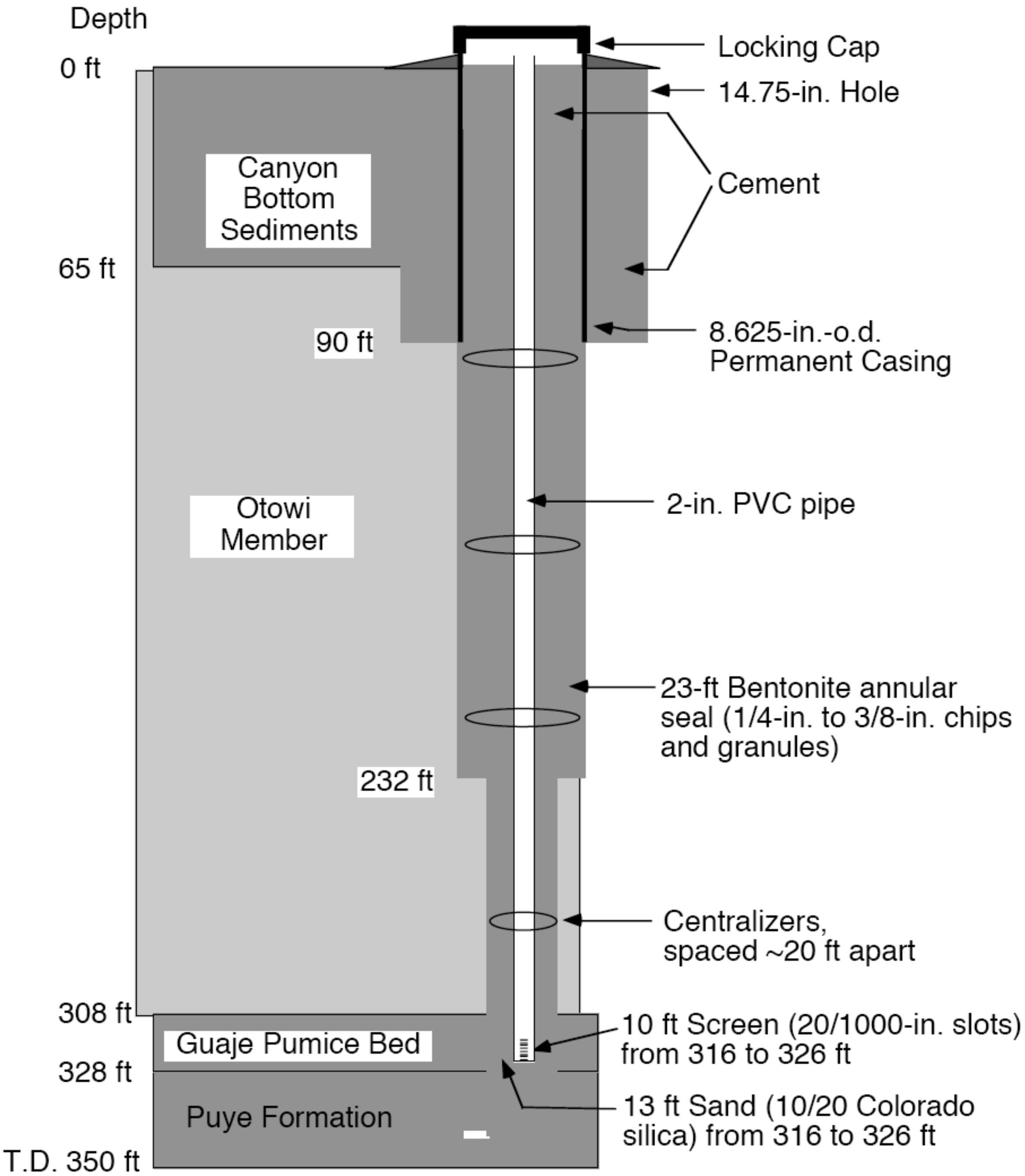
LADP-3 Well

	Description	Evaluation
Drilling Method	LADP-3 was drilled using a combination of HSA and air-rotary drilling methods. Air was the only fluid used to advance the borehole.	LADP-3 was drilled from the surface to 232 ft using an 8.5-in. HSA. The borehole was completed to the final depth of 350 ft using air-rotary drilling methods. Rock coring, using a 4.5-in.-diameter rock barrel, alternated with advancement of 5.625-in.-I.D. ODEX casing from 232 to 350 ft. Alluvial and surface groundwater were cased out of the borehole by installing and grouting permanent 8.625-in.-O.D. surface casing to a depth of 90 ft.
General Well Characteristics	LADP-3 is a single-screen well constructed of 2-in. PVC well casing.	The PVC materials used at LADP-3 are chemically inert.
Well Screen Construction	The well screen is constructed of 2-in.PVC with 0.020-in. slots.	The PVC materials used at LADP-3 are chemically inert.
Screen Length and Placement	The well screen extends from 316 to 326 ft and has a length of 10 ft. The most recent measurable water level datum was 322 ft in January 2009 (Koch and Schmeer 2010, 108926), indicating the screen straddled the perched water table at that time.	LADP-3 is designed to provide water-quality and water-level data for perched groundwater beneath Los Alamos Canyon, and the screen length and placement were selected with the following goals in mind: • Characterize water quality in the uppermost perched-intermediate groundwater zone beneath Los Alamos Canyon in the vicinity of TA-21 • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon Perched-intermediate groundwater was encountered at a depth of 325 ft in the lower part of the Guaje Pumice Bed. Borehole operations were temporarily suspended for several days, and the water level stabilized at about 320-ft depth. Drilling operations were resumed to determine the nature and extent of the groundwater. A clay layer a few inches thick at the top of the Puye Formation was interpreted as a paleosol and perching horizon. Drilling stopped at the 350-ft depth within the Puye Formation after it was determined that the groundwater is confined to the Guaje Pumice Bed. The screen length and placement for LADP-3 are appropriate for the conditions encountered at this location and meet the goals defined in the bullets above.
Filter Pack Materials and Placement	The primary filter pack consists of 10/20 sand from 316 to 326 ft. There is no mention of a secondary filter pack above the primary filter pack.	The primary filter pack is placed adjacent to the well screen, and there is no mention of the sand extending above or below the slotted well screen.
Sampling System	Bladder pump replaced with a Bennett pump in July 2008.	Dedicated pumps allow relatively high-flow sampling. Flow-through cells for measuring field parameters can be used at single-screen wells with dedicated pumps installed. Effective development is typically limited in intermediate wells because of insufficient flow rate and volume; however, development issues are not as critical in wells like LADP-3 that are installed in boreholes where no additives other than air are used during drilling.

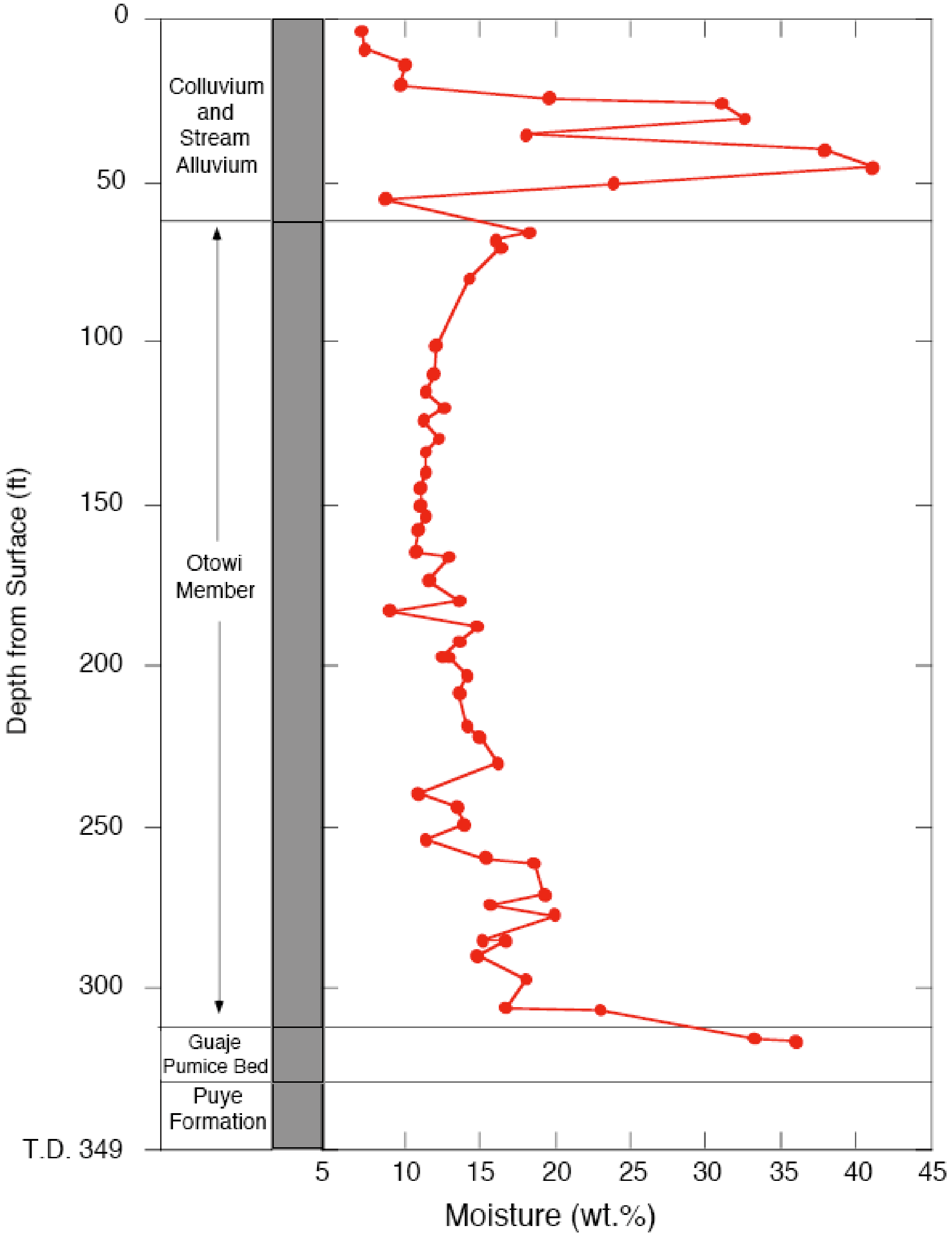
	Description	Evaluation
Other Issues that Could Affect the Performance of the Well	None	Nitrate-reducing conditions may be present in water samples from the well but are assumed to be representative of the groundwater at this location and not a residual effect of drilling or construction, because no drilling additives were used (Appendix B).
Additives Used During Drilling		Air
Annular Fill other than Filter and Transition Sands		Bentonite: bentonite chips and granules Cement grout surface seal



LADP-3 borehole design



LADP-3 well design



Geology and moisture distribution in LADP-3 borehole

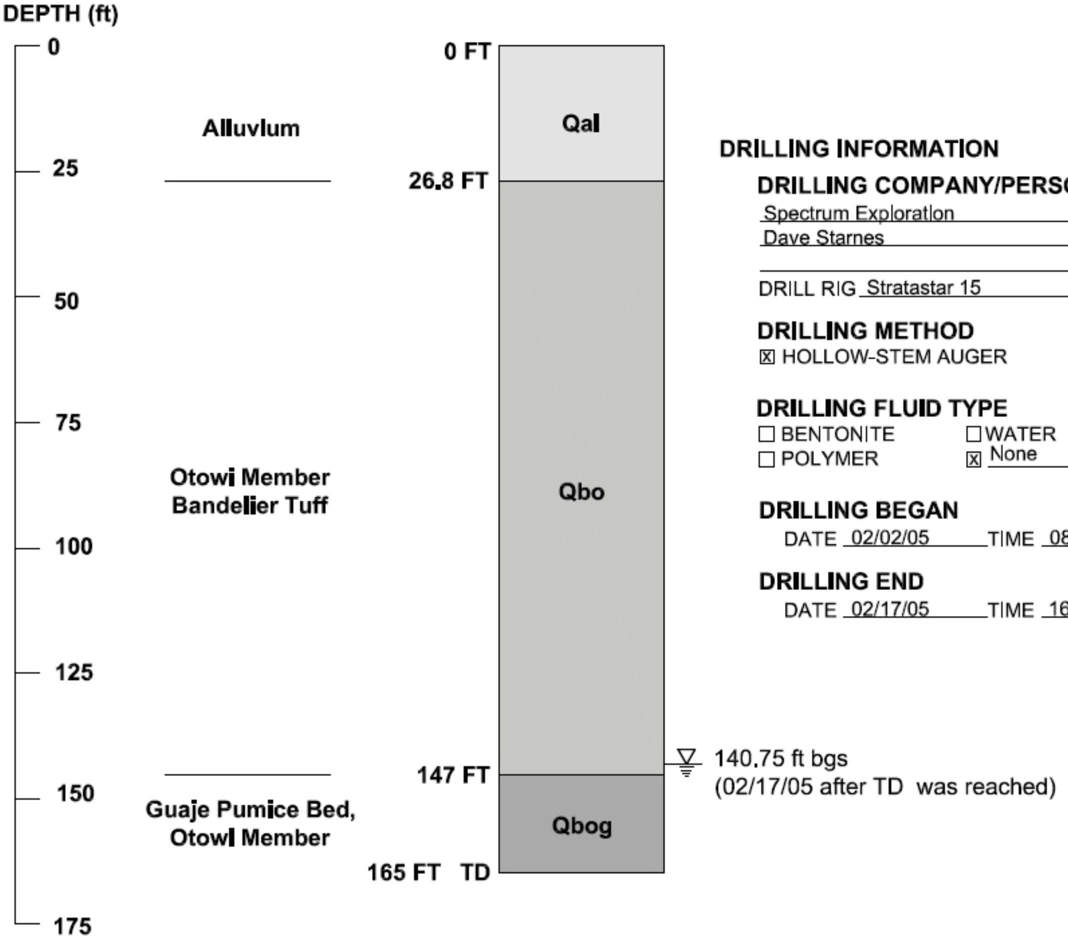
LAOI-3.2 and LAOI-3.2a Wells

LAOI-3.2 and LAOI-3.2a Wells

	Description	Evaluation
Drilling Method	LAOI-3.2 and LAOI-3.2a were continuously cored using air as the only fluid to TDs of 165 ft and 266.9 ft, respectively. Drill casing was used to seal off perched groundwater zones above the target horizons in both core holes.	LAOI-3.2 was cored with a target depth of 300 ft; however, drilling was halted at 165 ft bgs to install a perched-intermediate zone monitoring well for groundwater encountered in the Otowi Member and the Guaje Pumice Bed. LAOI-3.2 was cored using a Stratastar 15 HSA drill rig equipped with 8.25-in.-O.D./4.5-in.-I.D. augers and a 3.0-in.-O.D. 5-ft-long split-spoon sampler. At approximately 15 ft bgs, a boulder was encountered, and the rig was pulled off of the original location, which was backfilled with bentonite. The rig was moved 4 ft to the north and began collecting core from 15 ft bgs. An alluvial saturated zone extending from approximately 15 to 25 ft bgs was sealed off using 12-in.-O.D. conductor casing set to a depth of 37.5 ft bgs. Coring continued, and perched-intermediate groundwater was encountered in the Otowi Member at a depth of approximately 140 ft bgs. The borehole was advanced into the underlying Guaje Pumice Bed to a final TD of 165 ft bgs, and a groundwater monitoring well with a 9.5-ft screened interval was installed. A second well, LAOI-3.2a, was then drilled to reach the original LAOI-3.2 target depth of 300 ft, with the goal of identifying potential deeper perched water zones. LAOI-3.2a was drilled with a Delta Base 540 track-mounted drill rig using the air-rotary casing hammer technique. The initial LAOI-3.2a borehole was drilled to a depth of 234.4 ft, with continuous core being collected from 200 to 234.3 ft. However, when the drill casing was removed from the hole before well construction, the stainless-steel casing shoe could not be retrieved. Another piece of drilling equipment, called an elevator, was lost downhole while attempting to retrieve the casing shoe. After attempts to retrieve both pieces of equipment were unsuccessful, it was decided to plug and abandon the first hole and move the rig 5 ft to the north to drill a new LAOI-3.2a borehole. The relocated LAOI-3.2a was advanced using 6.625 in.-O.D. casing and a 7.5-in.-O.D. hammer bit. The casing was advanced to 230 ft bgs, and the remainder of the borehole was cored continuously to a depth of 266.9 ft. A well with a single 9.6-ft well screen was successfully installed in the new borehole within a perched-intermediate zone in the Puye Formation.
General Well Characteristics	LAOI-3.2 is a single-screen well constructed of 2.4-in.-O.D./2.1-in.-I.D. schedule 40 PVC casing. LAOI-3.2a is a single-screen well constructed of 3.1-in.-I.D./3.5-in.-O.D. 304 stainless-steel casing.	The PVC materials used at LAOI-3.2 are chemically inert. All PVC components, including the screen, were factory-cleaned before shipment. The stainless-steel well materials used at LAOI-3.2a are chemically inert and are designed to prevent corrosion.

	Description	Evaluation
Well Screen Construction	The LAOI-3.2 well screen is constructed of 2.1-in.-I.D./3.5-in.-O.D. PVC prepacked screen containing 10/20 sand and 0.010-in. slots. The LAOI-3.2a well screen is constructed of 3-in.-I.D./3.5-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The LAOI-3.2 PVC prepacked screens with 0.010-in. slots developed properly, producing water with an NTU value of 2 and stable water-quality parameters by the end of development. The LAOI-3.2a well screen construction (0.020-in. wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling. LAOI-3.2a produced water with an NTU value of 2.1 and had stable water-quality parameters by the end of development.
Screen Length and Placement	The LAOI-3.2 well screen extends from 153.3 to 162.8 ft and has a length of 9.5 ft. The top of the well screen is submerged 26.3 ft below the current water level of 127 ft below the surface (Koch and Schmeer 2010, 108926). The LAOI-3.2a well screen extends from 181.4 to 191 ft and has a length of 9.6 ft. The top of the well screen straddles the current water level of 183.4 ft below the surface (Koch and Schmeer 2010, 108926).	Both LAOI-3.2 and LAOI-3.2a were installed to provide water-quality and water-level data for the perched groundwater near the confluence of Los Alamos and DP Canyons, and the screen lengths and placements were selected with the following goals in mind: Further investigate the nature and extent of perched groundwater observed at nearby well R-6i and perched water that had been tentatively identified from a borehole video log at O-4 Characterize water quality in the uppermost perched-intermediate groundwater zone located downgradient of contaminant sources in Los Alamos and DP Canyons, particularly TA-21 Characterize water quality in the deeper perched-intermediate groundwater zone located in the Puye Formation Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos and DP Canyons Two zones of perched saturation were encountered in LAOI-3.2 and LAOI-3.2a. The first zone was encountered within the lower part of the Otowi Member and in the Guaje Pumice Bed. Depth to water in this upper perched zone is currently about 138.6 ft in the completed LAOI-3.2 well. The base of the perched water is uncertain because of incomplete core collection, but most likely it extends to the base of the Guaje Pumice Bed. A second intermediate perched zone was encountered within sedimentary deposits of the Puye Formation that overlie Cerros del Rio basalt. The perching horizon appears to be a stratified sequence of brown homogeneous silts and fine-grained sands, with subordinate clay in the interval from 195 to 266.5 ft. Depth to water in this upper perched zone is currently about 184.9 ft in the completed LAOI-3.2a well. The differences in depth to water in these two wells suggest that two separate water-bearing zones occur at this location. The screen lengths and placements for the LAOI-3.2 and LAOI-3.2a wells are appropriate for the conditions encountered at this location and meet the goals defined in the above bullets.

	Description	Evaluation
Filter Pack Materials and Placement	In addition to the PVC prepack well screen, LAOI-3.2 has a primary filter pack consisting of 10/20 sand from 151.3 ft to 165 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 149.8 to 151.3 ft. In LAOI-3.2a, the primary filter pack consists of 10/20 sand from 176.7 ft to 195.5 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 174.7 to 176.7ft.	At LAOI-3.2, the primary filter pack extends 2 ft above and 2.2 ft below the well screen. At LAOI-3.2a, the primary filter pack extends 4.7 ft above and 4.5 ft below the well screen. Placement of the filter pack in the two wells is within the optimum design for well screens.
Sampling System	Submersible pump	Dedicated pumps allow relatively high-flow sampling. Flow-through cells for measuring field parameters can be used at single-screen wells with dedicated pumps installed. Effective development is typically limited in intermediate wells because of insufficient flow rate and volume; however, development issues are not as critical in wells like LAOI-3.2 and LAOI-3.2a that are installed in core holes where no additives other than air are used during drilling.
Other Issues that Could Affect the Performance of the Well	None	n/a
Additives Used During Drilling		Air
Annular Fill other than Filter and Transition Sands		LAOI-3.2: Bentonite seal: bentonite chips (30.7 ft3) Cement grout surface seal (25.4 ft3) Bentonite backfill (0.2 ft3) Water removed during well development (1197 gal.) Water removed during aquifer testing (1278 gal.)
		LAOI-3.2a: Bentonite seal: bentonite chips (16.6 ft3) Cement grout surface seal (23.3 ft3) Bentonite backfill: pellets (8.7 ft3) Municipal water (270 gal.) Water removed during well development (3155 gal.) Water removed during aquifer testing (3797 gal.)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL

Spectrum Exploration

Dave Starnes

DRILL RIG Stratastar 15

DRILLING METHOD

☒ HOLLOW-STEM AUGER

DRILLING FLUID TYPE

☐ BENTONITE ☐ WATER

☐ POLYMER ☒ None

DRILLING BEGAN

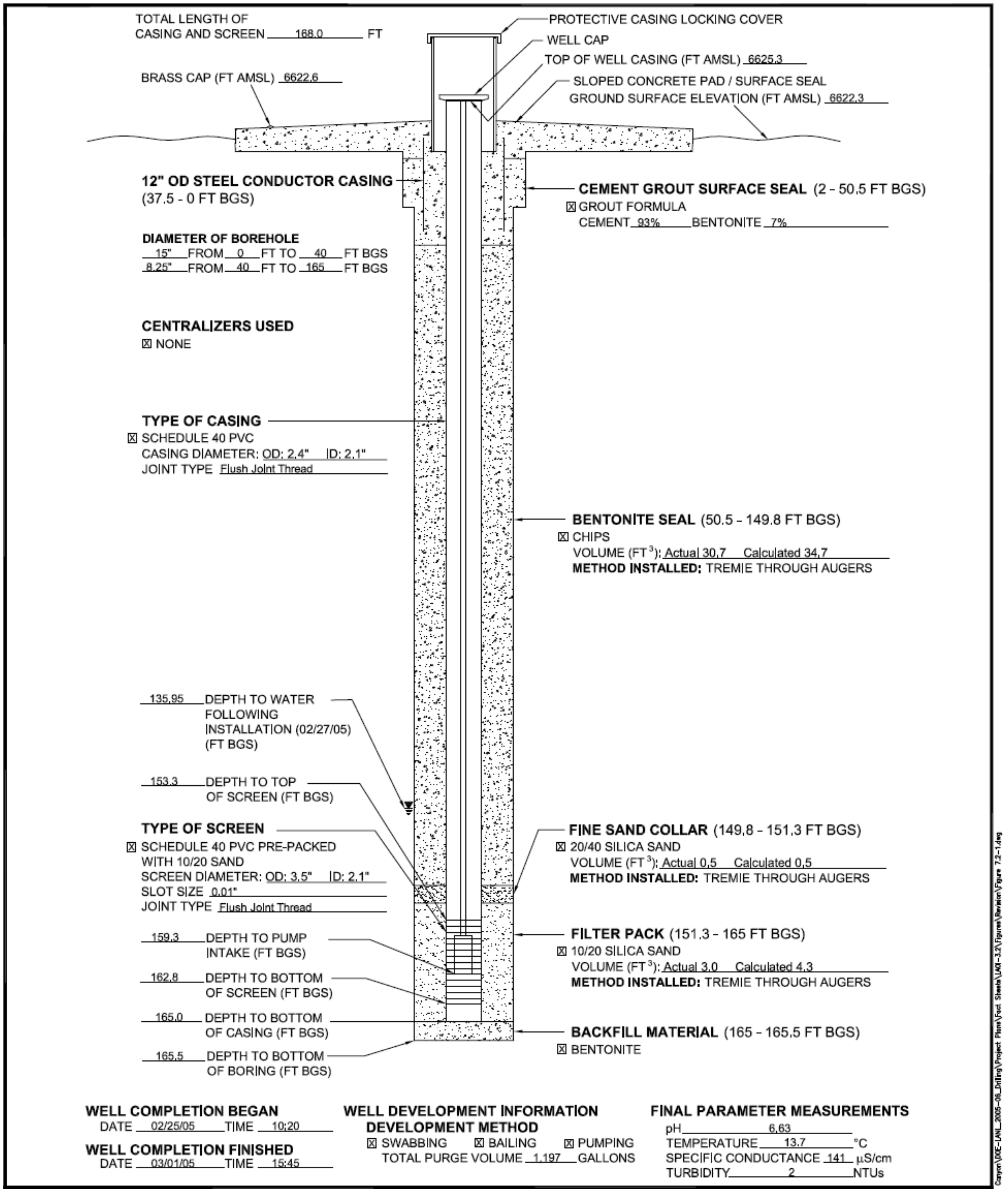
DATE 02/02/05 TIME 08:10

DRILLING END

DATE 02/17/05 TIME 16:30

Note:
Geologic contacts are preliminary and subject to change.

Borehole summary data sheet, intermediate well LAOI-3.2



TOTAL LENGTH OF CASING AND SCREEN 168.0 FT

BRASS CAP (FT AMSL) 6622.6

PROTECTIVE CASING LOCKING COVER

WELL CAP

TOP OF WELL CASING (FT AMSL) 6625.3

SLOPED CONCRETE PAD / SURFACE SEAL

GROUND SURFACE ELEVATION (FT AMSL) 6622.3

12" OD STEEL CONDUCTOR CASING
(37.5 - 0 FT BGS)

CEMENT GROUT SURFACE SEAL (2 – 50.5 FT BGS)
☒ GROUT FORMULA
CEMENT 93% BENTONITE 7%

DIAMETER OF BOREHOLE
15" FROM 0 FT TO 40 FT BGS
8.25" FROM 40 FT TO 165 FT BGS

CENTRALIZERS USED
☒ NONE

TYPE OF CASING
☒ SCHEDULE 40 PVC
CASING DIAMETER: OD: 2.4" ID: 2.1"
JOINT TYPE Flush Joint Thread

BENTONITE SEAL (50.5 – 149.8 FT BGS)
☒ CHIPS
VOLUME (FT^3): Actual 30.7 Calculated 34.7
METHOD INSTALLED: TREMIE THROUGH AUGERS

135.95 DEPTH TO WATER FOLLOWING INSTALLATION (02/27/05) (FT BGS)

153.3 DEPTH TO TOP OF SCREEN (FT BGS)

TYPE OF SCREEN
☒ SCHEDULE 40 PVC PRE-PACKED WITH 10/20 SAND
SCREEN DIAMETER: OD: 3.5" ID: 2.1"
SLOT SIZE 0.01"
JOINT TYPE Flush Joint Thread

FINE SAND COLLAR (149.8 – 151.3 FT BGS)
☒ 20/40 SILICA SAND
VOLUME (FT^3): Actual 0.5 Calculated 0.5
METHOD INSTALLED: TREMIE THROUGH AUGERS

159.3 DEPTH TO PUMP INTAKE (FT BGS)

162.8 DEPTH TO BOTTOM OF SCREEN (FT BGS)

FILTER PACK (151.3 – 165 FT BGS)
☒ 10/20 SILICA SAND
VOLUME (FT^3): Actual 3.0 Calculated 4.3
METHOD INSTALLED: TREMIE THROUGH AUGERS

165.0 DEPTH TO BOTTOM OF CASING (FT BGS)

165.5 DEPTH TO BOTTOM OF BORING (FT BGS)

BACKFILL MATERIAL (165 – 165.5 FT BGS)
☒ BENTONITE

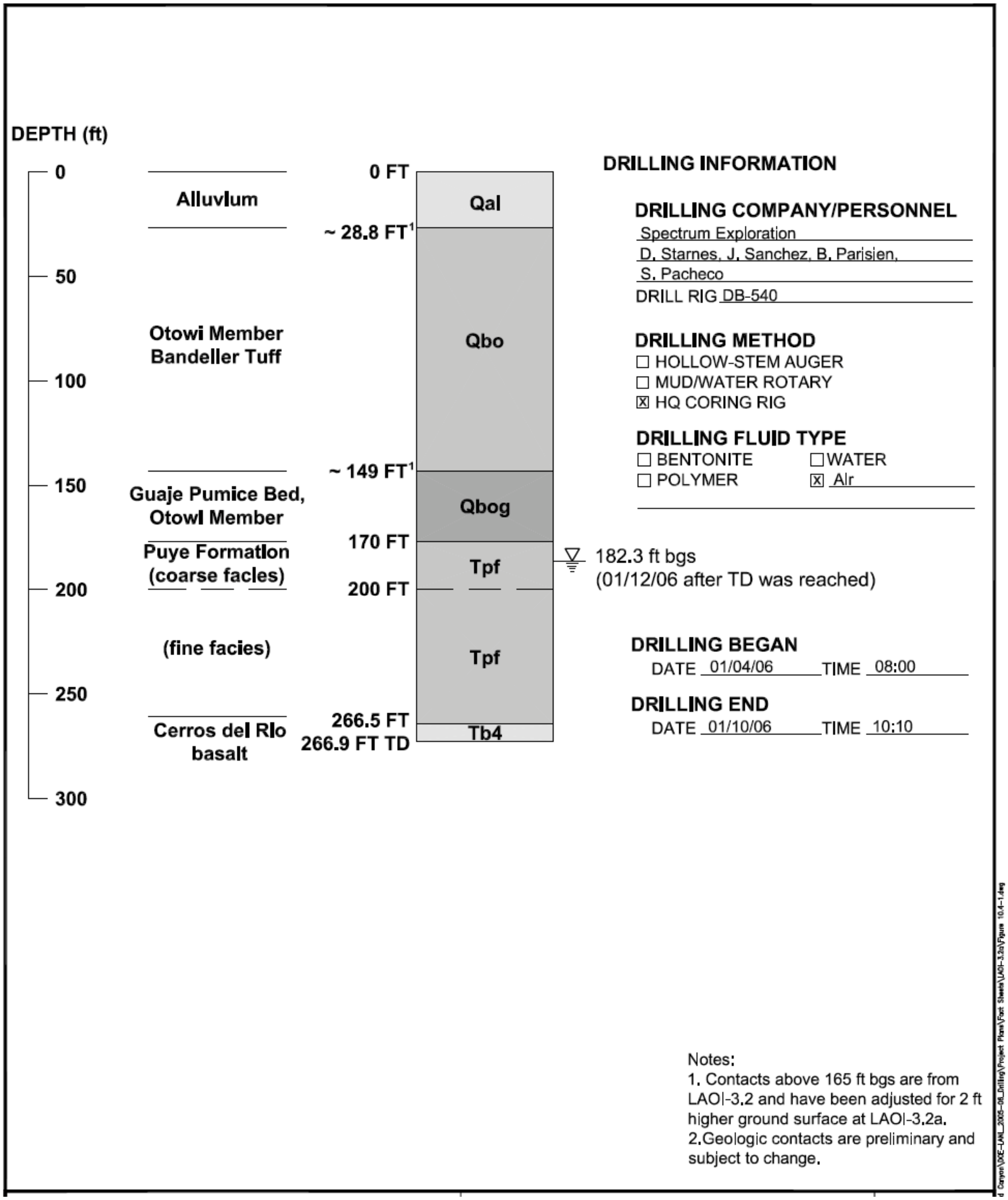
WELL COMPLETION BEGAN
DATE 02/25/05 TIME 10:20

WELL COMPLETION FINISHED
DATE 03/01/05 TIME 15:45

WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING ☒ PUMPING
TOTAL PURGE VOLUME 1,197 GALLONS

FINAL PARAMETER MEASUREMENTS
pH 6.63
TEMPERATURE 13.7 °C
SPECIFIC CONDUCTANCE 141 µS/cm
TURBIDITY 2 NTUs

Well schematic, intermediate well LAOI-3.2



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL

Spectrum Exploration
D. Starnes, J. Sanchez, B. Parisien,
S. Pacheco
DRILL RIG DB-540

DRILLING METHOD

☐ HOLLOW-STEM AUGER
☐ MUD/WATER ROTARY
☒ HQ CORING RIG

DRILLING FLUID TYPE

☐ BENTONITE ☐ WATER
☐ POLYMER ☒ Air

DRILLING BEGAN

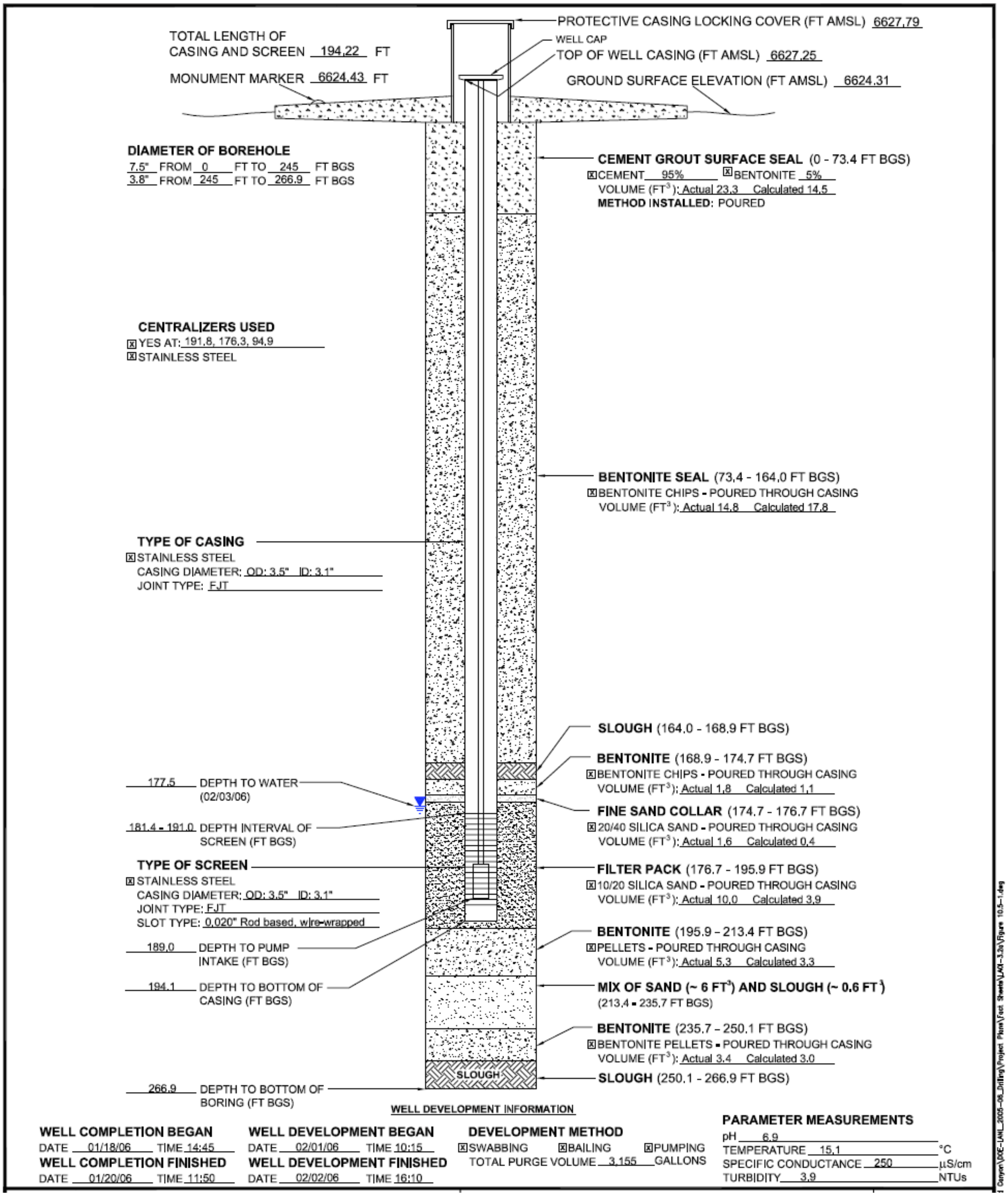
DATE 01/04/06 TIME 08:00

DRILLING END

DATE 01/10/06 TIME 10:10

Notes:
1. Contacts above 165 ft bgs are from LAOI-3.2 and have been adjusted for 2 ft higher ground surface at LAOI-3.2a.
2. Geologic contacts are preliminary and subject to change.

Borehole summary data sheet, intermediate well LAOI-3.2a



TOTAL LENGTH OF CASING AND SCREEN 194.22 FT

MONUMENT MARKER 6624.43 FT

PROTECTIVE CASING LOCKING COVER (FT AMSL) 6627.79

WELL CAP

TOP OF WELL CASING (FT AMSL) 6627.25

GROUND SURFACE ELEVATION (FT AMSL) 6624.31

DIAMETER OF BOREHOLE

7.5" FROM 0 FT TO 245 FT BGS

3.8" FROM 245 FT TO 266.9 FT BGS

CEMENT GROUT SURFACE SEAL (0 - 73.4 FT BGS)

☒CEMENT 95% ☒BENTONITE 5%

VOLUME (FT^3): Actual 23.3 Calculated 14.5

METHOD INSTALLED: POURED

CENTRALIZERS USED

☒YES AT: 191.8, 176.3, 94.9

☒STAINLESS STEEL

BENTONITE SEAL (73.4 - 164.0 FT BGS)

☒BENTONITE CHIPS - POURED THROUGH CASING

VOLUME (FT^3): Actual 14.8 Calculated 17.8

TYPE OF CASING

☒STAINLESS STEEL

CASING DIAMETER: OD: 3.5" ID: 3.1"

JOINT TYPE: FJT

SLOUGH (164.0 - 168.9 FT BGS)

BENTONITE (168.9 - 174.7 FT BGS)

☒BENTONITE CHIPS - POURED THROUGH CASING

VOLUME (FT^3): Actual 1.8 Calculated 1.1

177.5 DEPTH TO WATER (02/03/06)

FINE SAND COLLAR (174.7 - 176.7 FT BGS)

☒20/40 SILICA SAND - POURED THROUGH CASING

VOLUME (FT^3): Actual 1.6 Calculated 0.4

181.4 - 191.0 DEPTH INTERVAL OF SCREEN (FT BGS)

TYPE OF SCREEN

☒STAINLESS STEEL

CASING DIAMETER: OD: 3.5" ID: 3.1"

JOINT TYPE: FJT

SLOT TYPE: 0.020" Rod based, wire-wrapped

FILTER PACK (176.7 - 195.9 FT BGS)

☒10/20 SILICA SAND - POURED THROUGH CASING

VOLUME (FT^3): Actual 10.0 Calculated 3.9

189.0 DEPTH TO PUMP INTAKE (FT BGS)

BENTONITE (195.9 – 213.4 FT BGS)

☒PELLETS - POURED THROUGH CASING

VOLUME (FT^3): Actual 5.3 Calculated 3.3

194.1 DEPTH TO BOTTOM OF CASING (FT BGS)

MIX OF SAND (~ 6 FT^3) AND SLOUGH (~ 0.6 FT^3) (213.4 - 235.7 FT BGS)

BENTONITE (235.7 – 250.1 FT BGS)

☒BENTONITE PELLETS - POURED THROUGH CASING

VOLUME (FT^3): Actual 3.4 Calculated 3.0

SLOUGH

SLOUGH (250.1 - 266.9 FT BGS)

266.9 DEPTH TO BOTTOM OF BORING (FT BGS)

WELL DEVELOPMENT INFORMATION

WELL COMPLETION BEGAN

DATE 01/18/06 TIME 14:45

WELL COMPLETION FINISHED

DATE 01/20/06 TIME 11:50

WELL DEVELOPMENT BEGAN

DATE 02/01/06 TIME 10:15

WELL DEVELOPMENT FINISHED

DATE 02/02/06 TIME 16:10

DEVELOPMENT METHOD

☒SWABBING ☒BAILING ☒PUMPING

TOTAL PURGE VOLUME 3,155 GALLONS

PARAMETER MEASUREMENTS

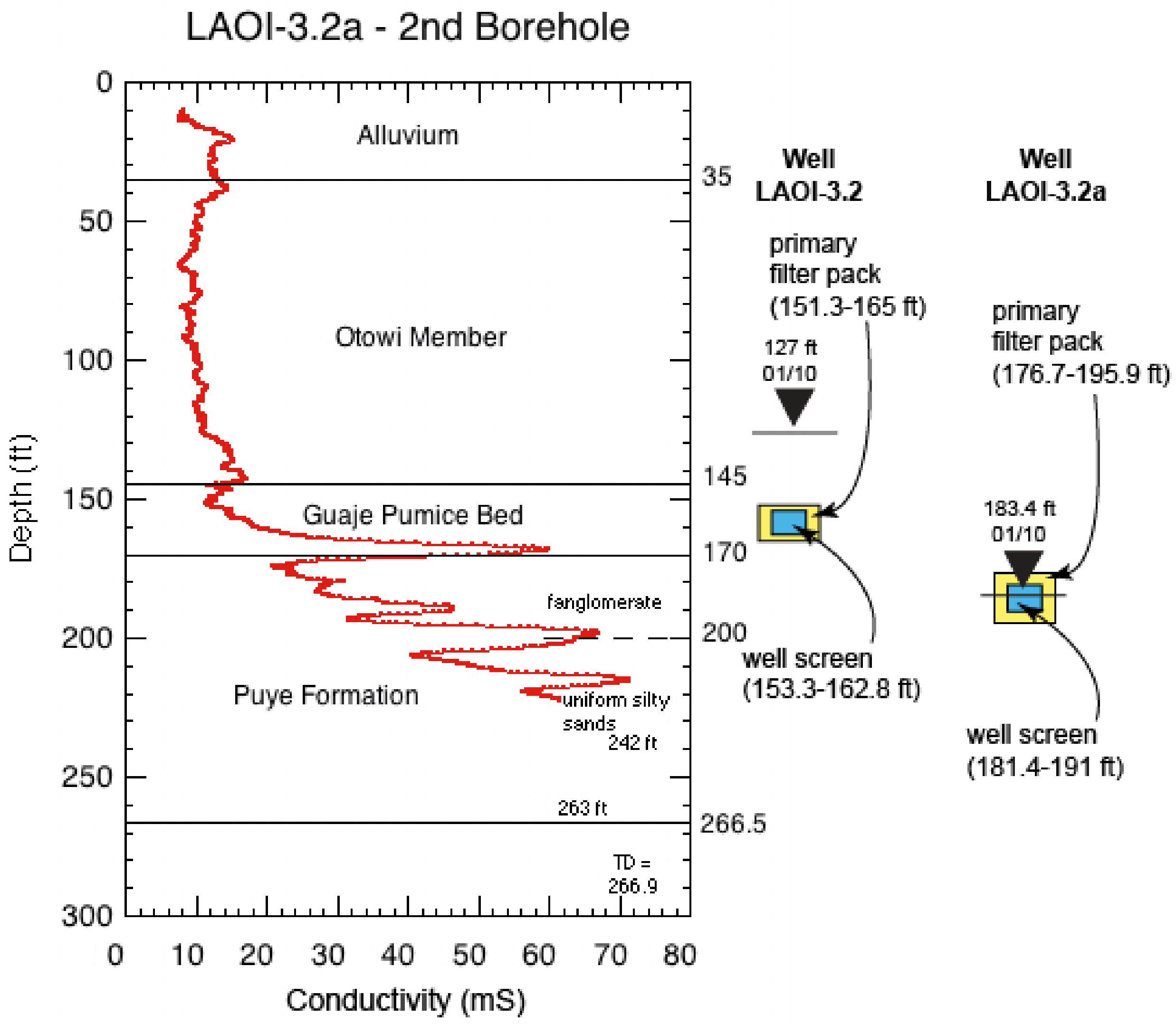
pH 6.9

TEMPERATURE 15.1 °C

SPECIFIC CONDUCTANCE 250 µS/cm

TURBIDITY 3.9 NTUs

Well schematic, intermediate well LAOI-3.2a



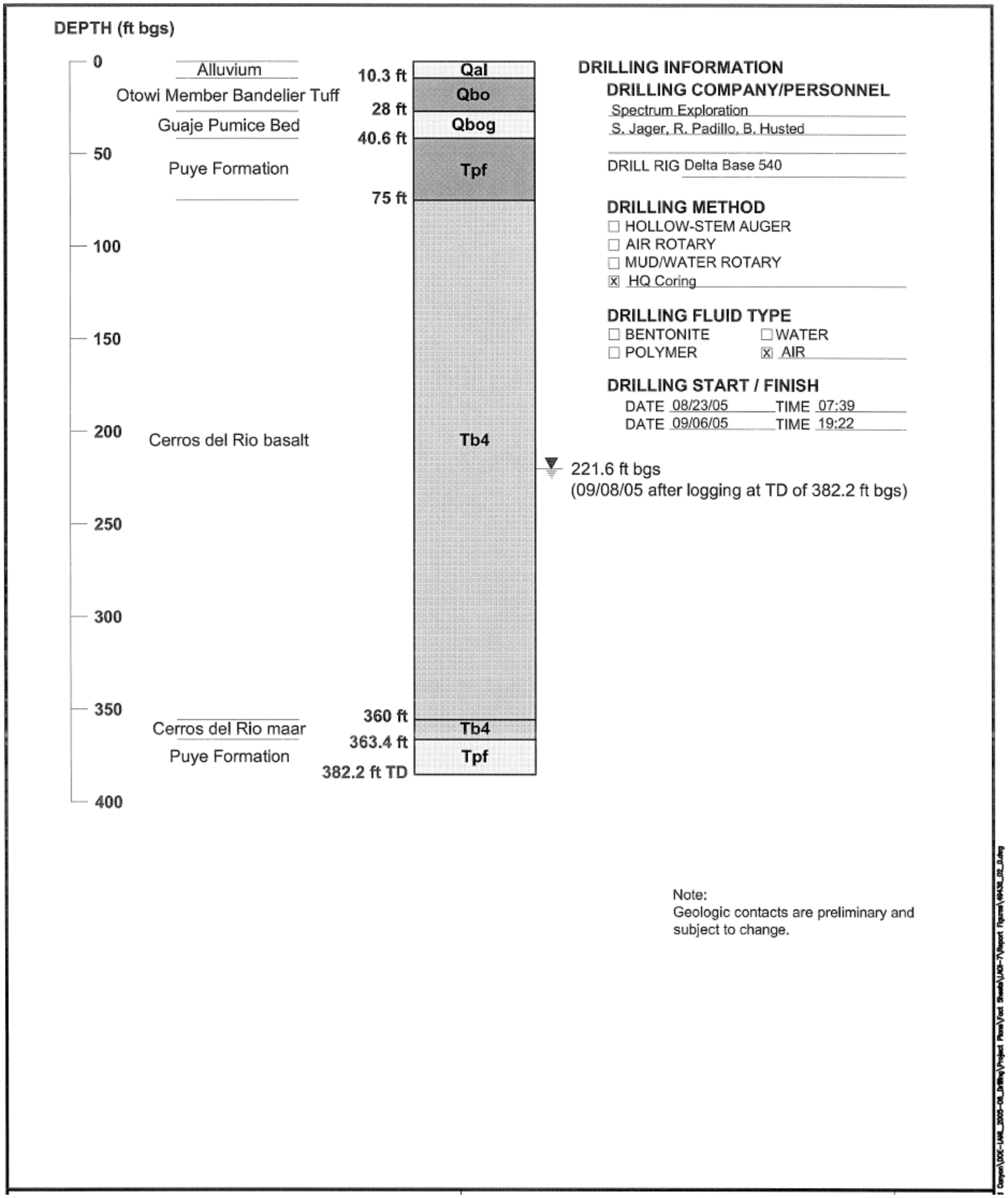
Position of LAOI-3.2 and LAOI-3.2a well screens relative to the conductivity data collected in the initial LAOI-3.2a borehole

LAOI-7 Well

LAOI-7 Well

	Description	Evaluation
Drilling Method	LAOI-7 was continuously cored to a TD of 382.2 ft.	LAOI-7 was cored by a Delta Base 540 track-mounted HQ coring rig using air as the drilling fluid. A 7.375-in.-diameter core hole was drilled to a depth of 280 ft using a temporary 6.625-in.-O.D. casing set at various depths to seal off perched groundwater. The core hole was completed by advancing a 3.9-in. open core hole from 280 to 382.2 ft.
General Well Characteristics	LAOI-7 is a single-screen well constructed of 3-in.-I.D./3.5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 3-in. I.D./3.5-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The LAOI-7 well screen construction (0.020-in. wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 240 to 259.6 ft and has a length of 19.6 ft. The top of the well screen is submerged within a perched zone that has a current water level of 219.6 ft below the surface (Koch and Schmeer 2010, 108926).	LAOI-7 is designed to provide water-quality and water-level data for the perched groundwater near the Laboratory's eastern boundary, and the screen lengths and placements were selected with the following goals in mind: • Characterize water quality in the uppermost perched groundwater zone located downgradient of contaminant sources in Los Alamos Canyon, particularly TA-02 and TA-21 • Determine the lateral extent of perched groundwater in Cerros del Rio basalt first identified in wells R-9 and R-9i • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon Two zones of perched saturation were encountered in LAOI-7. The first zone was encountered at shallow depths within the lower part of the Otowi Member and in the Guaje Pumice Bed. Depth to water was 26 ft and is probably closely connected to canyon floor alluvial groundwater. The base of the perched water is uncertain because of incomplete core recovery, but most likely it extends to the top of dry silt-rich sediments in Puye deposits that overlie the Cerros del Rio basalt in this area. No well screen was installed in this shallow perched zone.

	Description	Evaluation
Screen Length and Placement (continued)		A second, more complex, perched zone was encountered at several horizons in the interval between 237.2 and 286.8 ft. The saturated horizons seem to be interconnected via high-angle fractures because the saturated zones yielded similar water levels. Water was first noted in the core barrel after drilling the 237.2- to 242.2-ft interval. Coring was halted and the water level stabilized at 221.6 ft, suggesting confinement. Fractures below 234.3 ft commonly contain clay; clay is much less abundant above this depth. Additional zones of saturation in core occurred between depths of 256.8 and 262.2 ft in a basalt rubble zone and between depths of 282.2 and 286.8 ft in a vesicular basalt. Perching appears to occur above sections of massive basalt flows where fractures are rare to absent. The lowermost perching horizon is not known with certainty but may be layered near deposits between 360 and 363.4 ft at the base of the basalt sequence. The well screen targets the upper two intervals of water production in the upper half of the perched zone. The screen length and placement for LAOI-7 are appropriate for the conditions encountered at this location and meet the goals defined in the bullets above.
Filter Pack Materials and Placement	The primary filter pack consists of 10/20 sand from 235 to 265 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 233 to 235 ft.	The primary filter pack extends 5 ft above and 5.4 ft below the well screen. Placement of the filter pack is within the optimum design for the well screen.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well	None	n/a
Additives Used During Drilling		Air
Annular Fill other than Filter and Transition Sands		Bentonite seal: bentonite chips/pellets (44 ft3) Pel-Plug: refined elliptical bentonite pellets (12 ft3) Cement grout surface seal (10.7 ft3) Municipal water (251 gal.) Water removed during well development (3584 gal.) Water removed during aquifer testing (459 gal.)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL

Spectrum Exploration
S. Jager, R. Padillo, B. Husted

DRILL RIG Delta Base 540

DRILLING METHOD

☐ HOLLOW-STEM AUGER
☐ AIR ROTARY
☐ MUD/WATER ROTARY
☒ HQ Coring

DRILLING FLUID TYPE

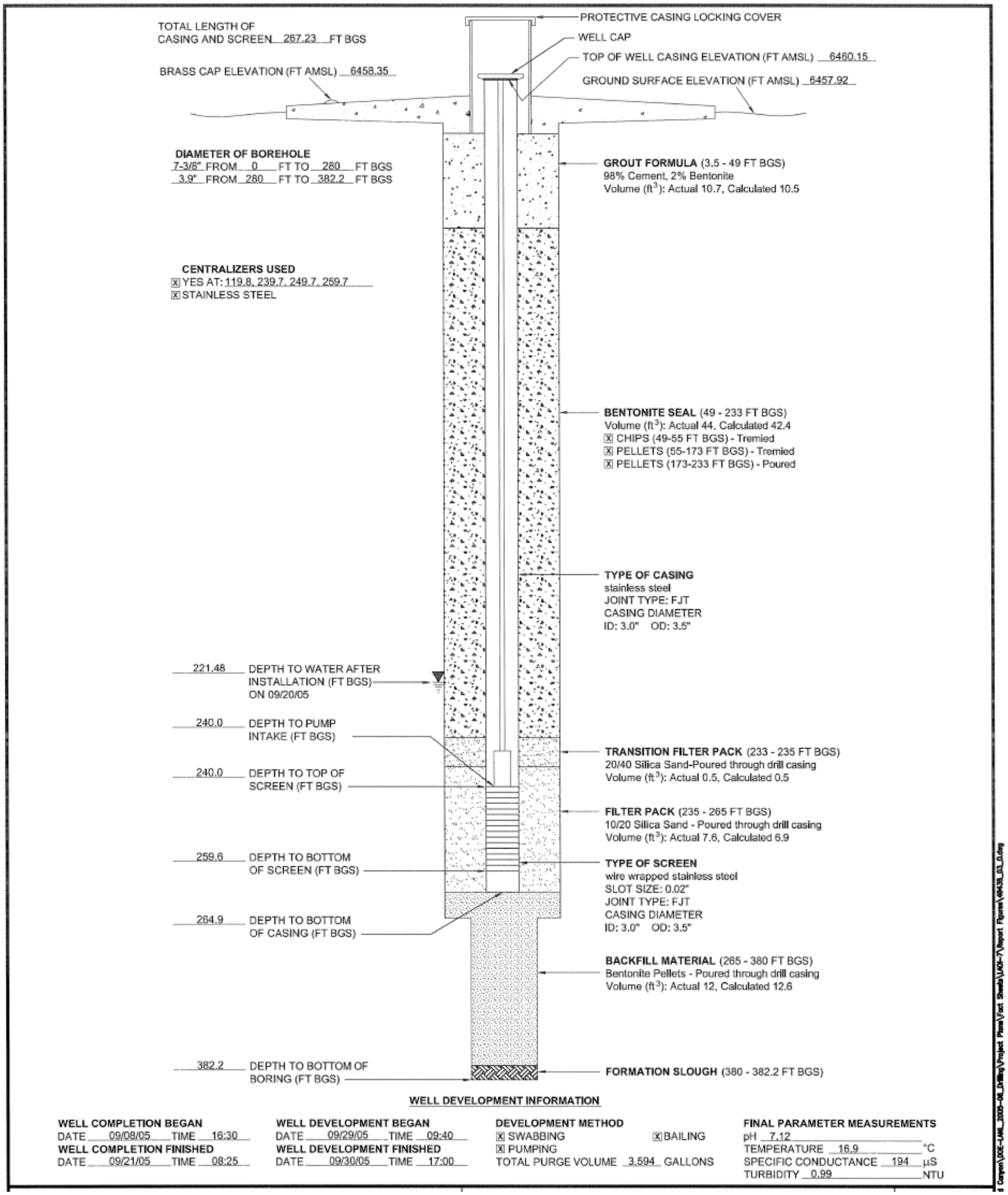
☐ BENTONITE ☐ WATER
☐ POLYMER ☒ AIR

DRILLING START / FINISH

DATE 08/23/05 TIME 07:39
DATE 09/06/05 TIME 19:22

Note:
Geologic contacts are preliminary and subject to change.

Borehole summary data sheet, intermediate well LAOI-7



TOTAL LENGTH OF CASING AND SCREEN 267.23 FT BGS

BRASS CAP ELEVATION (FT AMSL) 6458.35

TOP OF WELL CASING ELEVATION (FT AMSL) 6460.15

GROUND SURFACE ELEVATION (FT AMSL) 6457.92

DIAMETER OF BOREHOLE
7-3/8" FROM 0 FT TO 280 FT BGS
3.9" FROM 280 FT TO 382.2 FT BGS

GROUT FORMULA (3.5 - 49 FT BGS)
98% Cement, 2% Bentonite
Volume (ft^3): Actual 10.7, Calculated 10.5

CENTRALIZERS USED
☒ YES AT: 119.8, 239.7, 249.7, 259.7
☒ STAINLESS STEEL

BENTONITE SEAL (49 - 233 FT BGS)
Volume (ft^3): Actual 44, Calculated 42.4
☒ CHIPS (49-55 FT BGS) - Tremied
☒ PELLETS (55-173 FT BGS) - Tremied
☒ PELLETS (173-233 FT BGS) - Poured

TYPE OF CASING
stainless steel
JOINT TYPE: FJT
CASING DIAMETER
ID: 3.0" OD: 3.5"

221.48 DEPTH TO WATER AFTER INSTALLATION (FT BGS) ON 09/20/05

240.0 DEPTH TO PUMP INTAKE (FT BGS)

240.0 DEPTH TO TOP OF SCREEN (FT BGS)

TRANSITION FILTER PACK (233 - 235 FT BGS)
20/40 Silica Sand-Poured through drill casing
Volume (ft^3): Actual 0.5, Calculated 0.5

FILTER PACK (235 - 265 FT BGS)
10/20 Silica Sand - Poured through drill casing
Volume (ft^3): Actual 7.6, Calculated 6.9

259.6 DEPTH TO BOTTOM OF SCREEN (FT BGS)

TYPE OF SCREEN
wire wrapped stainless steel
SLOT SIZE: 0.02"
JOINT TYPE: FJT
CASING DIAMETER
ID: 3.0" OD: 3.5"

264.9 DEPTH TO BOTTOM OF CASING (FT BGS)

BACKFILL MATERIAL (265 - 380 FT BGS)
Bentonite Pellets - Poured through drill casing
Volume (ft^3): Actual 12, Calculated 12.6

382.2 DEPTH TO BOTTOM OF BORING (FT BGS)

FORMATION SLOUGH (380 - 382.2 FT BGS)

WELL DEVELOPMENT INFORMATION

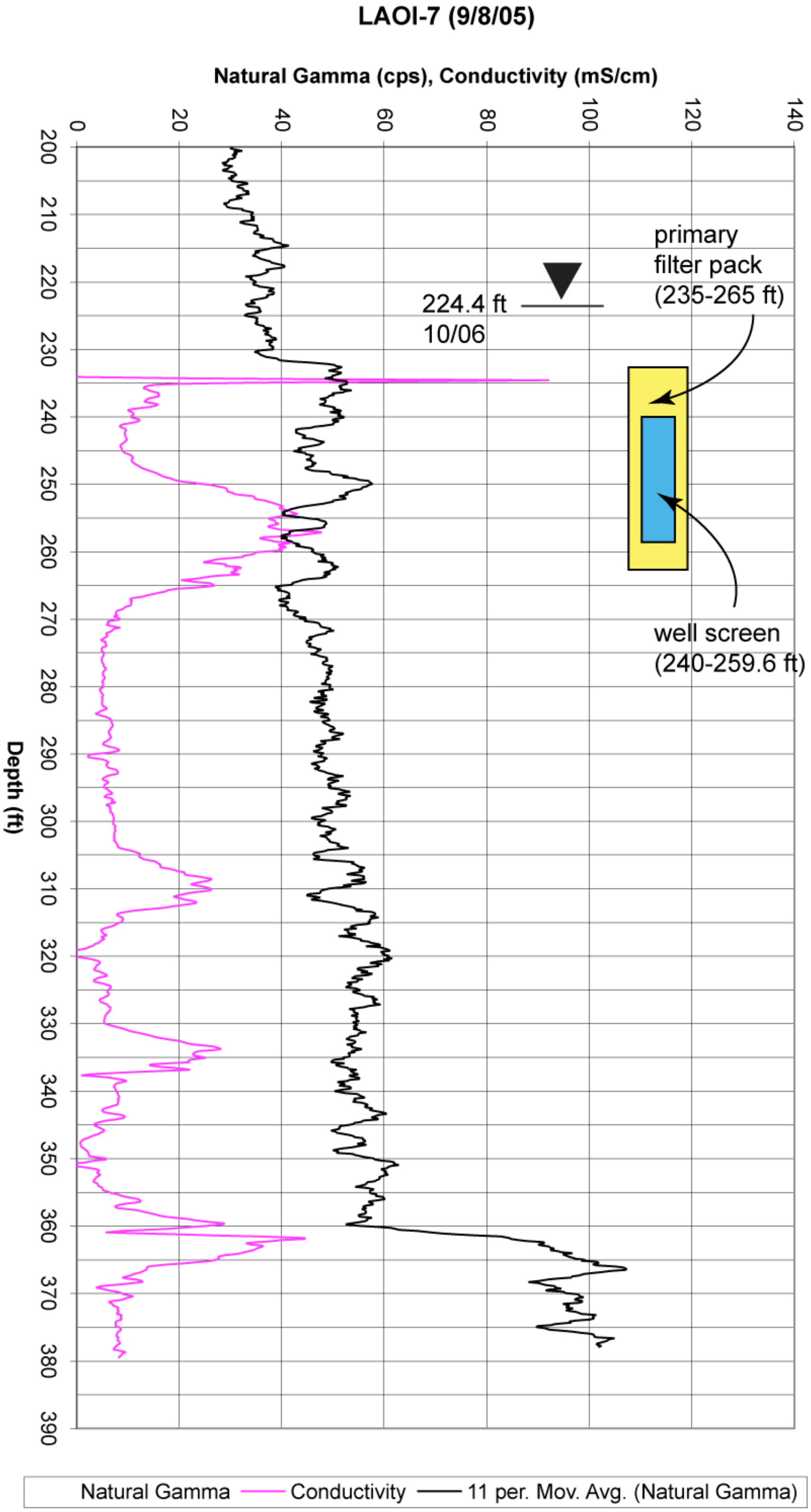
WELL COMPLETION BEGAN
DATE 09/08/05 TIME 16:30
WELL COMPLETION FINISHED
DATE 09/21/05 TIME 08:25

WELL DEVELOPMENT BEGAN
DATE 09/29/05 TIME 09:40
WELL DEVELOPMENT FINISHED
DATE 09/30/05 TIME 17:00

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
☒ PUMPING
TOTAL PURGE VOLUME 3,594 GALLONS

FINAL PARAMETER MEASUREMENTS
pH 7.12
TEMPERATURE 16.9 °C
SPECIFIC CONDUCTANCE 194 µS
TURBIDITY 0.99 NTU

Well schematic, intermediate well LAOI-7



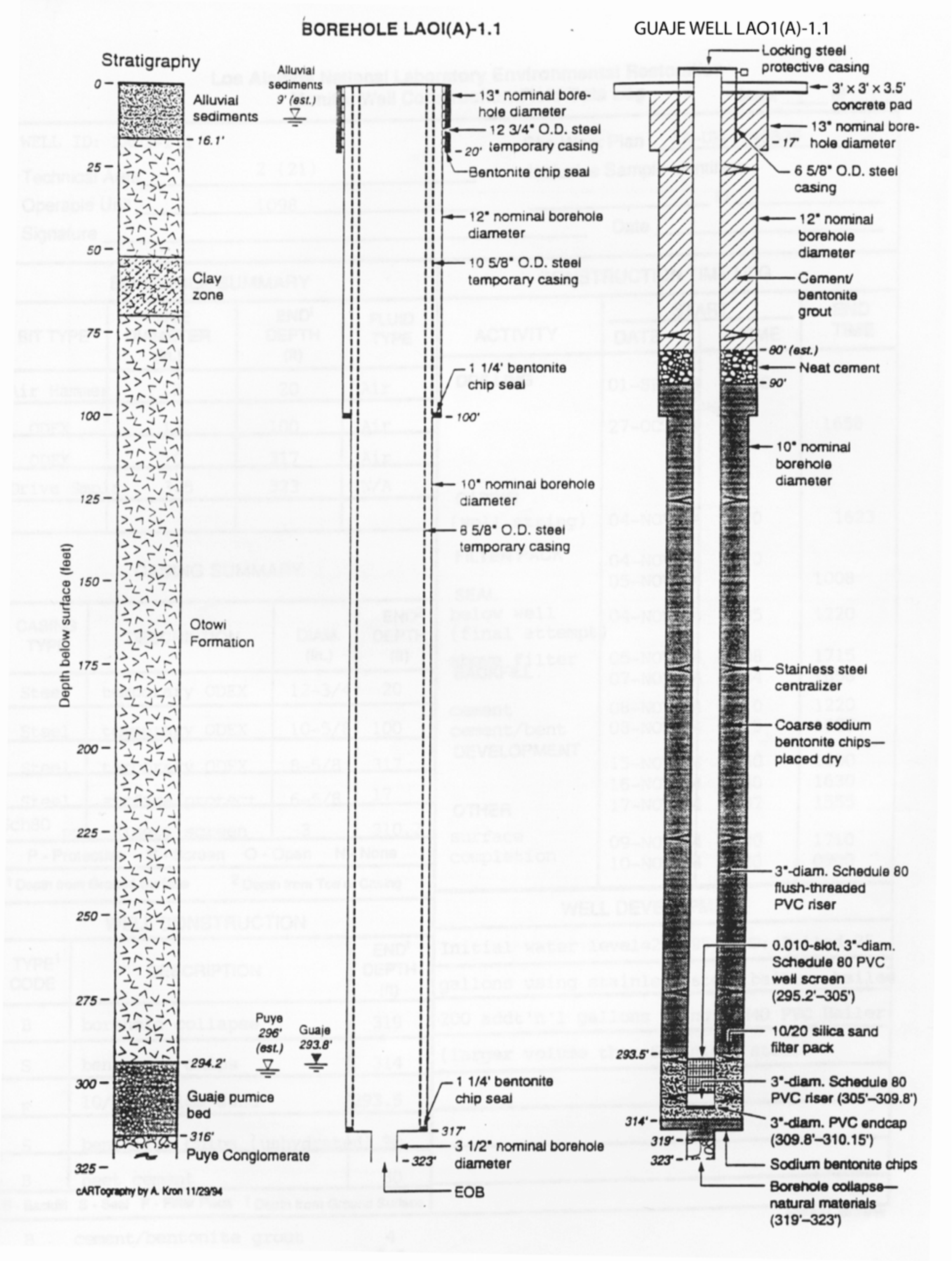
Position of LAOI-7 well screen relative to geophysical data collected in the borehole

LAOI(A)-1.1 Well

LAOI(A)-1.1 Well

	Description	Evaluation
Drilling Method	LAOI(A)-1.1 was drilled using a combination of coring, air-hammer, and ODEX casing methods.	LAOI-1.1 was the initial borehole drilled at this location using an HSA. The LAOI-1.1 borehole was plugged and abandoned after reaching a depth of 30 ft because the augers could not penetrate boulders in the alluvium. A new borehole designated LAOI(A)-1.1 was drilled 10 ft south of the abandoned borehole and was successfully completed to the final depth of 323 ft using air-rotary drilling methods. Rock coring alternated with advancement of ODEX casing. Surface water and alluvial groundwater were sealed out of the borehole by installing temporary 12.625-in.-O.D. casing to a depth of 20 ft and 10.625-in.-O.D. casing to a depth of 100 ft. The borehole below 100 ft was drilled by rock coring alternating with advancement of 8.625-in.-O.D. ODEX casing to 317 ft. Air was the only fluid used to advance the borehole. Core was collected using a split-barrel system from 0- to 100-ft depth and an air-rotary coring system from 100 to 317 ft. A small-diameter borehole was cored from 317 to 323 ft using a split-barrel sampler.
General Well Characteristics	LAOI(A)-1.1 is a single-screen well constructed of schedule 80 3-in. PVC well casing.	The PVC materials used at LAOI(A)-1.1 are chemically inert. All PVC components, including the screen, were factory-cleaned before shipment.
Well Screen Construction	The well screen is constructed of 3-in. PVC with 0.010-in. slots.	The PVC materials used at LAOI(A)-1.1 are chemically inert. All PVC components, including the screen, were factory-cleaned before shipment. The 0.010-in. slots are less effective for aggressive development than are 0.020-in. slots but are more effective in preventing fine-grained material from being drawn into the well. Turbidity >5 NTUs was a continuing problem at LAOI(A)-1.1 after its installation, suggesting the 0.010-in. slots may have been the appropriate choice for the turbid conditions encountered at this location.
Screen Length and Placement	The well screen extends from 295.2 to 305 ft and has a length of 9.8 ft. The top of the well screen is 2 ft below the current water level of 293.2 ft (Koch and Schmeer 2010, 108926).	LAOI(A)-1.1 is designed to provide water-quality and water-level data for perched groundwater beneath Los Alamos Canyon, and the screen lengths and placements were selected with the following goals in mind: • Characterize water quality in the uppermost perched-intermediate groundwater zone beneath Los Alamos Canyon in the vicinity of TA-21 • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon Perched-intermediate groundwater was first recognized in core collected at the top of the Guaje Pumice Bed and was present throughout that unit. Present-day water levels indicate that saturation also extends into the basal ash flow tuffs of the overlying Otowi Member. The contact between the Guaje Pumice Bed and the underlying Puye Formation occurs at a depth of 315.6 ft and is marked by about 5 in. of sandy and silty clay that may represent a soil horizon. Beneath this possible soil, the Puye Formation consists of heterogeneous silts, sands, gravels, and cobbles.

	Description	Evaluation
Screen Length and Placement (continued)		To determine if saturation extended into the Puye Formation, a temporary bentonite seal was placed at a depth of 317 ft, and the 8.625-in.-O.D. ODEX casing was set into the seal. Water was air-lifted from the ODEX casing, and then a 3-in.-diameter borehole was cored from 317 to 323 ft by means of a split-barrel sampler. Saturated cores from this interval suggested that the top of the Puye Formation is saturated at this location. Following HSWA permit requirements, the final well design placed the screen near the top of saturation. The screen length and placement for LAOI(A)-1.1 are appropriate for the conditions encountered at this location and meet the goals defined in the bullets above.
Filter Pack Materials and Placement	The primary filter pack consists of 10/20 sand from 293.5 to 314 ft. There is no mention of a secondary filter pack above the primary filter pack.	The primary filter pack extends 1.7 ft above and 9 ft below the well screen. The sand pack below the well screen is slightly longer than the current well design of 5 ft. The primary filter pack is entirely within the Guaje Pumice Bed, and the extra sand pack length below the well screen does not impact the ability of the well to collect representative water samples.
Sampling System	Bladder pump replaced with a Bennett pump in July 2008	Dedicated pumps allow relatively high-flow sampling. Flow-through cells for measuring field parameters can be used at single-screen wells with dedicated pumps installed. Effective development is typically limited in intermediate wells because of insufficient flow rate and volume; however, development issues are not as critical in wells like LAOI(A)-1.1 that are installed in boreholes where no additives other than air were used during drilling.
Other Issues that Could Affect the Performance of the Well	None	No obvious drilling-related conditions are indicated by evaluation of water-quality samples from LAOI(A)-1.1 (Appendix B). Total iron concentrations and turbidities are consistently higher than are typically observed in groundwater in the absence of drilling effects, but these conditions are assumed to be representative of the geologic formation because no drilling additives were used during drilling.
Additives Used During Drilling		Air
Annular Fill other than Filter and Transition Sands		Bentonite: coarse bentonite chips, placed dry Type I/II Portland Cement: 56 gal. placed on top of bentonite Cement/bentonite grout surface seal (7 gal. of water mixed with each 94-lb bag of cement mixed with 1%–2% bentonite)



LAOI(A)-1.1 geology, borehole configuration, and well design

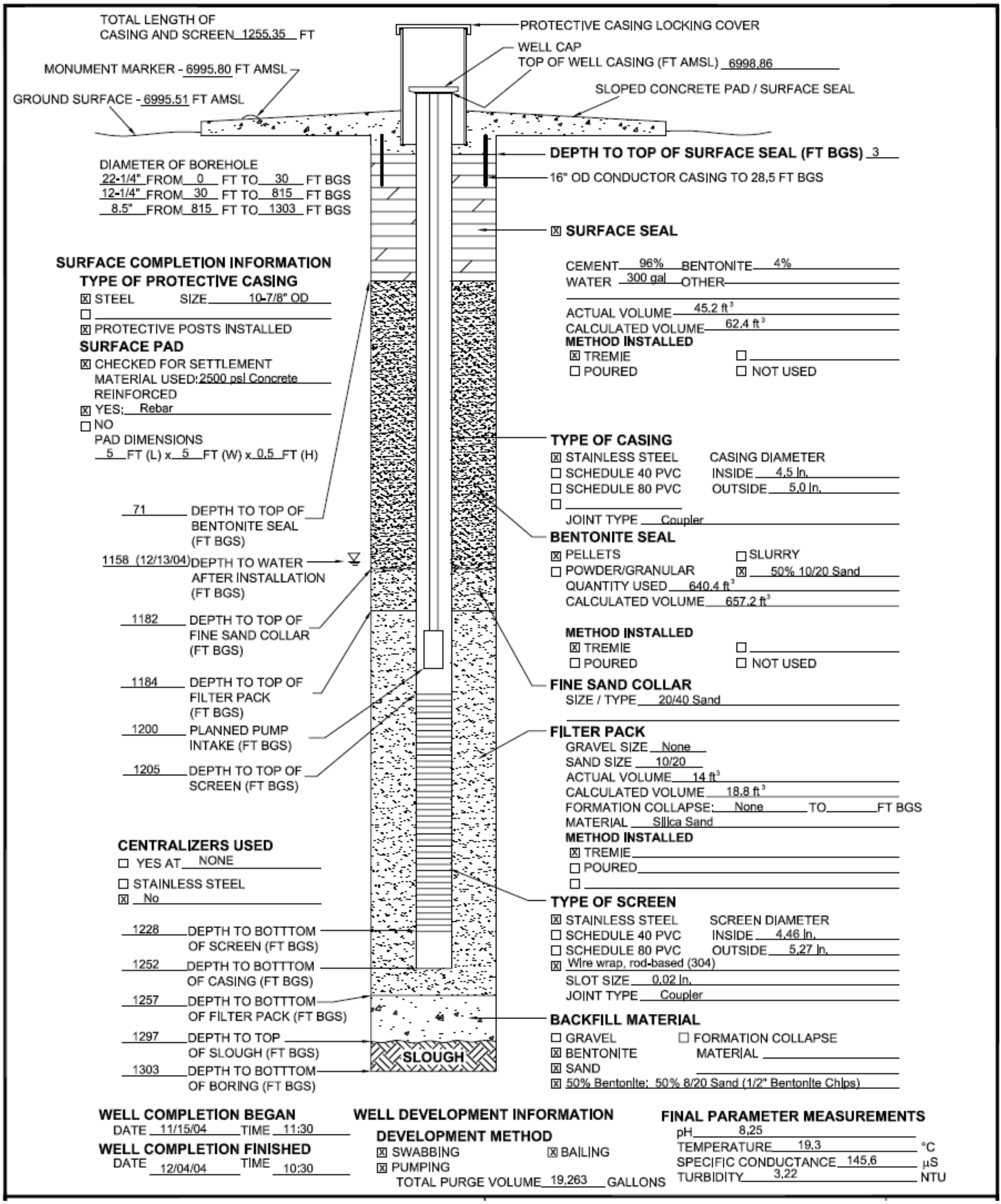
R-6 Well

R-6 Well

	Description	Evaluation
Drilling Method	R-6 was drilled using fluid-assisted air-rotary casing advance methods and mud-rotary drilling methods.	R-6 was initially drilled using a combination of conventional-circulation air-rotary and fluid-assisted air-rotary methods in open hole to 945-ft depth. Due to frequent episodes of lost circulation and clogging of the bits with gravel, the bottom part of the borehole was drilled to TD at 1303 ft by conventional-circulation mud-rotary drilling. There were significant problems with lost circulation and hole deviation during mud-rotary drilling, and eventually casing was set to 815-ft depth to isolate the upper part of the borehole. Finally, the bottom part of the borehole was drilled by open-hole mud-rotary drilling to TD at 1303 ft. Drilling additives included air and municipal water mixed with QUIK-FOAM, EZ-MUD in the upper part of the borehole, and municipal water mixed with bentonite (MAX-GEL and QUIK-GEL), N-SEAL, DRISPAC, and soda ash in the lower part. Drilling additives can adversely affect the ability to collect representative water samples if not removed from the immediate vicinity of the well screen during well development or during purging before sample collection.
General Well Characteristics	R-6 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in. I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The R-6 well screen construction (0.020-in. wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 1205 to 1228 ft and has a length of 23 ft. The top of the screen is 46.2 ft below the water table (currently 1158.8 ft below the surface).	R-6 is designed to replace TW-3, and its screen length and placement were selected with the following goals in mind: • Provide upgradient monitoring for municipal water-supply well O-4 • Characterize water quality in the uppermost part of regional groundwater downgradient of TA-21 • Provide a monitoring point in a productive zone near the top of the regional aquifer to detect whether infiltration beneath Los Alamos Canyon has resulted in contamination of the regional groundwater system • Monitor water-level responses in the upper part of the regional aquifer to pumping from nearby water-supply wells • Submerge the screen fully to facilitate well development. There were no direct measurements of depth to the regional water table because R-6 was drilled by mud-rotary techniques. The R-6 well design was based on a depth-to-water estimate of 1182 ft, based on mud log temperatures and Schlumberger's preliminary interpretation of the geophysical logs. However, water-level measurements in the completed well indicate that the depth to water was about 1157 ft, or about 25 ft higher than expected.

	Description	Evaluation
Screen Length and Placement (continued)		Reprocessing of geophysical logs after the well was installed indicated that strata from 1154 ft to the bottom of the log interval (1296 ft) is fully saturated and that the porosity across this interval mostly ranged from 26% to 34% of the total rock volume. A few tight zones with porosity as low as 10% were found in the uppermost part of the regional groundwater system at 1154 to 1156 ft, 1168 to 1172 ft, and 1173 to 1182 ft. Below 1182 ft, the strata are characterized by fairly uniform hydrogeologic properties, including high estimated effective porosity (17% to 24%). The well screen and filter pack span the upper part of this zone of uniform hydrogeologic properties. The strata consist of bedded Miocene (?) volcaniclastic sands and gravels that dip mostly <20 degrees toward the southwest and southeast. Individual beds are well stratified and range in thickness from a few inches to 2 ft.
Filter Pack Materials and Placement	The primary filter pack is made up of 10/20 sand from 1184 to 1257 ft. A secondary filter packs of 20/40 sand was placed above the primary filter pack from 1182 to 1184 ft.	The primary filter pack extends 21 ft above and 29 ft below the well screen. The well design called for the primary filter pack to extend 8 ft above and 5 ft below the well screen, and it is unclear from the completion report why the filter pack is so long. Emplacement of the filter pack through a column of mud may have hindered the accurate placement of materials in the annulus of the well. The long filter pack above the well screen may actually be advantageous because the water table was higher than planned for in the well design, and the excess filter pack allows water to be drawn into the well screen from strata closer to the water table. The longer-than-planned-for filter pack below the well screen could result in sampling of potential groundwater flow paths as deep as 100 ft below the water table. Because of uncertainties associated with flow pathways within heterogeneous aquifer materials, it is not clear whether the long filter pack aids or hinders detection of contamination.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well	None	n/a

	Description	Evaluation
Additives Used During Drilling		Municipal water: 7485 gal. during air-rotary drilling, 80,000 gal. to regain circulation for mud drilling in open hole, and 3200 gal. for mud drilling after casing installed to 815 ft QUIK-FOAM: 110 gal. EZ-MUD: 45 gal. N-SEAL: 7140 lb Soda ash: 500 lb MAX-GEL: 2800 lb DRISPAC: 1100 lb QUIK-GEL: 37,700 lb Fluid volume recovered (48,359 gal.; includes drilling, well development, and hydrologic testing)
Annular Fill other than Filter and Transition Sands		Bentonite seal: bentonite chips and 10/20 silica sand (50:50) (640.4 ft3) Cement slurry for surface seal (45.2 ft3) Potable water (36,300 gal.)



TOTAL LENGTH OF CASING AND SCREEN 1255.35 FT

MONUMENT MARKER - 6995.80 FT AMSL

GROUND SURFACE - 6995.51 FT AMSL

PROTECTIVE CASING LOCKING COVER

WELL CAP

TOP OF WELL CASING (FT AMSL) 6998.86

SLOPED CONCRETE PAD / SURFACE SEAL

DEPTH TO TOP OF SURFACE SEAL (FT BGS) 3

16" OD CONDUCTOR CASING TO 28.5 FT BGS

DIAMETER OF BOREHOLE
22-1/4" FROM 0 FT TO 30 FT BGS
12-1/4" FROM 30 FT TO 815 FT BGS
8.5" FROM 815 FT TO 1303 FT BGS

SURFACE COMPLETION INFORMATION

TYPE OF PROTECTIVE CASING
☒ STEEL SIZE 10-7/8" OD
☐
☒ PROTECTIVE POSTS INSTALLED

SURFACE PAD
☒ CHECKED FOR SETTLEMENT
MATERIAL USED: 2500 psi Concrete
REINFORCED
☒ YES; Rebar
☐ NO
PAD DIMENSIONS
5 FT (L) x 5 FT (W) x 0.5 FT (H)

71 DEPTH TO TOP OF BENTONITE SEAL (FT BGS)

1158 (12/13/04) DEPTH TO WATER AFTER INSTALLATION (FT BGS)

1182 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)

1184 DEPTH TO TOP OF FILTER PACK (FT BGS)

1200 PLANNED PUMP INTAKE (FT BGS)

1205 DEPTH TO TOP OF SCREEN (FT BGS)

CENTRALIZERS USED
☐ YES AT NONE
☐ STAINLESS STEEL
☒ No

1228 DEPTH TO BOTTOM OF SCREEN (FT BGS)

1252 DEPTH TO BOTTOM OF CASING (FT BGS)

1257 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)

1297 DEPTH TO TOP OF SLOUGH (FT BGS)

1303 DEPTH TO BOTTOM OF BORING (FT BGS)

☒ **SURFACE SEAL**
CEMENT 96% BENTONITE 4%
WATER 300 gal OTHER
ACTUAL VOLUME 45.2 ft^3
CALCULATED VOLUME 62.4 ft^3
METHOD INSTALLED
☒ TREMIE ☐
☐ POURED ☐ NOT USED

TYPE OF CASING
☒ STAINLESS STEEL CASING DIAMETER
☐ SCHEDULE 40 PVC INSIDE 4.5 In.
☐ SCHEDULE 80 PVC OUTSIDE 5.0 In.
☐
JOINT TYPE Coupler

BENTONITE SEAL
☒ PELLETS ☐ SLURRY
☐ POWDER/GRANULAR ☒ 50% 10/20 Sand
QUANTITY USED 640.4 ft^3
CALCULATED VOLUME 657.2 ft^3
METHOD INSTALLED
☒ TREMIE ☐
☐ POURED ☐ NOT USED

FINE SAND COLLAR
SIZE / TYPE 20/40 Sand

FILTER PACK
GRAVEL SIZE None
SAND SIZE 10/20
ACTUAL VOLUME 14 ft^3
CALCULATED VOLUME 18.8 ft^3
FORMATION COLLAPSE: None TO FT BGS
MATERIAL Silica Sand
METHOD INSTALLED
☒ TREMIE
☐ POURED
☐

TYPE OF SCREEN
☒ STAINLESS STEEL SCREEN DIAMETER
☐ SCHEDULE 40 PVC INSIDE 4.46 In.
☐ SCHEDULE 80 PVC OUTSIDE 5.27 In.
☒ Wire wrap, rod-based (304)
SLOT SIZE 0.02 In.
JOINT TYPE Coupler

BACKFILL MATERIAL
☐ GRAVEL ☐ FORMATION COLLAPSE
☒ BENTONITE MATERIAL
☒ SAND
☒ 50% Bentonite; 50% 8/20 Sand (1/2" Bentonite Chips)

WELL COMPLETION BEGAN
DATE 11/15/04 TIME 11:30

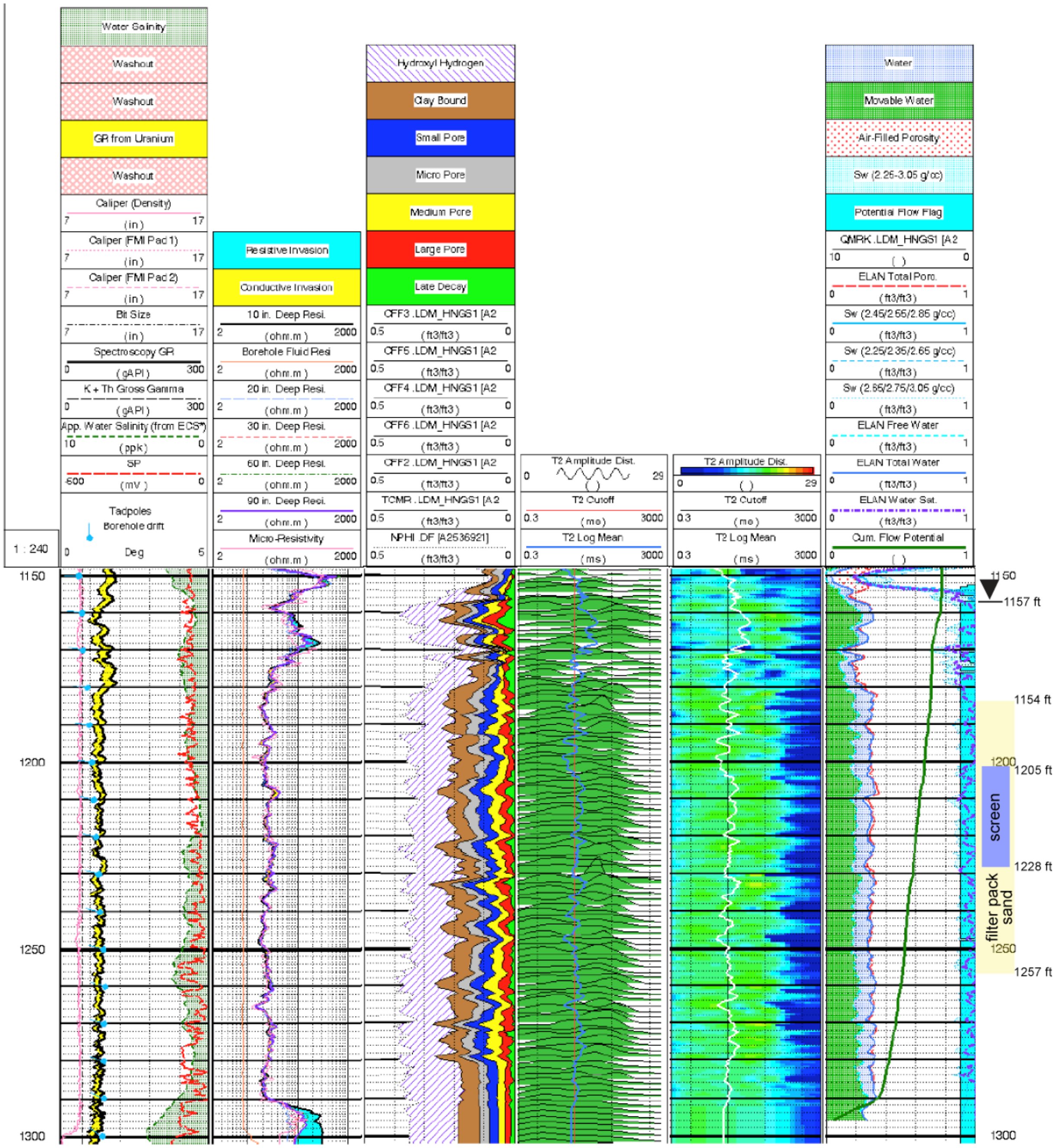
WELL COMPLETION FINISHED
DATE 12/04/04 TIME 10:30

WELL DEVELOPMENT INFORMATION

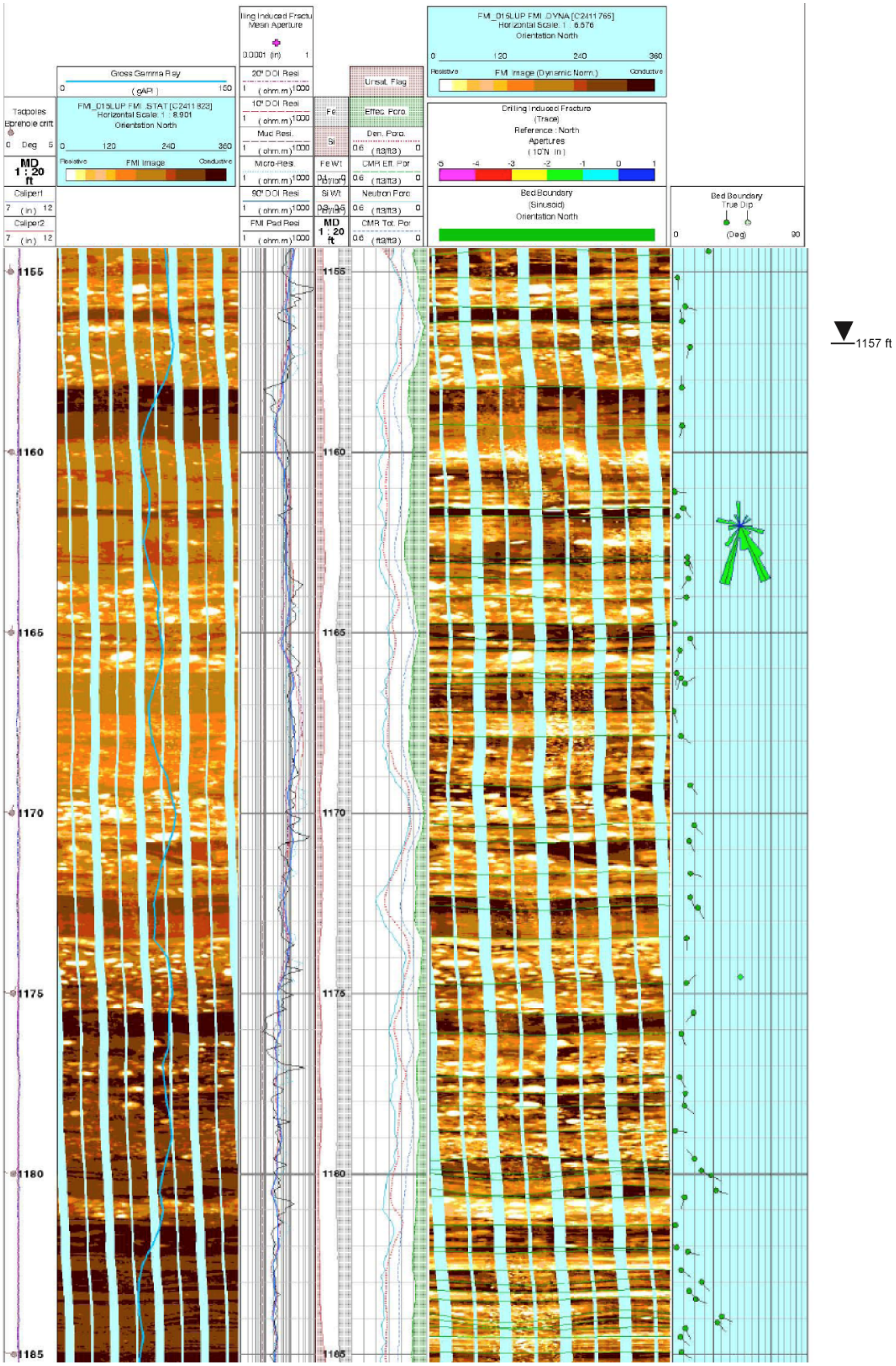
DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
☒ PUMPING
TOTAL PURGE VOLUME 19,263 GALLONS

FINAL PARAMETER MEASUREMENTS
pH 8.25
TEMPERATURE 19.3 °C
SPECIFIC CONDUCTANCE 145.6 µS
TURBIDITY 3.22 NTU

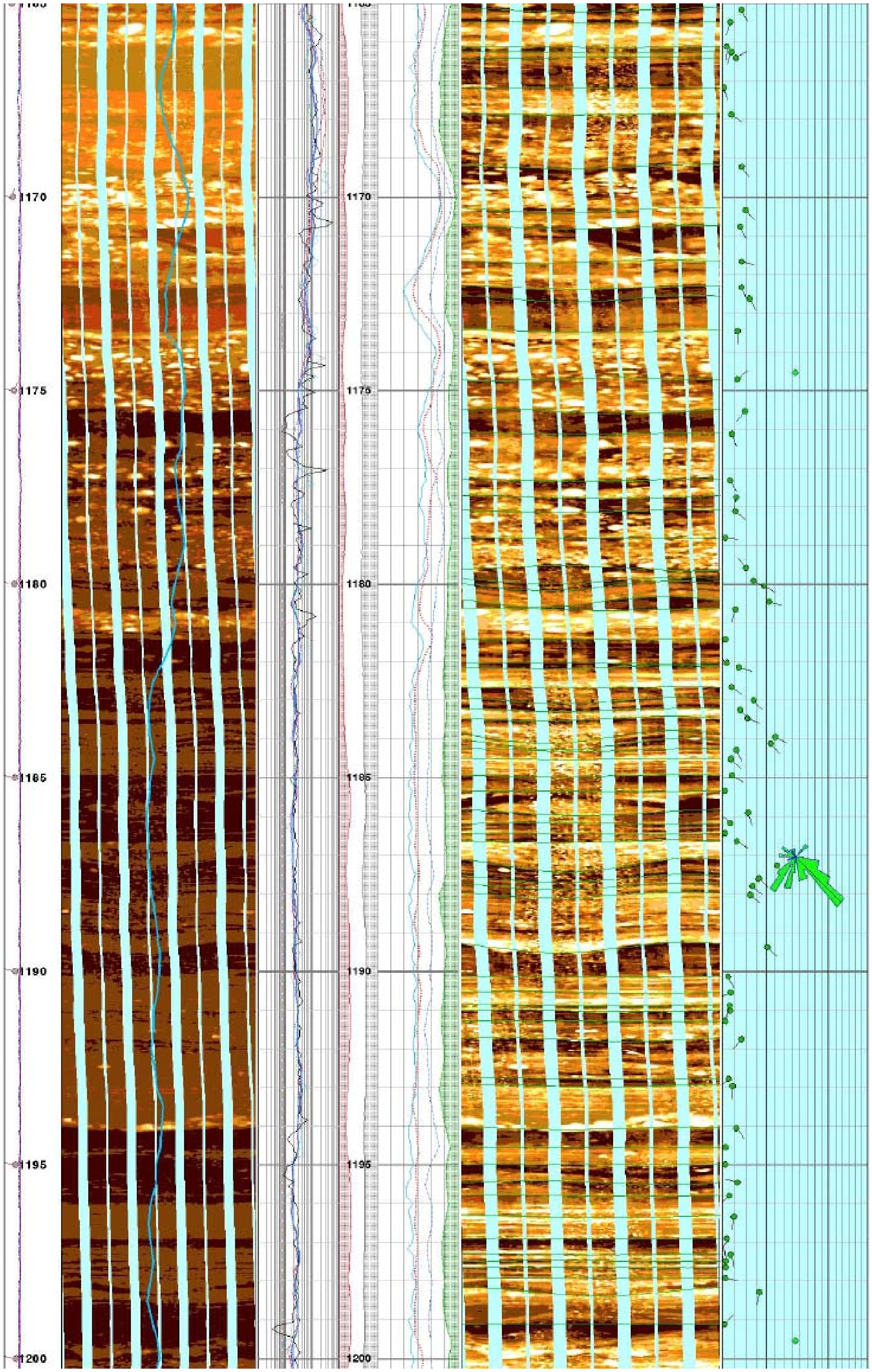
Well schematic for characterization well R-6



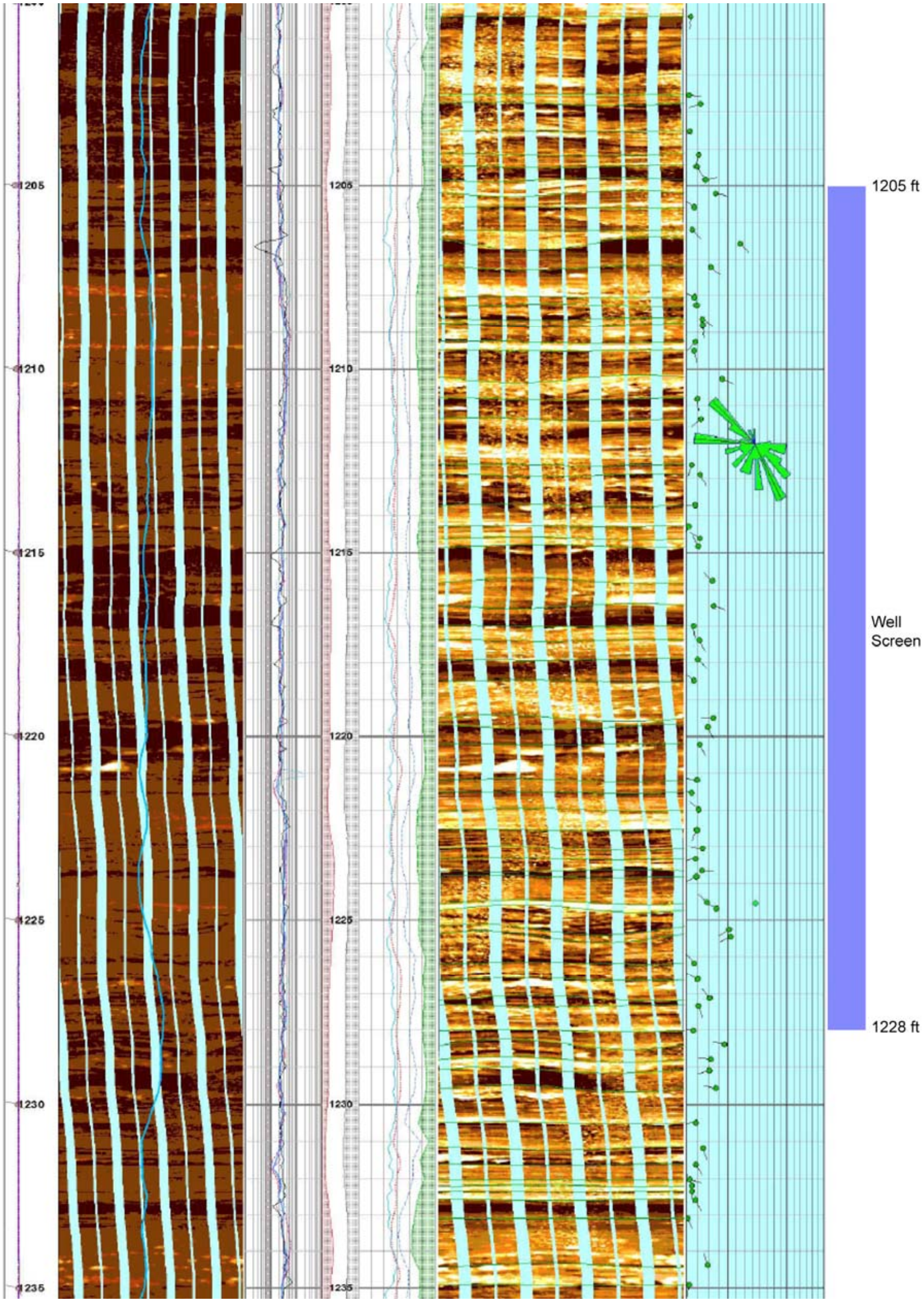
Summary of R-6 borehole geophysical logs for the regional aquifer



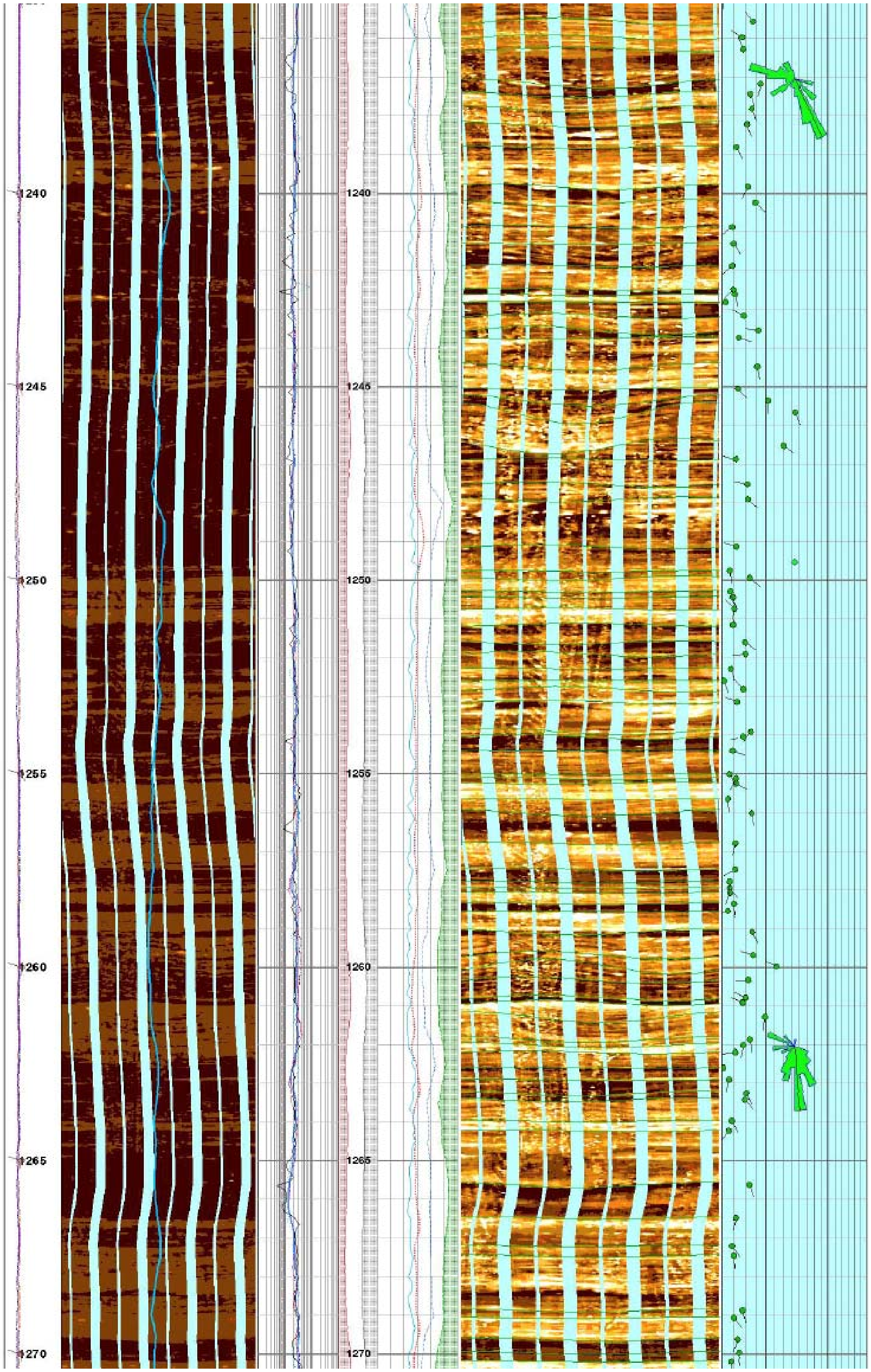
FMI log for R-6



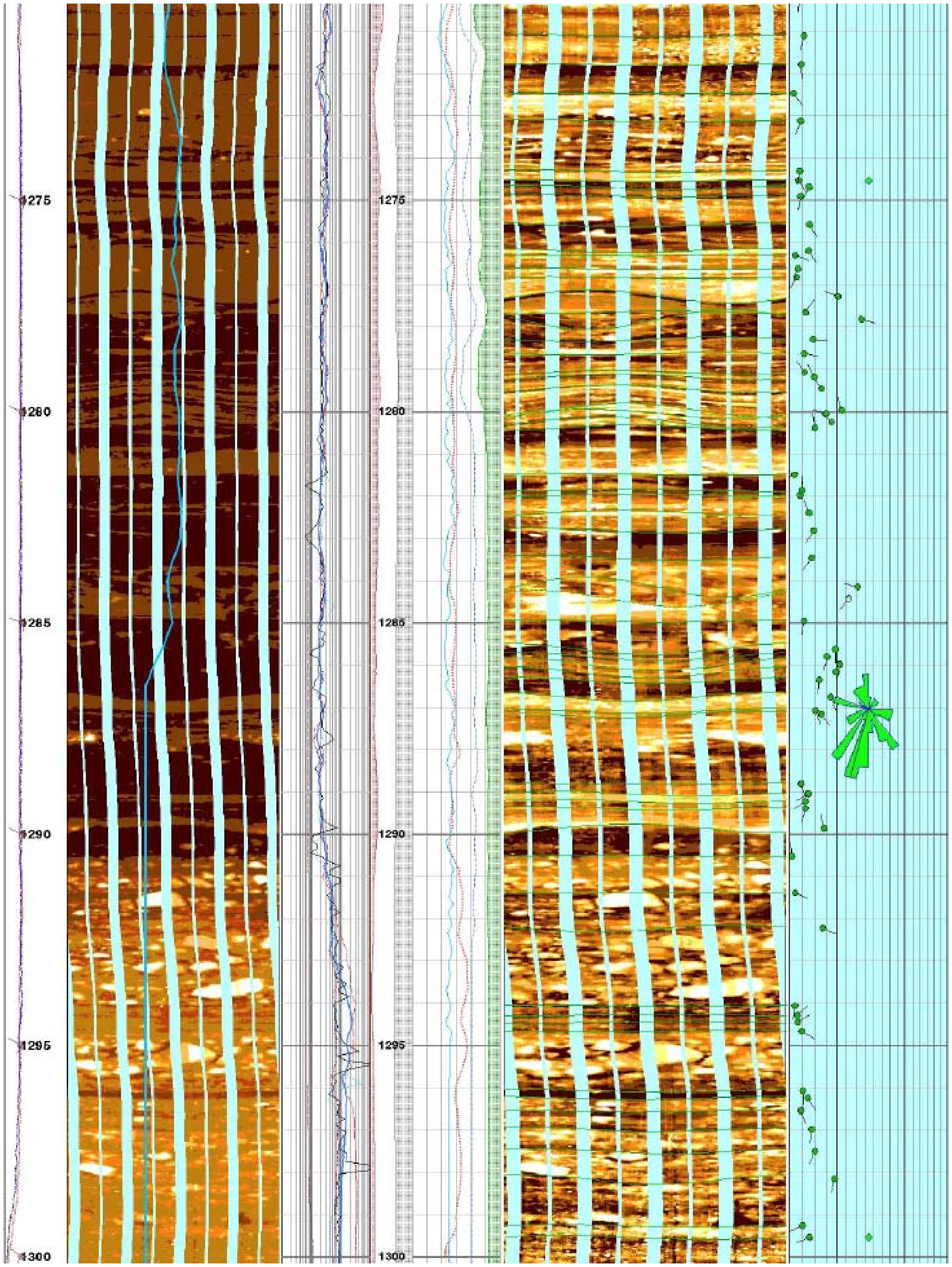
FMI log for R-6 (continued)



FMI log for R-6 (continued)



FMI log for R-6 (continued)



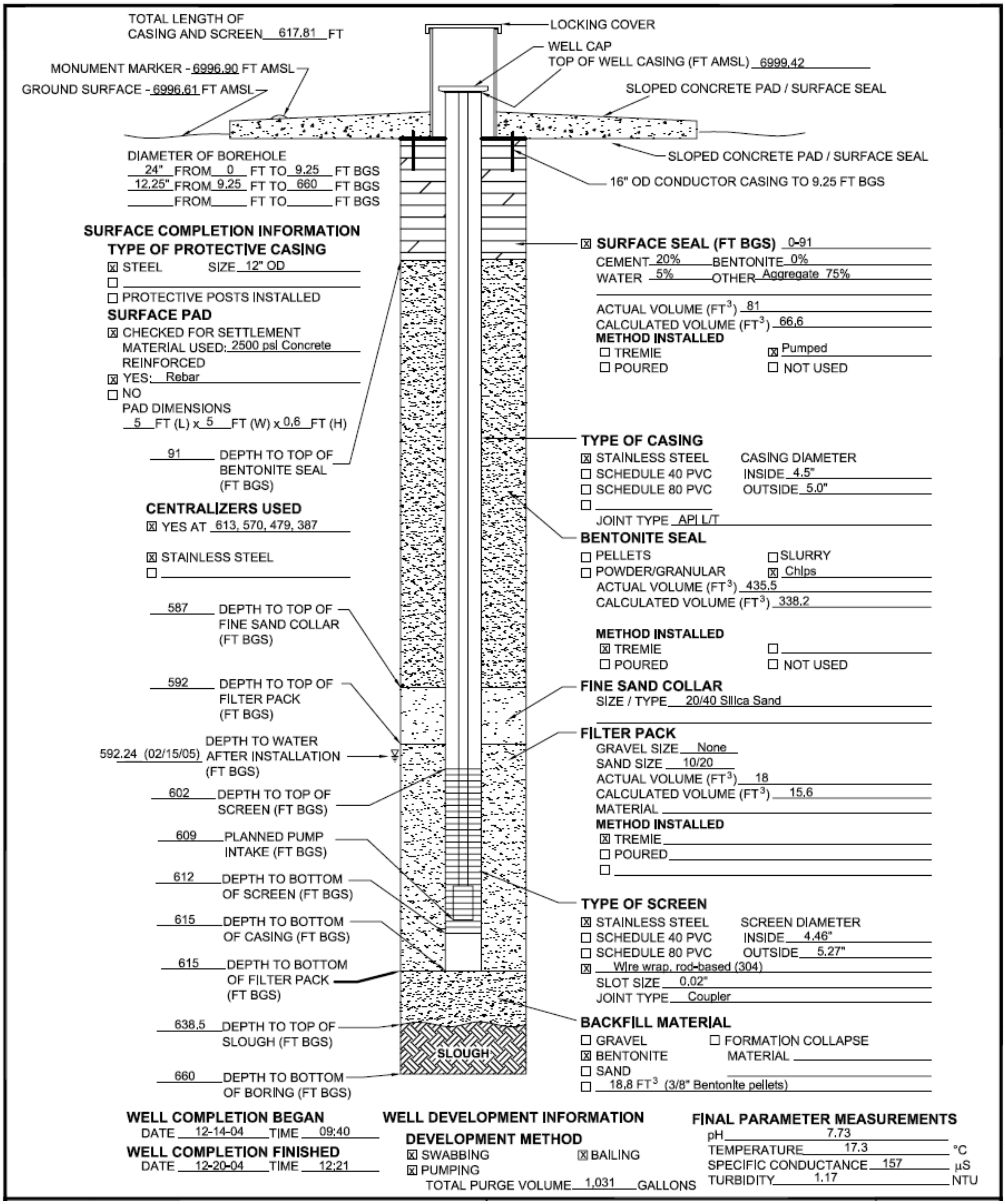
FMI log for R-6 (continued)

R-6i Well

R-6i Well

	Description	Evaluation
Drilling Method	R-6i was drilled using air-rotary and fluid-assisted air-rotary methods.	R-6i was drilled using conventional-circulation air-rotary and fluid-assisted air-rotary methods in open hole to 660-ft depth. Drilling additives included air and a mixture of municipal water mixed with QUIK-FOAM. Drilling additives can adversely affect the ability to collect representative water samples, and their use was minimized in the R-6i borehole.
General Well Characteristics	R-6i is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The R-6i well screen construction (0.020-in. wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 602 to 612 ft and has a length of 10 ft. The top of the screen is 9.4 ft below the perched water table that is currently 592.6 ft below the ground surface (Koch and Schmeer 2010, 108926).	R-6i is designed to sample perched groundwater that was found while drilling regional well R-6, located about 20 ft to the northeast. The screen length and its placement were selected with the following goals in mind: • Monitor the water quality of perched-intermediate groundwater near supply well O-4 • Characterize water quality of perched-intermediate groundwater in the vicinity of TA-21 • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon • Submerge the screen fully to facilitate well development Perched-intermediate groundwater occurs in upper Puye Formation sedimentary deposits that are stratigraphically above Cerros del Rio basalt. The Puye Formation in this interval consists of dacitic gravels from 516- to 625-ft depth and silts and fine sands from 625 to 683 ft. A borehole video showed perched groundwater entering the R-6i borehole at about 604 ft, the same depth at which groundwater was seen entering the R-6 borehole. The interval between 615- and 625-ft depth appeared to be fairly tight and nonproductive, and an induction log showed a zone of markedly higher conductivity from 598 to 616 ft. The well screen targeted this zone of flowing water and elevated conductivity.
Filter Pack Materials and Placement	The primary filter pack is made up of 10/20 sand from 592 to 615 ft. A secondary filter packs of 20/40 sand was placed above the primary filter pack from 587 to 592 ft.	The primary filter pack extends 10 ft above and 3 ft below the well screen. The well screen and filter pack design are appropriate for sampling perched-intermediate groundwater from this zone.

	Description	Evaluation
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well	None	n/a
Additives Used During Drilling		Municipal water (3530 gal. introduced during air-rotary drilling) QUIK-FOAM (56 gal.) Fluid volume recovered (3560 gal. during drilling and 5006 gal. during development and aquifer testing)
Annular Fill other than Filter and Transition Sands		Bentonite seal: bentonite chips (435.5 ft^3) Bentonite backfill (18.8 ft^3) Cement slurry for surface seal (81 ft^3) Potable water (1350 gal.)



TOTAL LENGTH OF CASING AND SCREEN 617.81 FT

MONUMENT MARKER - 6996.90 FT AMSL

GROUND SURFACE - 6996.61 FT AMSL

TOP OF WELL CASING (FT AMSL) 6999.42

DIAMETER OF BOREHOLE
24" FROM 0 FT TO 9.25 FT BGS
12.25" FROM 9.25 FT TO 660 FT BGS
___ FROM ___ FT TO ___ FT BGS

SURFACE COMPLETION INFORMATION

TYPE OF PROTECTIVE CASING
☒ STEEL SIZE 12" OD
☐
☐ PROTECTIVE POSTS INSTALLED

SURFACE PAD
☒ CHECKED FOR SETTLEMENT
MATERIAL USED: 2500 psi Concrete
REINFORCED
☒ YES: Rebar
☐ NO
PAD DIMENSIONS
5 FT (L) x 5 FT (W) x 0,6 FT (H)

91 DEPTH TO TOP OF BENTONITE SEAL (FT BGS)

CENTRALIZERS USED
☒ YES AT 613, 570, 479, 387
☒ STAINLESS STEEL
☐

587 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)

592 DEPTH TO TOP OF FILTER PACK (FT BGS)

592.24 (02/15/05) DEPTH TO WATER AFTER INSTALLATION (FT BGS)

602 DEPTH TO TOP OF SCREEN (FT BGS)

609 PLANNED PUMP INTAKE (FT BGS)

612 DEPTH TO BOTTOM OF SCREEN (FT BGS)

615 DEPTH TO BOTTOM OF CASING (FT BGS)

615 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)

638.5 DEPTH TO TOP OF SLOUGH (FT BGS)

660 DEPTH TO BOTTOM OF BORING (FT BGS)

☒ **SURFACE SEAL (FT BGS)** 0-91
CEMENT 20% BENTONITE 0%
WATER 5% OTHER Aggregate 75%
ACTUAL VOLUME (FT^3) 81
CALCULATED VOLUME (FT^3) 66,6
METHOD INSTALLED
☐ TREMIE ☒ Pumped
☐ POURED ☐ NOT USED

TYPE OF CASING
☒ STAINLESS STEEL CASING DIAMETER
☐ SCHEDULE 40 PVC INSIDE 4.5"
☐ SCHEDULE 80 PVC OUTSIDE 5.0"
☐
JOINT TYPE API L/T

BENTONITE SEAL
☐ PELLETS ☐ SLURRY
☐ POWDER/GRANULAR ☒ Chips
ACTUAL VOLUME (FT^3) 435,5
CALCULATED VOLUME (FT^3) 338,2
METHOD INSTALLED
☒ TREMIE ☐
☐ POURED ☐ NOT USED

FINE SAND COLLAR
SIZE / TYPE 20/40 Silica Sand

FILTER PACK
GRAVEL SIZE None
SAND SIZE 10/20
ACTUAL VOLUME (FT^3) 18
CALCULATED VOLUME (FT^3) 15,6
MATERIAL
METHOD INSTALLED
☒ TREMIE
☐ POURED
☐

TYPE OF SCREEN
☒ STAINLESS STEEL SCREEN DIAMETER
☐ SCHEDULE 40 PVC INSIDE 4.46"
☐ SCHEDULE 80 PVC OUTSIDE 5.27"
☒ Wire wrap, rod-based (304)
SLOT SIZE 0.02"
JOINT TYPE Coupler

BACKFILL MATERIAL
☐ GRAVEL ☐ FORMATION COLLAPSE
☒ BENTONITE MATERIAL
☐ SAND
☐ 18,8 FT^3 (3/8" Bentonite pellets)

WELL COMPLETION BEGAN
DATE 12-14-04 TIME 09:40

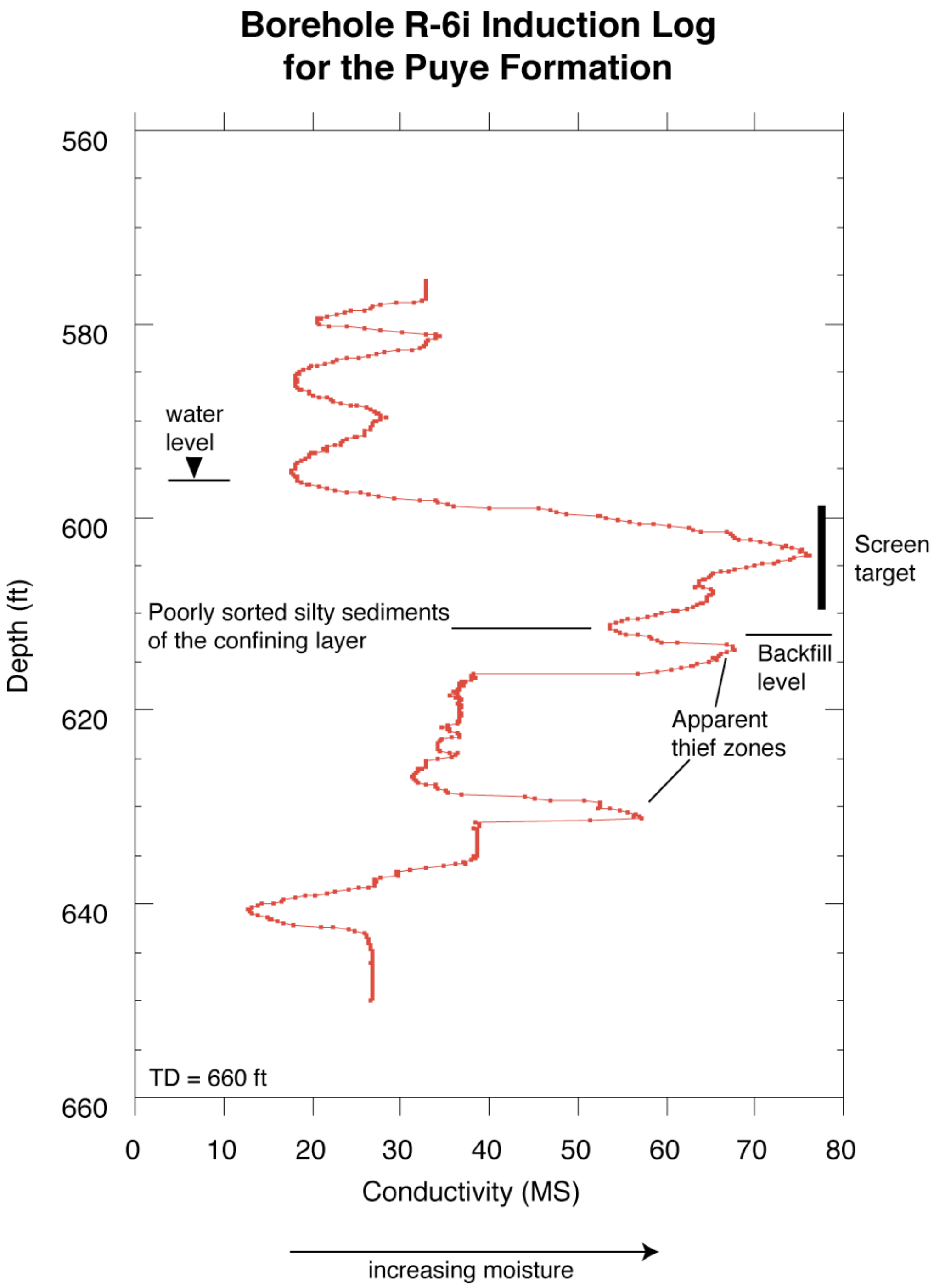
WELL COMPLETION FINISHED
DATE 12-20-04 TIME 12:21

WELL DEVELOPMENT INFORMATION

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
☒ PUMPING
TOTAL PURGE VOLUME 1,031 GALLONS

FINAL PARAMETER MEASUREMENTS
pH 7.73
TEMPERATURE 17.3 °C
SPECIFIC CONDUCTANCE 157 µS
TURBIDITY 1.17 NTU

Well schematic for characterization well R-6i



R-6i borehole geophysical logs for the perched-intermediate groundwater zone

R-7 Well

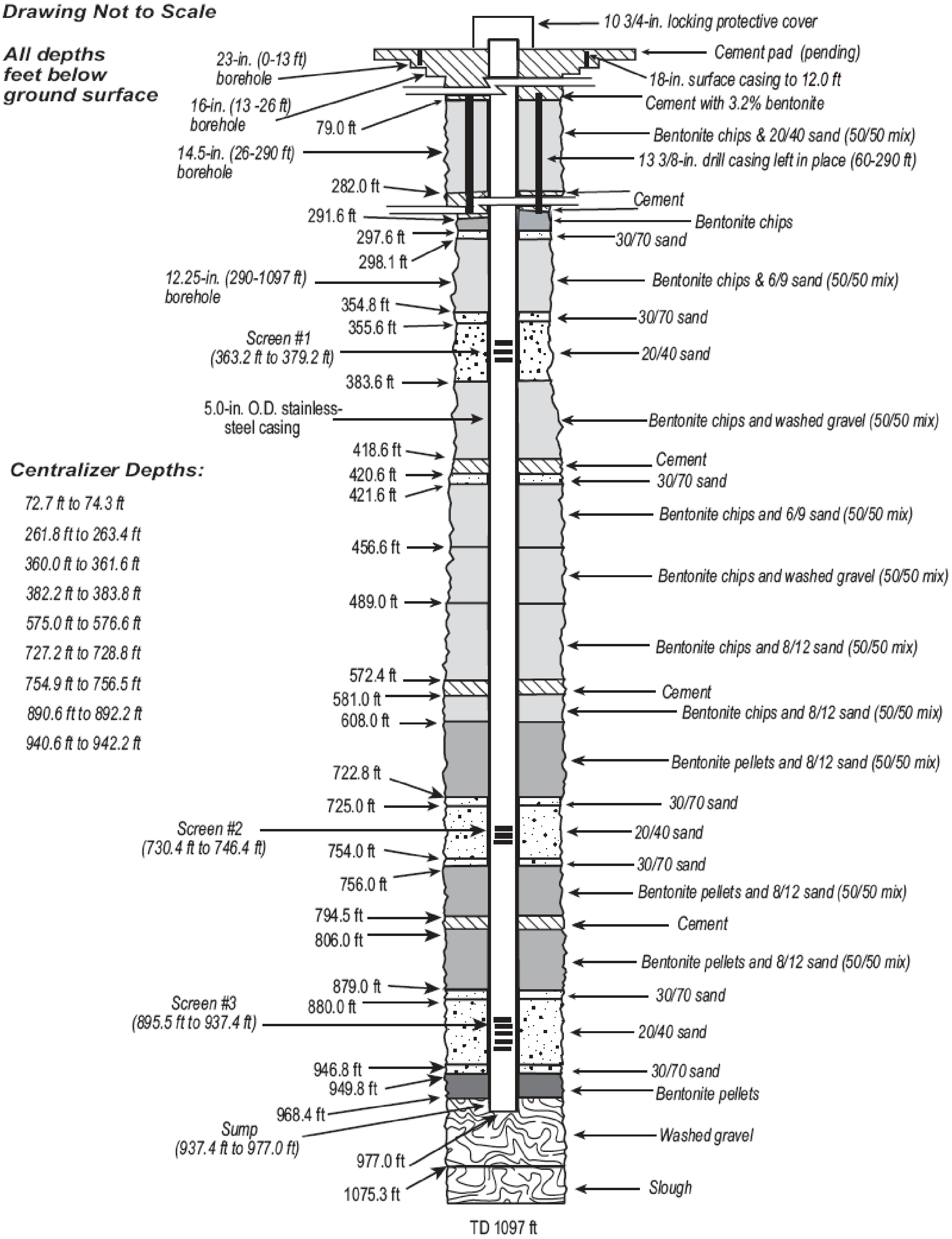
R-7 Well

	Description	Evaluation
Drilling Method	R-7 was drilled using fluid-assisted air-rotary casing advance methods.	R-7 was drilled using a combination of reverse-circulation fluid-assisted air-rotary methods in open hole and with casing advance to 809 ft followed by reverse-circulation fluid-assisted air-rotary drilling in open hole to TD at 880 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives, including QUIK-FOAM and EZ-MUD. Drilling additives can adversely affect the ability to collect representative water samples.
General Well Characteristics	R-7 is a three-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screen is constructed of 4.5-in.-I.D./ 5.56-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was used after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development is less effective in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-7 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development.
Screen Length and Placement	Screen 1 extends from 363.2 to 379.2 ft (length of 16 ft) and is submerged in perched water within the Puye Formation. Screen 2 extends from 730.4 to 746.4 ft (length of 16 ft); it targeted potential perched water at the contact between Puye Formation and Miocene pumiceous deposits but has been dry since installation.	The screen lengths and their placements were selected with the following goals in mind: • Characterize water quality in the uppermost part of regional groundwater approximately 3350 ft downgradient of TA-02 • Characterize water quality adjacent to TA-21, particularly in the vicinity of MDA B and MDA V • Monitor water-level responses in the upper part of the regional aquifer to pumping from nearby water-supply wells • Characterize water quality of perched groundwater beneath Los Alamos Canyon • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon

	Description	Evaluation
Screen Length and Placement (continued)	Screen 3 extends from 895.5 to 937.4 ft (length of 41.9 ft), and it straddles the regional water table (currently 903.2 ft below the surface) within Miocene pumiceous sediments (Koch and Schmeer 2010, 108926). The amount of submerged screen is 34.2 ft.	Screen 1 was placed in the uppermost interval of perched-intermediate groundwater that was detected by borehole video near the top of the Puye Formation. The saturation occurred within fluvial sedimentary deposits between the depths of 362 and 382 ft bgs. The perching horizon is probably clay-rich sediments, extending from a depth of 382 to 397 ft. The top of the perched saturation was at a depth of 374 ft bgs at the time the well was installed, but over time the water level has declined and the screen has been dry since about 2005 (Koch and Schmeer 2010, 108926). Screen 2 targeted a poorly defined zone of possible perched saturation above Miocene pumiceous sedimentary deposits. Borehole geophysics indicated relatively high moisture content above the regional water table, especially below 734 ft, where total and effective water-filled porosity averages about 20% and greater than 5%, respectively. Screen 2 has been dry since installation (Koch and Schmeer 2010, 108926). Screen 3 is designed to straddle the regional water table downgradient of TA-02 and adjacent to TA-21. The main goal for this screen was to determine if infiltration beneath Los Alamos Canyon results in contamination of regional groundwater. Thus, screen 3 was placed in the uppermost part of the regional groundwater system to detect the highest concentrations of contaminants before becoming diluted by mixing with uncontaminated groundwater. The screen is located within Miocene pumiceous sedimentary deposits that dip less than 10 degrees toward the west (dip azimuths vary between 230 and 310 degrees). The screen interval spans parts of two pumice-rich intervals that may include primary fall deposits. Total porosities within the screen interval range between 20% and 35%, and effective porosities range between 10% and 27%. The electrical resistivity image (FMI log) shows that these deposits consist of thinly laminated beds. The clay content of this interval is lower than deeper strata, and pumices from this interval are vitric, indicating bulk hydraulic properties are minimally affected by secondary alteration of volcanic glassy pyroclasts. However, the inability to pump water from screen 3 during development indicates that these deposits are poorly transmissive at this location. The placement of the three well screens at R-7 meets the characterization and monitoring goals for a well for this location.
Filter Pack Materials and Placement	The filter packs and their placements are discussed for the three well screens in the column to the right.	The primary filter pack for screen 1 is made up of 20/40 sand from 355.6 to 383.6 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 354.8 to 355.6 ft. The primary filter pack extends 7.6 ft above and 4.4 ft below the well screen. The combination of this filter pack with a 16-ft well screen allows groundwater to be drawn from throughout the perched groundwater interval where the distribution of water-producing beds is poorly known.

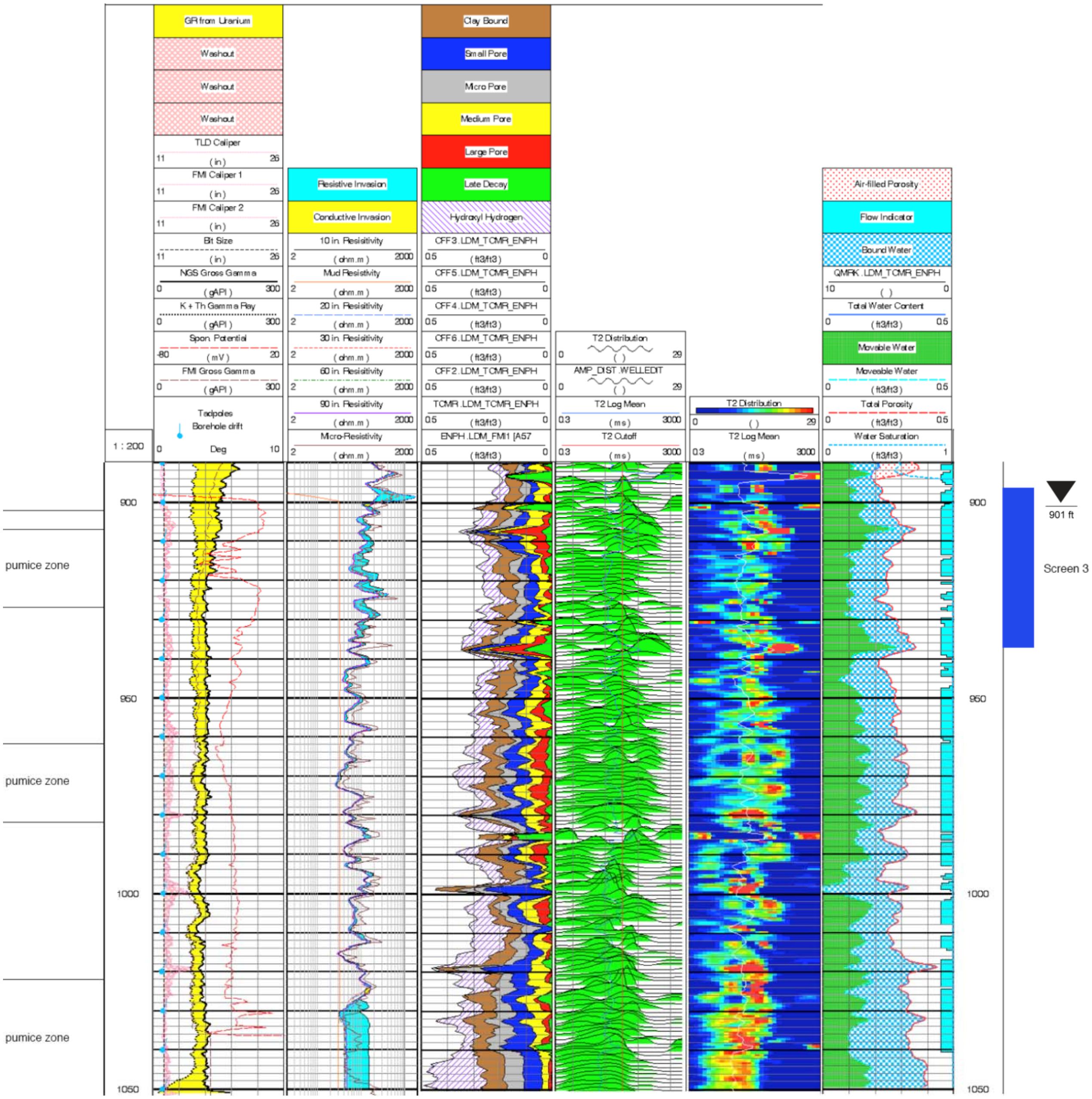
	Description	Evaluation
Filter Pack Materials and Placement (continued)		The primary filter pack for screen 2 is made up of 20/40 sand from 725 to 754 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 722.8 to 725 ft and 754 to 756 ft, respectively. The primary filter pack extends 5.4 ft above and 7.6 ft below the well screen. Screen 2 has been dry since installation. The primary filter pack for screen 3 is made up of 20/40 sand from 880 to 946.8 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 879 to 880 ft and 946.8 to 949.8 ft, respectively. The primary filter pack extends 15.5 ft above and 9.4 ft below the well screen. This upper part of the filter pack length is above the water table and does not affect well performance. The lower part of the filter pack extends slightly farther below the well screen than current well designs (about 5 ft below the well screen). However, because the Miocene sedimentary deposits at this location are poorly transmissive, a slightly long filter pack allows groundwater to be drawn from a larger volume in rocks where the amount and location of water production are uncertain.
Sampling System	Westbay MP sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well due to low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval. Screen 3 in particular is in poorly transmissive sedimentary deposits and is therefore poorly developed, a likely cause of the sulfate- and iron-reducing conditions that persist at this screen (Appendix B, LANL 2007, 096330).
Other Issues that Could Affect the Performance of the Well	Development was inhibited by poor water production from the three well screens.	The development strategy for R-7 called for two phases and three steps for each screened interval. The preliminary phase was to include wire-brushing followed by bailing. The final phase was to involve pumping until values for field parameters met goals or could not be improved. Development of screens 1 and 2 was not possible because of insufficient water production from these zones. Screen 3 was wire-brushed and bailed. However, it soon became apparent that productivity was also low in screen 3. It was not possible to develop screen 3 by pumping. Water rarely reached the surface, and the pump tripped off repeatedly because the pumping rate exceeded the production rate.

	Description	Evaluation
Other Issues that Could Affect the Performance of the Well (continued)		As a result, R-7 was developed as much as possible by bailing. Field parameters were checked at the outset of bailing and checked periodically thereafter. The initial turbidity value was 237 NTUs. The withdrawal of 3000 gal. of water over a 1.5-d period improved this value to 21 NTUs. Development was terminated when turbidity values remain stable at 21 NTUs during approximately 10 h of bailing. However, this development appears to have been inadequate for removal of all residual organic drilling products from the well, based upon the persistent sulfate- and iron-reducing conditions in screen 3 (Appendix B, LANL 2007, 096330).
Additives Used		Municipal water QUIK-FOAM EZ-MUD
Annular Fill other than Filter and Transition Sands		Benseal: high-solids multipurpose bentonite grout (2 bags) Holeplug: 0.375-in. angular and unrefined bentonite chips (391.5 bags) Pel-Plug bentonite: 0.25-in. by 0.375-in. refined elliptical pellets (166.5 buckets) Portland cement mixed with municipal water at a ratio of 5 gal. per bag (82 bags) Yard Art gravel was used to fill wash-out zones (250.5 bags).

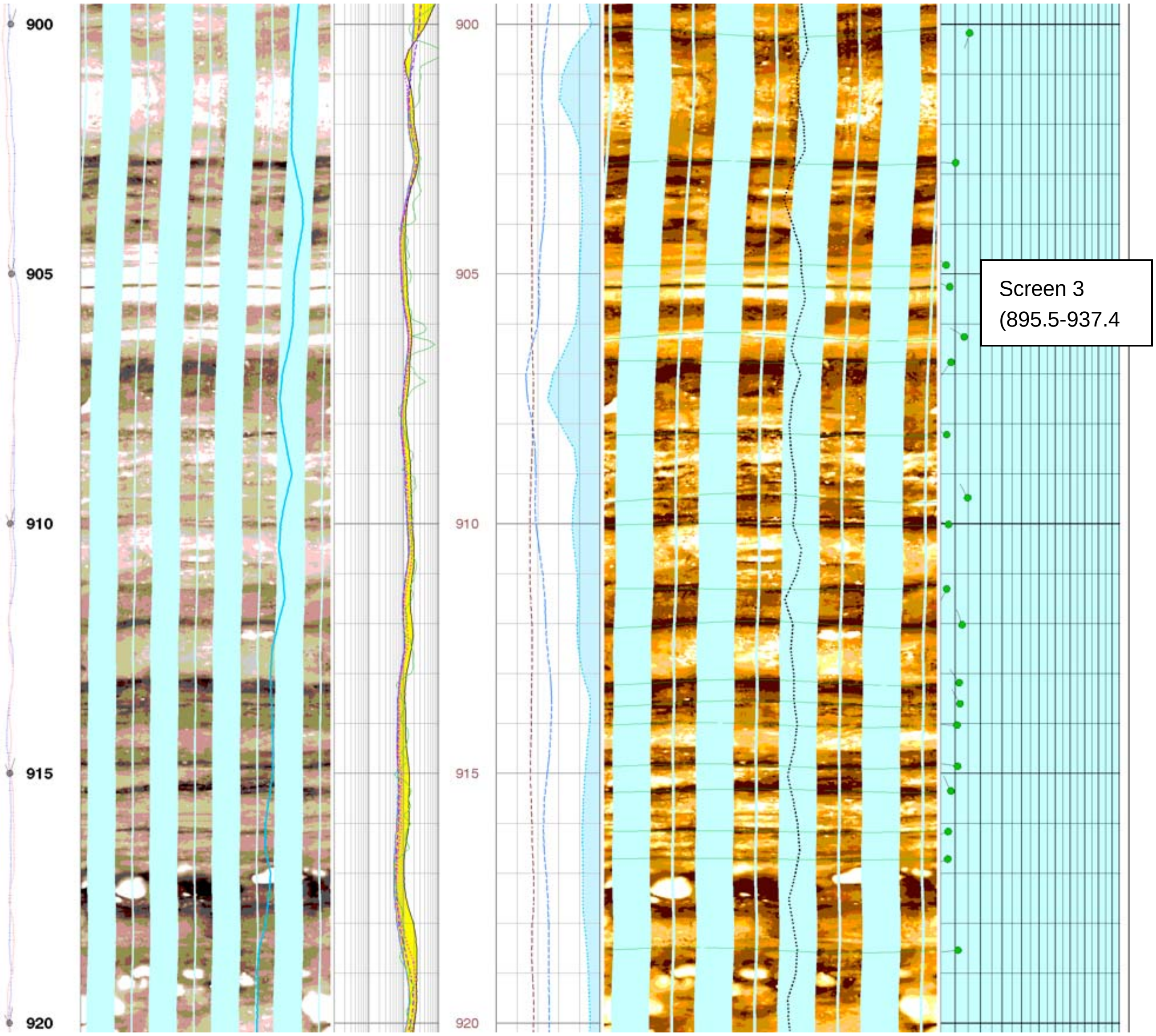


Note: The screen intervals list the footages of the pipe perforations, not the tops and bottoms of screen joints.

As-built well completion diagram for well R-7

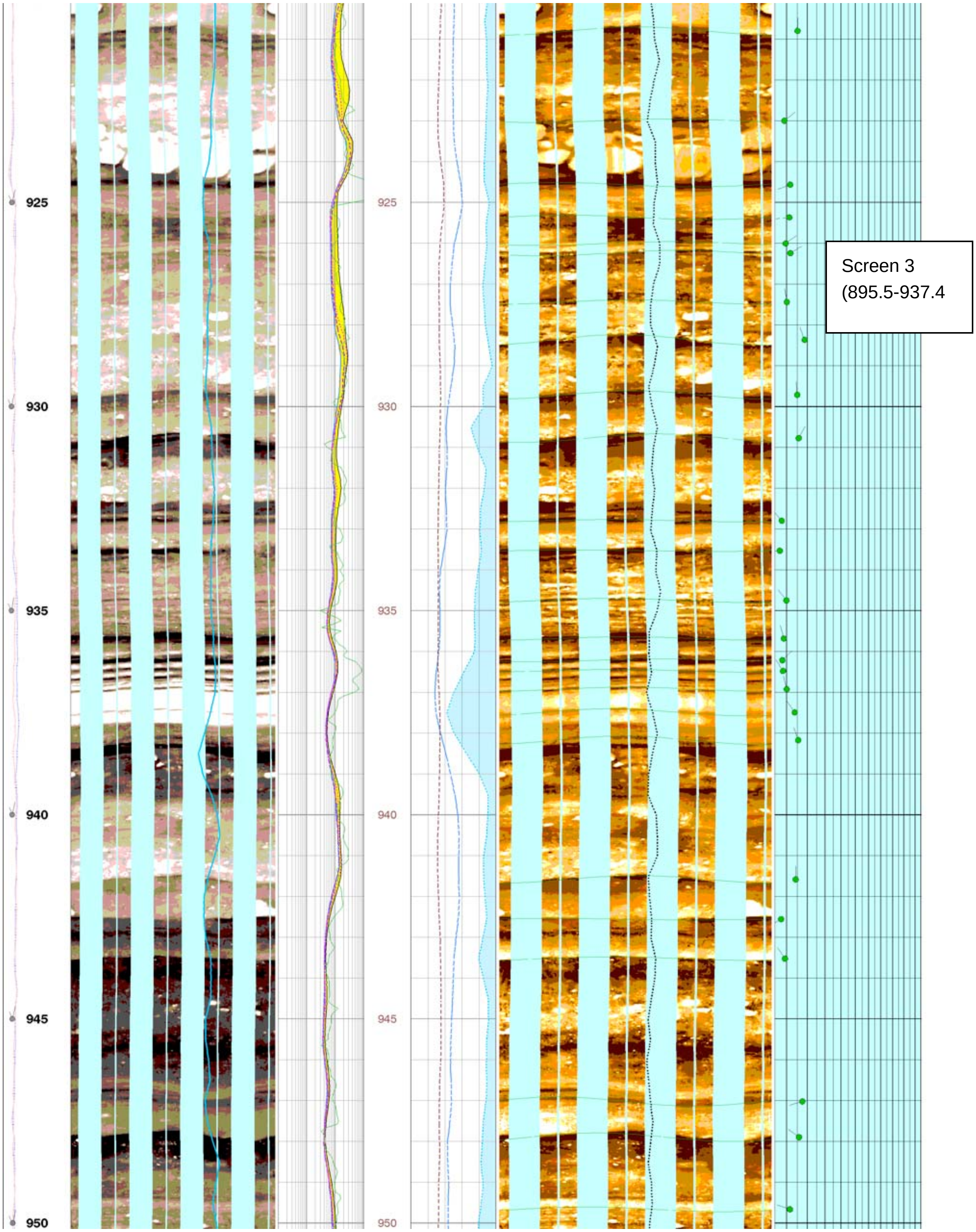


Summary of R-7 borehole geophysical logs for the regional aquifer



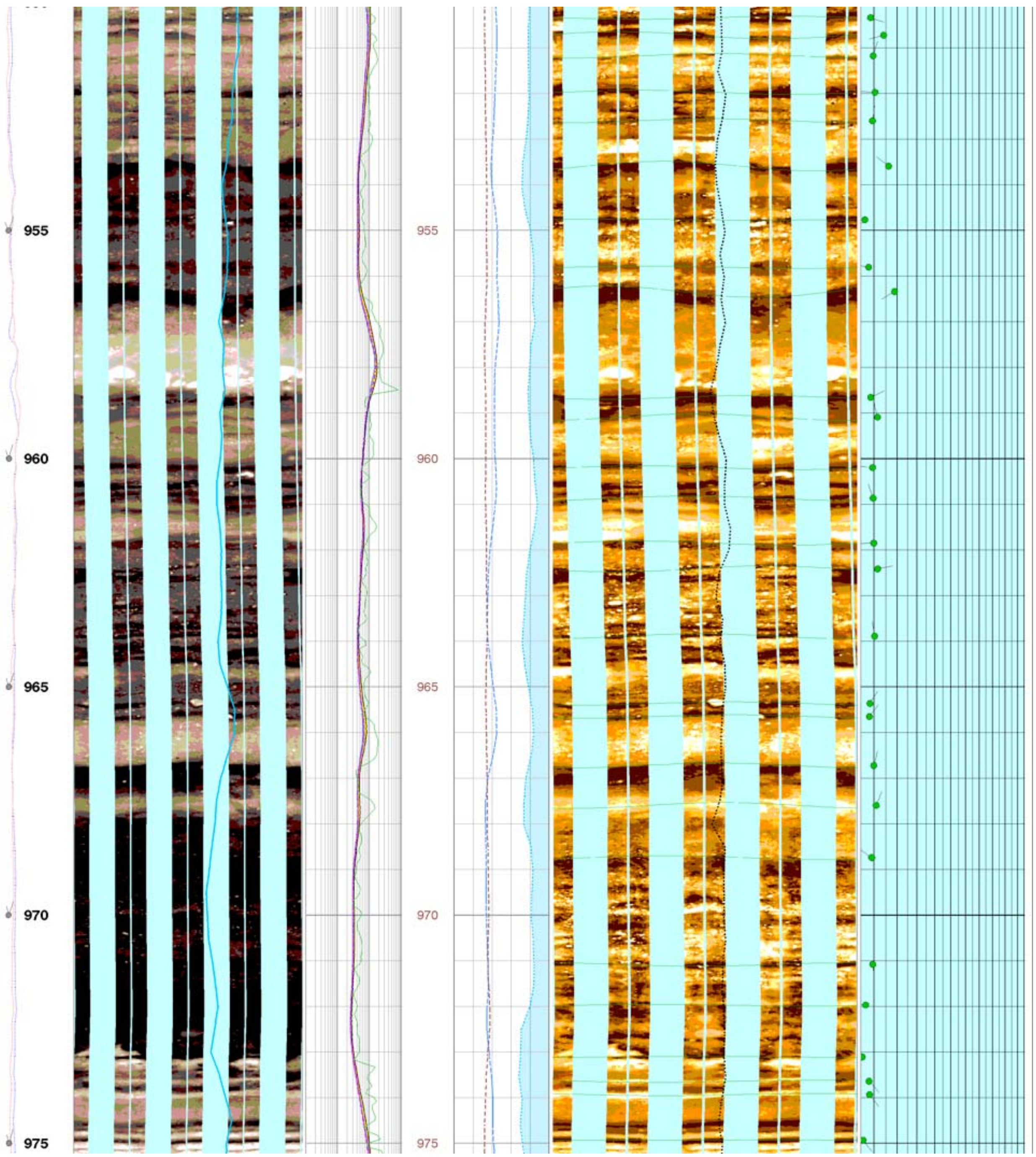
Screen 3
(895.5-937.4

FMI log for R-7

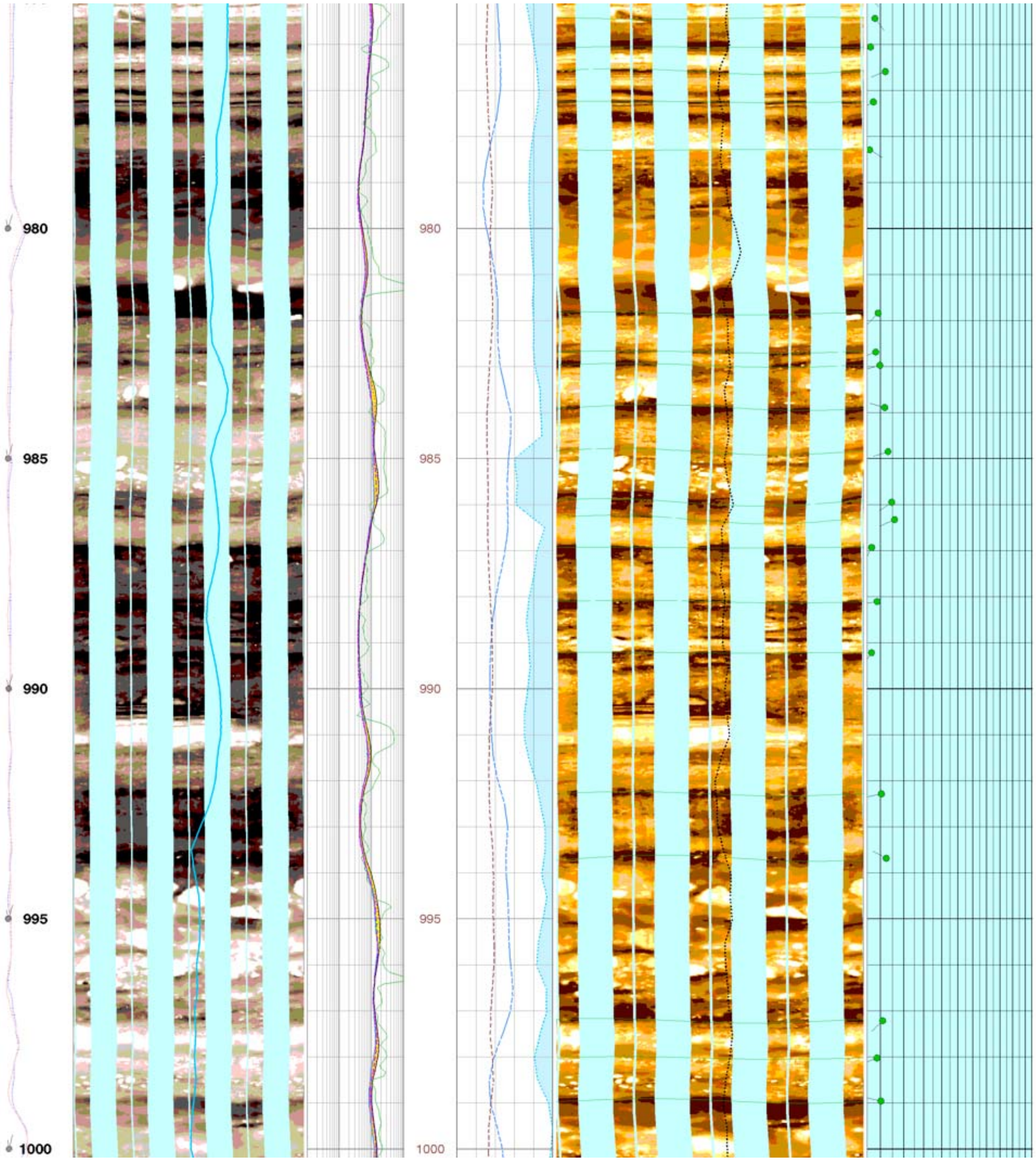


Screen 3
(895.5-937.4

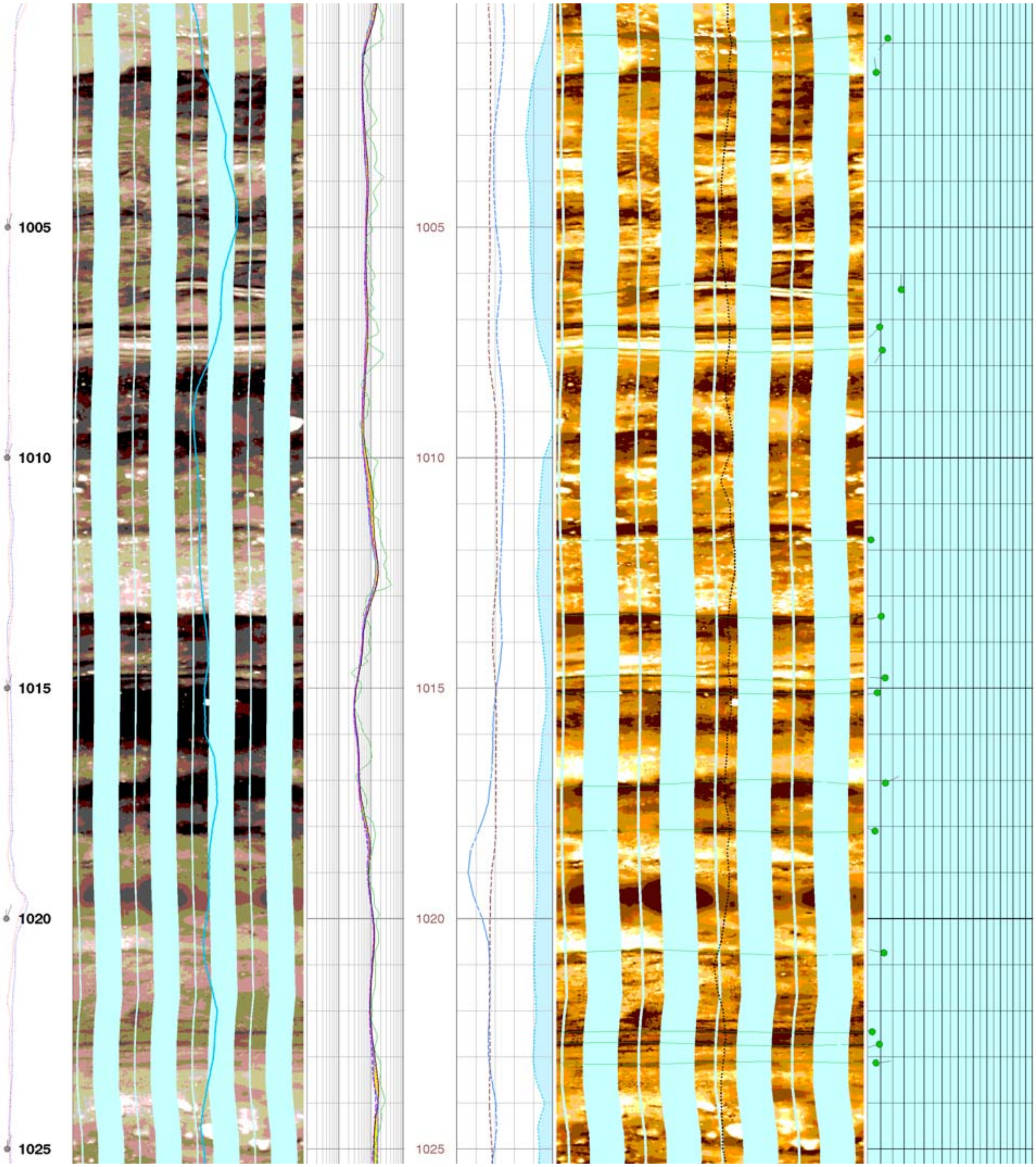
FMI log for R-7 (continued)



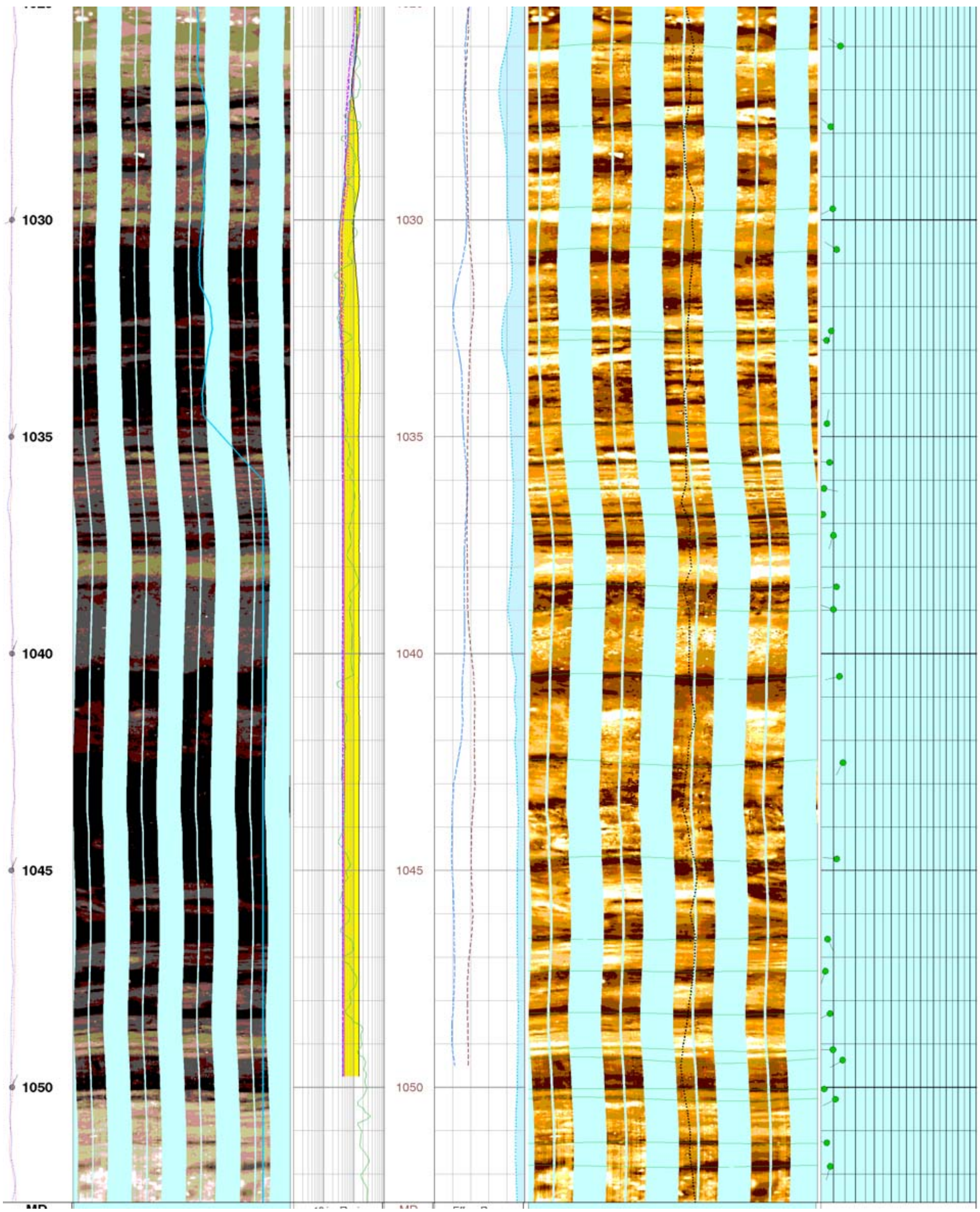
FMI log for R-7 (continued)



FMI log for R-7 (continued)



FMI log for R-7 (continued)



FMI log for R-7 (continued)

R-8 Well

R-8 Well

	Description	Evaluation
Drilling Method	R-8 was drilled using a combination of reverse-circulation fluid-assisted air-rotary methods in open hole and with casing advance to 809 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 880 ft.	The first borehole (BH1) was cored to a depth of 261 ft and drilled to a depth of 1022 ft using air-rotary drilling methods. BH1 was plugged and abandoned after efforts to retrieve drilling equipment that became lodged in the borehole were unsuccessful. The installation of well R-8 was completed on February 14, 2002, in the second borehole (BH2) that was drilled to a depth of 880 ft. BH2 was drilled using reverse-circulation fluid-assisted air-rotary methods. Casing advance was used to stabilize the borehole to a depth of 809 ft, and an open hole was drilled from 809 to 880 ft. Drilling additives included air and municipal water mixed with QUIK-FOAM, EZ-MUD, and TORKease. Drilling additives can adversely affect the ability to collect representative water samples if not removed from the immediate vicinity of the well screen during well development or during purging before sample collection.
General Well Characteristics	R-8 is a two-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screen is constructed of 4.5-in.-I.D./ 5.56-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was introduced after two well screens were damaged during installation of the R-25 well. A drawback to pipe-based screens is that water surged into the filter pack, and formation during development is less effective in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-8 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in.-slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells. Evaluations of water-quality data from screens 1 and 2 at R-8 do not reveal any residual effects of drilling products (Appendix B).
Screen Length and Placement	Well screen 1 extends from 705.3 to 755.7 ft and has a length of 50.4 ft. The top of the screen is 15.3 ft below the water level that is currently 690 ft below the surface (Allen and Koch 2007, 095268).	

	Description	Evaluation
Screen Length and Placement (continued)	Well screen 2 extends from 821.3 to 828 ft and has a length of 6.7 ft. Depth to water in screen 2 is currently 709.7 ft (Allen and Koch 2007, 095268).	R-8 is designed to replace TW-3, and its screen length and placement were selected with the following goals in mind: • Characterize water quality in the uppermost part of regional groundwater downgradient of contaminant sources in Los Alamos Canyon, particularly TA-02 and TA-21 • Place screen 1 (705.3 to 755.7 ft) at the water table that was measured at 709-ft depth in the open borehole before well construction. The purpose of this screen is to detect maximum contaminant concentrations due to infiltration beneath Los Alamos Canyon. • Place screen 2 somewhat deeper in the aquifer (821.3 to 828 ft) to target the uppermost productive zone in the regional aquifer where the strata were expected to be more transmissive than those at the water table • Determine vertical hydraulic gradients in the regional groundwater system • Monitor water-level responses in the upper part of the regional aquifer to pumping from nearby water-supply wells Both well screens are sited in sedimentary deposits that are probably Miocene. In the vicinity of the regional water table, the interval from 622 to 787 ft bgs contains clay-rich volcaniclastic sands and gravels with clasts of porphyritic dacite, silicified dacite, and flow-banded rhyolite. These deposits also contain a component of Precambrian quartzite and metamorphosed granitic rocks, ranging from 5% to 15% by volume. The clay-rich nature of these strata, particularly between 680 and 750 ft, caused numerous drilling problems in both BH1 and BH2, including stuck drill casings and a twisted-off drill bit. Swelling clays plugged the open borehole at BH1, allowing collection of only limited borehole geophysical logs (0 to 761 ft in a cased hole and 761 to 764 ft in an open hole). Because the geophysical logs could not be collected at 764 ft, information for siting well screen 2 was limited to lithologic description of drill cuttings, water-level measurements, and driller's observations. R-8 was originally intended to be a single screen well targeting the top of the regional water table. However, the clay-rich nature of the strata straddling the water table caused the original well design to be modified to include a second well screen placed deeper in the aquifer in more transmissive rocks beneath clay-rich zones. Because of the clay-rich nature of the rocks near the water table, screen 1 was designed with a relatively long screen (50.4 ft) to allow groundwater from thin productive intervals to enter the well. Well screen 2 (821.3 to 828 ft) was sited within a lithologic interval from 762 to 842 ft bgs that is made up of fine sand to gravel layers with mixed varieties of volcanic clasts (dacite to basalt) and generally contains only a trace of quartzite clasts. The well screen is relatively short (6.7 ft), compared with other characterization wells, resulting in sampling of a more discrete zone within the regional aquifer.

	Description	Evaluation
Filter Pack Materials and Placement	The primary filter pack for screen 1 consists of 20/40 sand from 745.3 to 758.0 ft and slough from 694.3 to 745.3 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 687.4 to 694.3 ft. The primary filter pack for screen 2 consists of 20/40 sand from 812.3 to 832.4 ft. Secondary filter packs of 30/70 sand were placed above and below the primary filter pack from 810.2 to 812.3 ft and 832.4 to 838 ft, respectively.	The primary filter pack for screen 1 covers only the lower 10.4 ft of the well screen. During well construction, the borehole wall sloughed into the annulus next to the well screen as the drill casing was retracted from the borehole. The slough next to screen 1 is likely to contain clay-rich sands and gravels similar to those found in the cuttings for this interval. As a result, water drawn into the well during development, hydraulic testing, and groundwater sampling may come largely from the lower part of the well screen. The primary filter pack for screen 2 extends 9 ft above and 4.4 ft below the well screen. The length of filter pack above the well screen is slightly longer than current well designs of 5 ft. The longer filter pack is probably advantageous in this case because it allows groundwater from a slightly longer vertical profile to be drawn into a relatively short well screen, increasing the chance of capturing potential contaminant flow pathways within heterogeneous aquifer materials.
Sampling System	Westbay MP sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well due to low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues that Could Affect the Performance of the Well	Isolation of well screens	The well design specified that the annulus between the borehole wall and well casing be filled with bentonite to isolate the two well screens. However, unstable borehole conditions resulted in slough filling the annulus next to the well casing in the interval 758 to 796.8 ft during well construction as the drill casing was retracted. Fortunately, the field team was able to place 13.4 ft of bentonite in the interval 796.8 to 810.2 ft above the screen 2 secondary filter pack before slough filled the annulus. This amount of bentonite is apparently successful in isolating screens 1 and 2 because the water levels in these two screens differ by about 20 ft. Additionally, screen 2 shows a clear response to pumping of nearby municipal supply wells, and screen 1 shows little or no response.

	Description	Evaluation
Additives Used During Drilling		QUIK-FOAM EZ-MUD TORKease Fluid volume recovered (12,740 gal. during well development and hydrologic testing)
Annular Fill other than Filter and Transition Sands		Holeplug: 0.375-in. angular and unrefined bentonite chips to provide borehole annular seal (24,800 lb) Pel Plug: 0.25 in. by 0.375 in. refined elliptical bentonite pellets to provide a borehole annular seal below the water table (23,000 lb) Cement for annular support and surface seal (6580 lb) Benseal: high solids, multipurpose bentonite grout (100 lb) Potable water: 5720 gal.

Location: TA-53, Los Alamos Canyon, near confluence with DP canyon.

Survey coordinates (brass marker in NW corner of BH2/R-8 cement pad):
x: 1641139 E y: 1772554 N (NAD 83)
z: 6544.7 ft asl (NGVD 29)
BH1 is 62 ft due east from BH2/R-8 at survey coordinates (center of cement plug):
x: 1641195 E y: 1772533 N (NAD 83)
z: 6542.9 ft asl (NGVD 29)

Drilling: air rotary core w/ wireline retrieval and fluid-assist air rotary reverse circulation with casing advance.
BH1 Start date: 09/25/01.
BH1 End date: 12/11/01.
BH2 Start date: 01/09/02.
BH2 End date: 01/27/02.

Borehole BH1 drilled to 1022 ft. bgs. (T.D.).
Borehole BH2 drilled to 880 ft. bgs. (T.D.).

Data collection:
Hydrologic properties:
Field Hydraulic Testing: Falling head test on R-8 screen #2.
Cores/cuttings submitted for geochemical and contaminant characterization: 156/6
Groundwater samples submitted for geochem and contaminant characterization: 1 (BH1)
Geologic properties:
Mineralogy, petrography, and chemistry: 11
Borehole logs from BH1:
Lithologic: 0-1022 ft.
Video (LANL tool): 0-850 ft. (well casing)
Natural gamma (LANL tool): 0-30 ft. and 0-761 ft. (cased); 30-261 ft. and 761-768 ft. bgs. (open hole)
Induction (LANL tool): 0-30 ft. (cased); 30-261 ft. (open hole)
Schlumberger Logs: 0-761 ft. (cased); 761-764 ft. (open hole): Litho density, Spectral Gamma, Elemental Capture, Thermal/Epithermal Neutron, Natural Gamma.

Contaminants Detected in BH1 Water Sample:
Tritium at 15 pCi/l.

Well construction:
Drilling Completed (BH2): 01/27/02.
Contract Geophysics (BH1): 11/13/01.
Well Constructed (BH2/R-8): 01/28/02 - 02/01/02.
Well Developed (R-8): 02/04/02 - 02/14/02.
Westbay Installed (R-8): 02/21/02 - 02/24/02

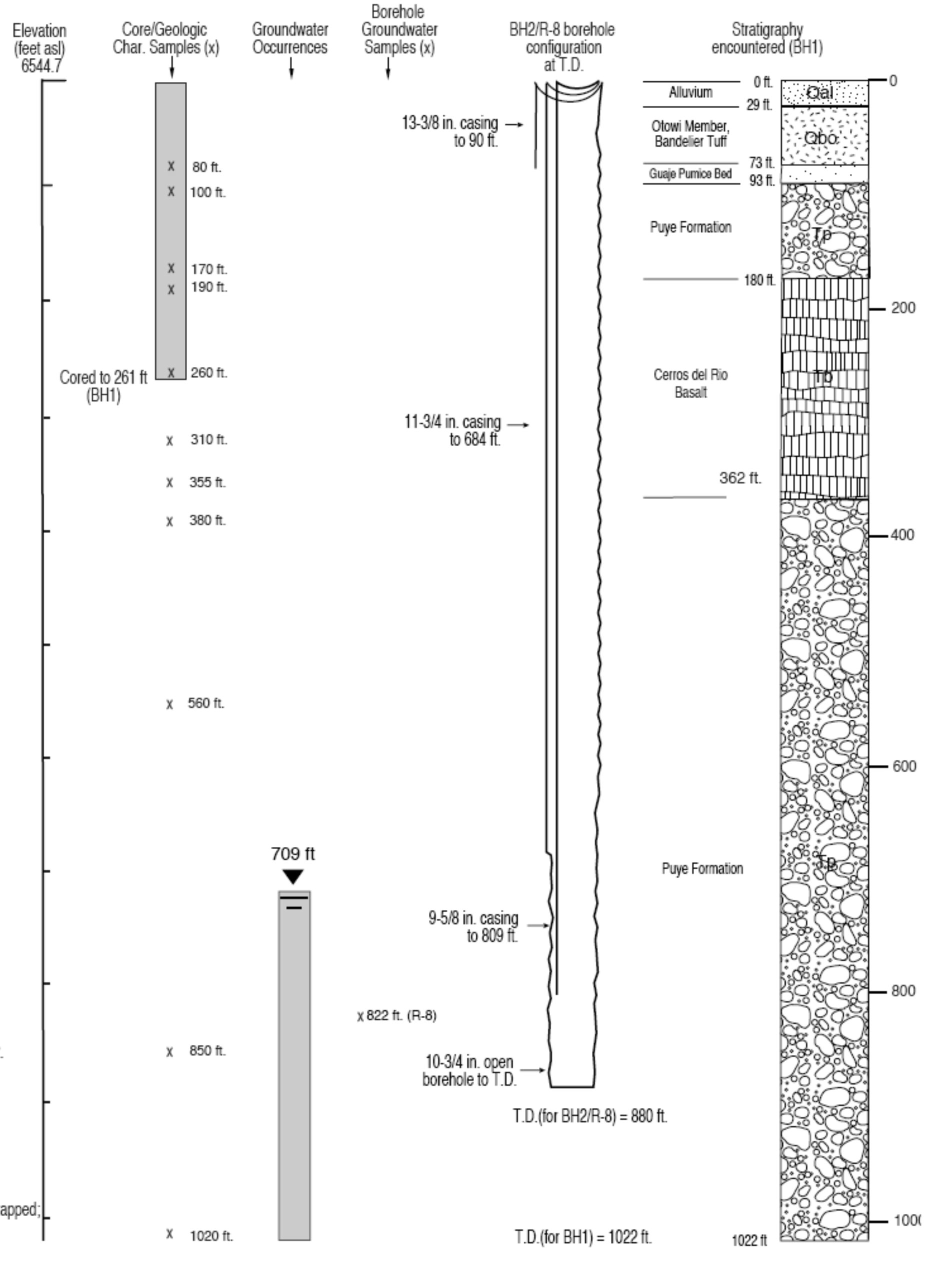
Casing: 4.5-in. I.D./5.0-in. O.D. stainless steel with external couplings.

Number of Screens: 2
4.5-in. I.D./5.56-in. O.D. pipe based, s.s. wire-wrapped; 0.010-in slotted.

Screen (perforated pipe interval):
Screen #1 - 705.3-755.7 ft. bgs.
Screen #2 - 821.3-828.0 ft. bgs.

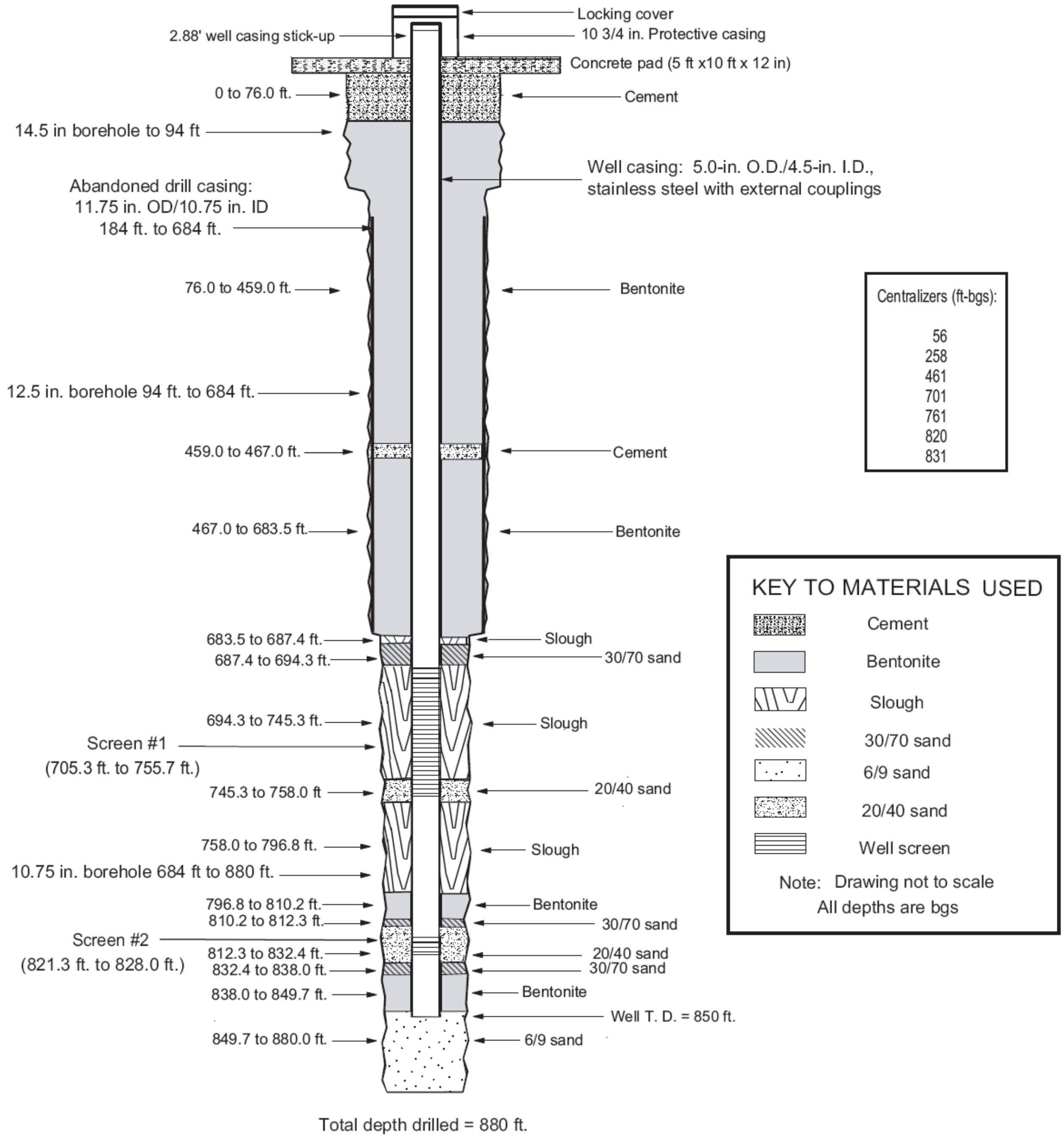
Well development consisted of wire brushing, bailing, surging, swabbing, and pumping.

Groundwater occurrence was determined in BH1 by recognition of first water produced while drilling, by borehole geophysics, and by borehole video. Static water levels were determined after borehole BH1 was rested.



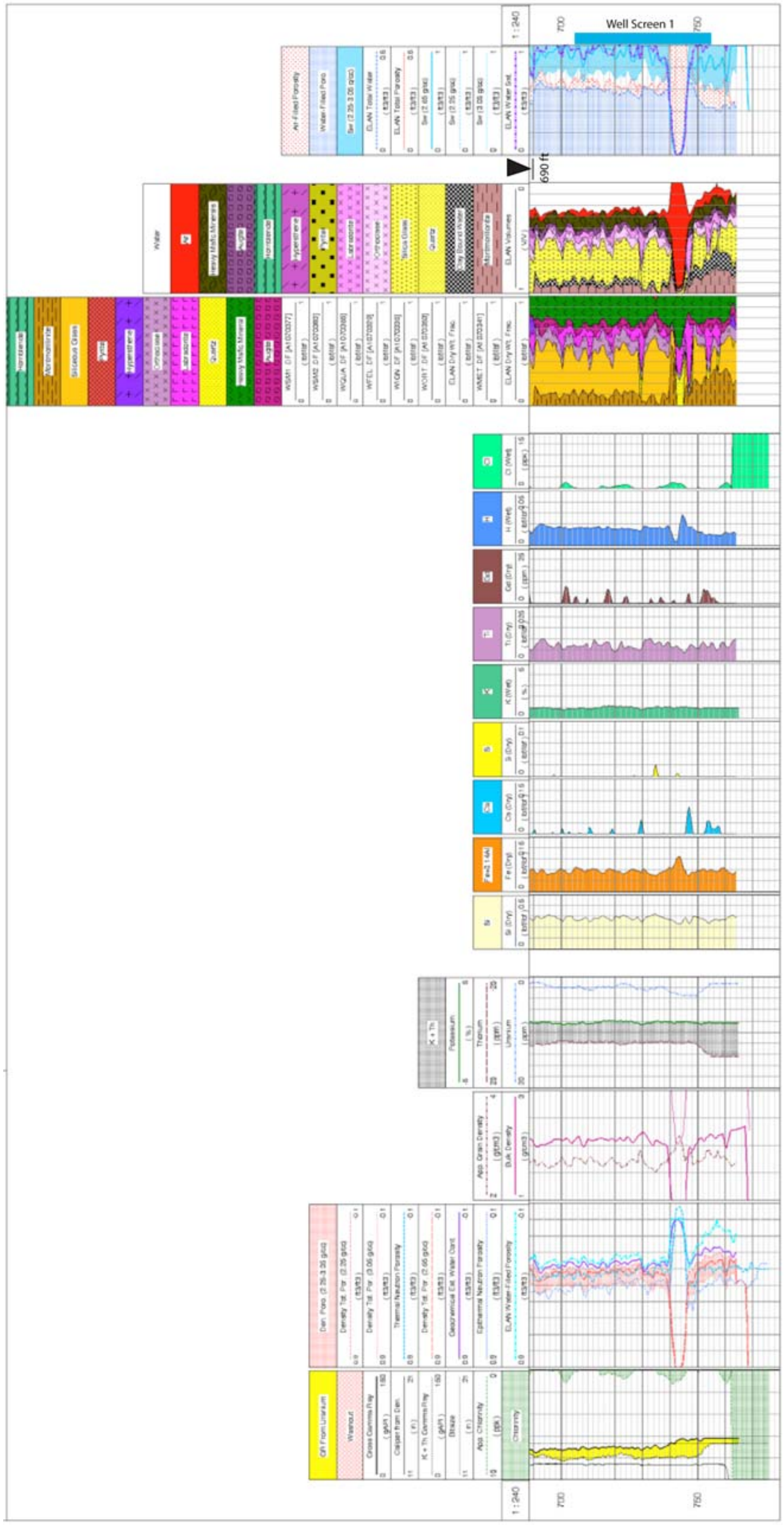
Geologic contacts are from BH1 and were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrographic, geochemical, or mineralogical analysis of geologic samples. No samples collected from borehole BH2.

Well summary data for characterization well R-8



Notes: 1. The screen intervals list the footages of the pipe perforations, not the top and bottom of screen joints.
2. The formation slough around screen #1 consists of volcaniclastic sands and gravels.
3. Pipe-based screen: 5.56-in. O.D./ 4.5-in. I.D., 304 stainless steel with s.s. wire wrap; 0.010-in slots.

As-built configuration diagram of characterization well R-8 in BH2



Geophysical logs for the top of regional saturation for well R-8

R-9 Well

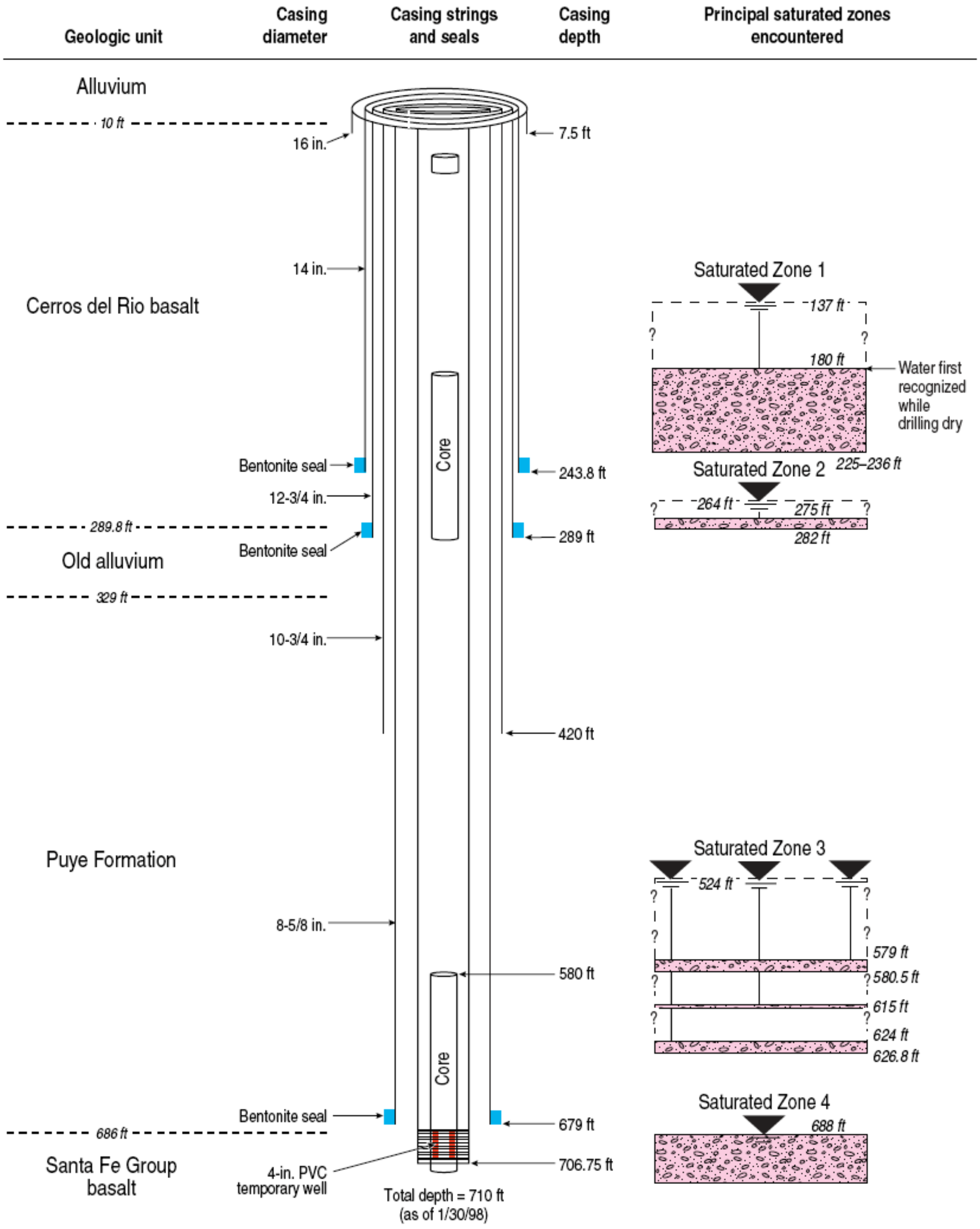
R-9 Well

	Description	Evaluation
Drilling Method	R-9 was drilled using a combination of reverse-circulation air-rotary methods in open hole and with casing advance to 710 ft followed by reverse-circulation fluid-assisted air-rotary drilling in open hole to TD at 771 ft.	R-9 was initially drilled to 710-ft depth using combination of open-hole and casing-advance reverse-circulation air-rotary drilling methods with intervals of intermittent core collection. The casing-advance system was used to stabilize the borehole wall and to seal off as many as three discrete zones of perched groundwater that were encountered during drilling. A temporary PVC well was installed at a depth of 710 ft on February 3, 1998, because depth to the regional aquifer in R-9 could not be identified with certainty. Several discrete zones of saturation had been encountered in the lower part of the borehole, and it was unclear which, if any, of these zones represented regional groundwater. Work on R-9 was halted until R-12, located 1 km to the south, could be drilled and depth to the regional water table could be better constrained. Data collected from drilling activities at R-12 helped clarify groundwater conditions at R-9, and the final phase of drilling and installation of a permanent well at R-9 took place from September 22, 1999, to October 18, 1999. After removal of the temporary PVC well, the borehole was deepened by reverse-circulation fluid-assisted air-rotary drilling in open hole from 710 to 771 ft. R-9 was deepened to find more productive zones within the Miocene basalt aquifer and to accommodate the desired length of the well screen and sump. The R-9 borehole was drilled using air as the circulation fluid from the surface to 710 ft. Bentonite, mixed with municipal water, was introduced into the borehole in small amounts to create seals at the bottoms of drill casing strings landed at depths of 243.8 ft, 289 ft, and 679 ft; these drill casings were sealed with bentonite to prevent perched groundwater from entering the borehole as it advanced toward the regional aquifer. Drilling additives, including air and municipal water mixed with QUIK-FOAM and EZ-MUD, were used to deepen the borehole from 710 to 771 ft after the temporary PVC well was removed. These drilling additives can adversely affect the ability to collect representative water samples if not removed from the immediate vicinity of the well screen during well development or during purging before sample collection.
General Well Characteristics	R-9 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. schedule 40 low-carbon steel casing to a depth of 552.5 ft and 4.5-in.-I.D./5-in.-O.D. schedule 40 stainless-steel casing below 552.5 ft.	The low-carbon steel casing was used in the vadose zone and thus does not affect chemistry of the regional groundwater samples collected. Use of stainless-steel well materials below 552.5 ft is designed to prevent corrosion in the vicinity of the regional aquifer.

	Description	Evaluation
Well Screen Construction	The well screen is constructed of 304 stainless-steel wire wrap with 0.010-in. slots.	Wire-wrapped screen is considered the optimum design for promoting the free flow of water during well development and sampling. The wire wrap on the R-9 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped screen to develop properly must be judged on the quality of groundwater data collected from the wells. R-9 consistently yields water samples considered representative of groundwater conditions in the regional aquifer at this location (see Appendix B). Field parameters, including turbidity, are consistently within acceptable limits. These data indicate that the well screen is properly designed, installed, and developed.
Screen Length and Placement	The R-9 well screen extends from 683 to 748.5 ft and has a length of 65.5 ft. The screen straddles the water table that is currently at a depth of 690.8-ft depth (Allen and Koch 2007, 095268). The top of the screen is 7.8 ft, above the water table, and 57.7 ft of the screen is submerged.	R-9 is designed to provide water-quality and water-level data for the regional aquifer near the Laboratory's eastern boundary, and its screen length and placement were selected with the following goals in mind: • Characterize water quality in the uppermost part of regional groundwater downgradient of contaminant sources in Los Alamos Canyon, particularly TA-02 and TA-21 • Place the well screen straddling the water table to detect maximum contaminant concentrations due to infiltration beneath Los Alamos Canyon • Collect water-level data for the regional aquifer • Monitor water-level responses in the upper part of the regional aquifer to pumping from nearby water-supply wells The upper 3 ft of the well screen from 683 to 686 ft is within Miocene clay-rich volcanogenic sedimentary rocks; this portion of the well screen has always been above the water level. The remainder of the well screen is within Miocene basaltic rocks, with the main productive zones probably occurring within fractured basalt. A zone of soil development within the uppermost foot of the basalt is indicated by thick accumulations of clay and calcite with some drusy quartz in vesicles and fractures. Calcite veins extend downward in hairline fractures an additional 0.8 ft below this depth. Regional groundwater in R-9 appears to be unconfined. There was no measurable water-level rise after saturation was encountered in the basalt. The regional water level in R-9 (and in nearby R-12) is anomalously low compared with nearby water-supply wells PM-1 and O-1 under nonpumping conditions. Water levels measured at R-9 are also anomalously low when compared with predictions based on regional water-table maps (see Figure O-2 in LANL 2006, 094161).

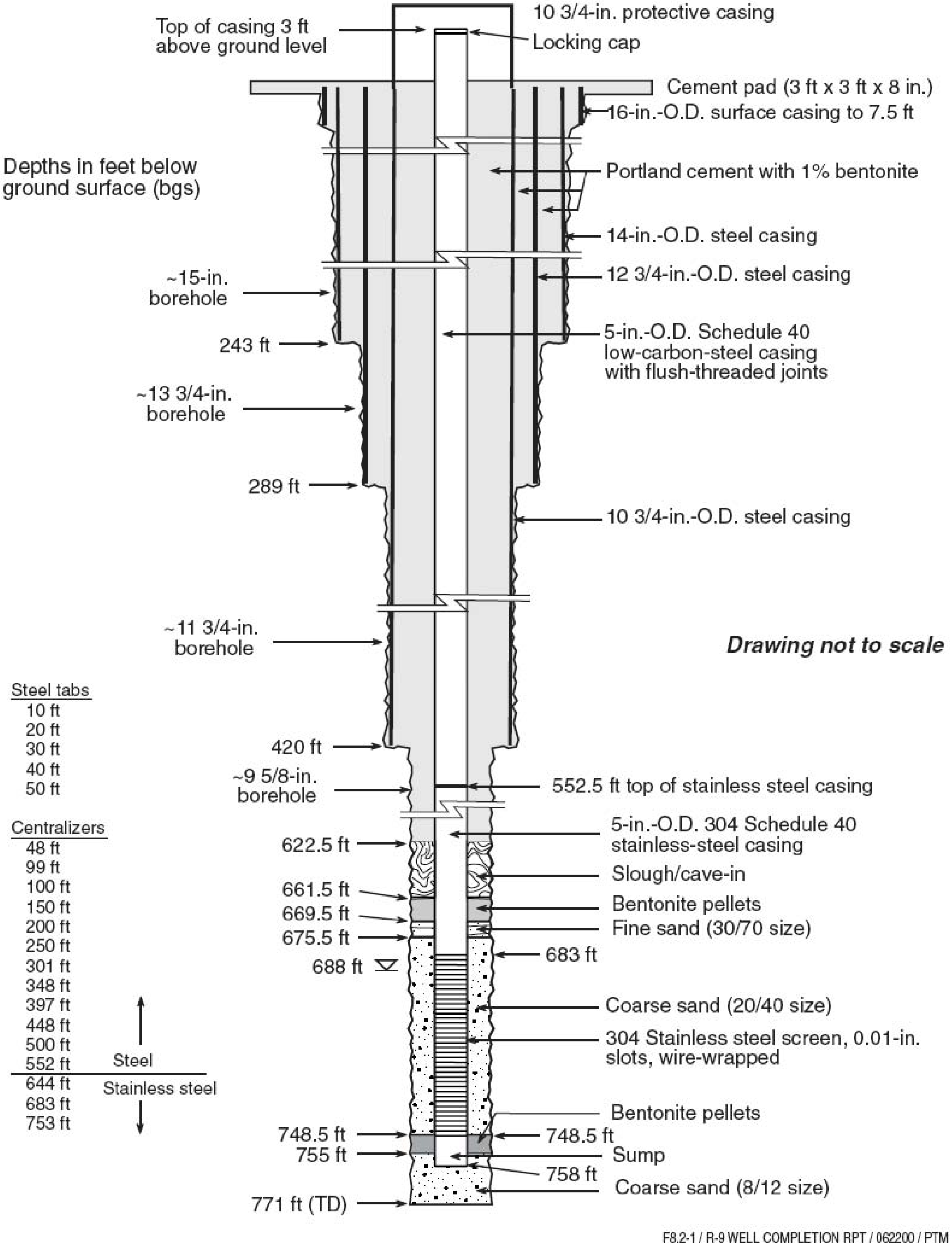
	Description	Evaluation
Screen Length and Placement (continued)		The screen length and placement are appropriate for the goals defined in the second, third, and fourth bullets above. However, the anomalously low water level in R-9 raises questions about how well regional groundwater in the Miocene basalt is in communication with other parts of the regional groundwater system, particularly to the west. Resolving this question is important for evaluating whether the current well location is appropriate for addressing the first bullet. A similar situation is present at R-12, and a replacement well (R-36) has been drilled west of the R-12 location so that groundwater can be monitored in the sedimentary deposits above the Miocene basalt. Water-level and water-quality results for R-36 and R-12 should be compared after the new well is installed to determine if there are significant differences in the monitoring data collected from the sedimentary deposits and the basalts. The location of R-9 as a monitoring well for contaminant sources in Los Alamos Canyon should be reevaluated based on the comparison of R-12 and R-36 data.
Filter Pack Materials and Placement	The primary filter pack consists of 20/40 sand from 675.5 to 748.5 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 669.5 to 675.5 ft and 748.5 to 755 ft, respectively.	The primary filter pack extends 7.5 ft above the well screen, and it extends to the bottom of the well screen. The filter pack above the well screen is slightly longer than the optimum design of 5 ft but has no effect on samples collected because the top of the well screen is above the water table.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well	Abandoned drill casings	During well-construction operations, the 8-in. well casing was successfully pulled back in increments, while annular materials were placed around the well with a tremie line. The 8.62-in. casing was completely removed from the borehole, and the annular materials were installed to the bottom of the 10.75-in. drill casing. However, when attempts were made to pull back on the 10.75-in. drill casing, it was discovered that the 5-in. well casing had become locked to the drill casing. Attempts to decouple the 5-in. well casing from the 10.75-in. drill casing were unsuccessful. Because further attempts to pull back on the 10.75-in. drill casing could have caused severe damage to the well completion string, the decision was made to cement in place the 10.75-in. casing and the two other remaining drill casings. Cement between and outside the abandoned drill casings seals the regional aquifer from overlying perched groundwater. These abandoned drill casings do not affect the performance of R-9 as a monitoring well.

	Description	Evaluation
Additives Used During Drilling		Municipal water QUIK-FOAM EZ-MUD
Annular Fill other than Filter and Transition Sands		Pel Plug: 0.25 in. by 0.375 in. refined elliptical bentonite pellets to provide a borehole annular seal from 661.5 to 669.5 ft Cement for sealing off abandoned drill casing and surface seal Slough: Slough filled the well annulus between 622.5 and 661.5 ft when the 8.62-in. drill casing was retracted during well construction. The slough is sandwiched by cement above and bentonite below.



F2.3-1 / R-9 WELL COMPLETION RPT / 050200 / PTM

Configuration of R-9 borehole as of January 30, 1998



As-built completion diagram of well R-9

R-9i Well

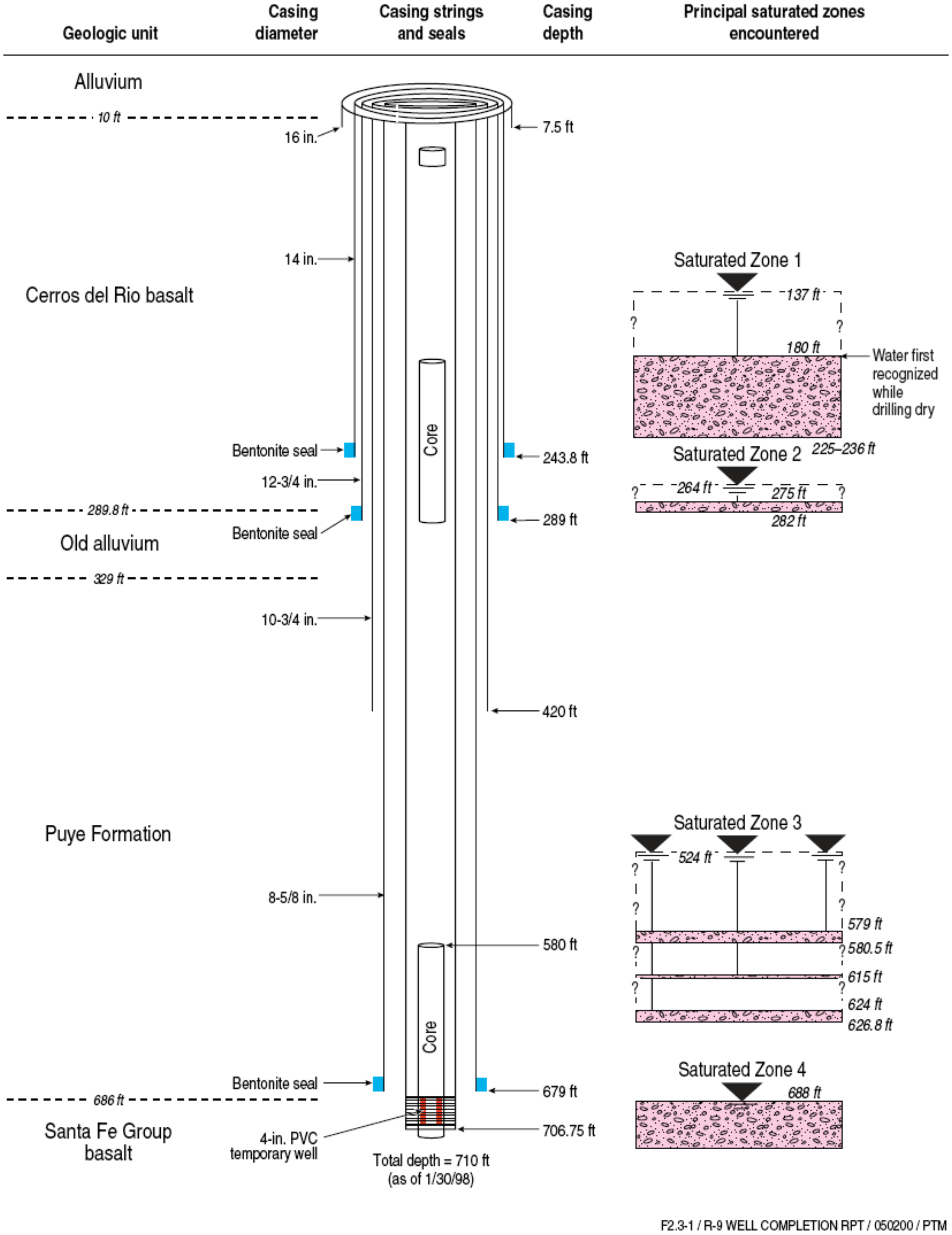
R-9i Well

	Description	Evaluation
Drilling Method	R-9i was drilled using a combination of fluid-assisted reverse-circulation air-rotary methods in open hole and with casing advance.	R-9i is primarily designed to provide water-quality and water-level data for the two uppermost perched zones of saturation identified during the drilling of characterization well R-9. R-9i is located 35 ft west of R-9. R-9i was initially drilled to 18-ft depth using casing-advance reverse-circulation air-rotary drilling methods to install 13.375-in. surface casing. The remainder of the borehole (18 to 322 ft) was drilled using fluid-assisted reverse-circulation air-rotary methods in an open borehole. Air and municipal water mixed with EZ-MUD were used to circulate cuttings out of the borehole. Drilling additives such as EZ-MUD can adversely affect the ability to collect representative water samples if not removed from the immediate vicinity of the well screen during well development or during purging before sample collection.
General Well Characteristics	R-9i is a two-screen well constructed of 4.5-in.-I.D./5.56-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 5-in. I.D./5.5-in.-O.D. 304 stainless-steel wire wrap with 0.010-in. slots.	Wire-wrapped screen is considered the optimum design for promoting the free flow of water during well development and sampling. The wire wrap on the R-9i well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped screen to develop properly must be judged on the quality of groundwater data collected from the wells. Evaluations of water-quality data from the two screens in R-9i do not reveal any residual effects of drilling products in the most recent samples (Appendix B).
Screen Length and Placement	Well screen 1 extends from 189.1 to 199.5 ft and has a length of 10.4 ft. The screen is submerged within a perched zone that may be under confining conditions. The water level in screen 1 is currently at a depth of 146 ft below the surface (Allen and Koch 2007, 095268). The top of the screen is 43.1 ft below the water level.	R-9i is designed to provide water-quality and water-level data for the perched groundwater near the Laboratory’s eastern boundary, and the screen lengths and placements were selected with the following goals in mind: • Characterize water quality in the uppermost perched groundwater zone located downgradient of contaminant sources in Los Alamos Canyon, particularly TA-02 and TA-21. This perched zone is located within the Cerros del Rio basalt and is one of the largest perched water zones encountered in the eastern part of the Laboratory. This goal was met by installation of screen 1. • Characterize water quality in the smaller perched groundwater zone located near the base of the Cerros del Rio basalt. This goal was met by installation of screen 2. • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon. This goal is met by water-level measurements in screens 1 and 2.

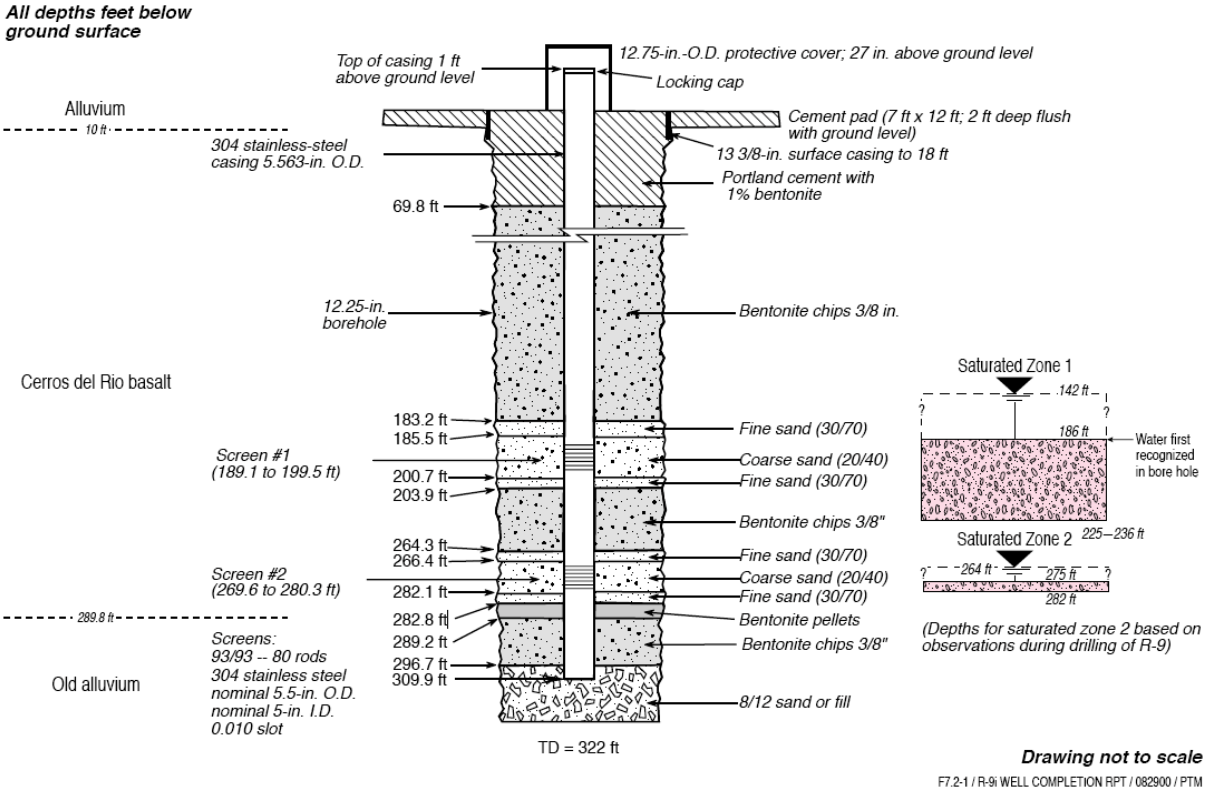
	Description	Evaluation
Screen Length and Placement (continued)	Well screen 2 extends from 269.6 to 280.3 ft and has a length of 10.7 ft. The screen is submerged within a perched zone that may be under confining conditions. The water level in screen 2 is currently at a depth of 255 ft below the surface (Allen and Koch 2007, 095268). The top of the screen is 14.6 ft below the water level.	Two zones of perched saturation were encountered in R-9i, as expected from observations at adjacent regional well R-9. The upper perched water lies within the interior of the stack of Cerros del Rio basalt. The lower zone of perched saturation lies at the base of the Cerros del Rio basalt. The position of the top of the uppermost zone of perched saturation was not clearly understood at R-9. Thus, steps were taken at R-9i to resolve this uncertainty. Specifically, minimal amounts of drilling fluid were used to avoid plugging any productive zones, and operations were halted periodically to allow any formation water present to accumulate in the borehole. At such times, water injection was ceased, but circulation of compressed air was allowed to continue. Drilling was stopped at depths of 140 ft, 145 ft, 148 ft, 155 ft, 160 ft, 168 ft, 175 ft, 180 ft, and 188 ft. At all these depths, except 188 ft, the hole dried out within 5 min, suggesting significant saturation had not yet been encountered. At a depth of 184 ft, red-orange clay and red scoria and breccia showed up in the cuttings, and at 186 ft the driller noticed an increase in the penetration rate and ceased injecting water. The basalt flow beneath the breccia is highly fractured, and these fractures probably provide the permeability in this perched zone. While shut down at a depth of 188 ft, water was produced from the borehole. Based on these observations, the top of the uppermost saturation is believed to lie at a depth of 186 ft. Drilling was continued until a depth of 200 ft was reached. Then the bit was pulled back to a depth of 187 ft, leaving 12 ft of open hole. After 1.5 h, a composite water-level depth of 142 ft was obtained. At R-9i, information about the first occurrence of groundwater and the static water-level depth for the lower perched water could not be determined because the lower zone was flooded by water from the upper perched zone during open-hole drilling. However, the upper perched zone was sealed off by drill casing when nearby well R-9 was drilled. Observations during R-9 drilling indicate that the second perched zone was encountered in a breccia zone at the base of the Cerros del Rio lavas. Saturation was first recognized at a depth of 275 ft, and water slowly rose to a static level of 264 ft. The basaltic breccia appears to constitute the permeable interval within the second perched zone. The perching layer occurs at a depth of 282 ft within fine-grained, highly stratified basaltic tephra. Hydraulic conductivity of the second perched zone appears to be significantly less than in the first perched zone, as evidenced by the slow recovery of water levels in the borehole after the samples were collected and the resistance to injection of water during hydraulic-property testing. The observations described above suggest that both perched zones at R-9i may be under confined conditions. Thus, the well screens target the zones where water was first produced during drilling rather than the levels to which groundwater rose. The length and placement of the two screens in R-9i are appropriate for the conditions encountered at this location and meet the goals defined in the preceding bullets.

	Description	Evaluation
Filter Pack Materials and Placement	The screen 1 primary filter pack consists of 20/40 sand from 185.5 to 200.7 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 183.2 to 185.5 ft and 200.7 to 203.9 ft, respectively. The screen 2 primary filter pack consists of 20/40 sand from 266.4 to 282.1 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 264.3 to 266.4 ft and 282.1 to 282.8 ft, respectively.	The primary filter pack for screen 1 extends 3.6 ft above and 1.2 ft below the well screen. For screen 2, the primary filter pack extends 3.2 ft above and 1.8 ft below the well screen. Placement of the filter packs is within the optimum design for both well screens.
Sampling System	Westbay MP sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well due to low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues that Could Affect the Performance of the Well	The lower groundwater zone was flooded by upper perched zone water during open-hole drilling and in the completed well before installation of the Westbay sampling system.	The lower zone was flooded by water from the upper perched zone during open-hole drilling. In addition, the lower well screen was open to large amounts of water from screen 1 until isolation of the well screens was accomplished by installation of the Westbay system.

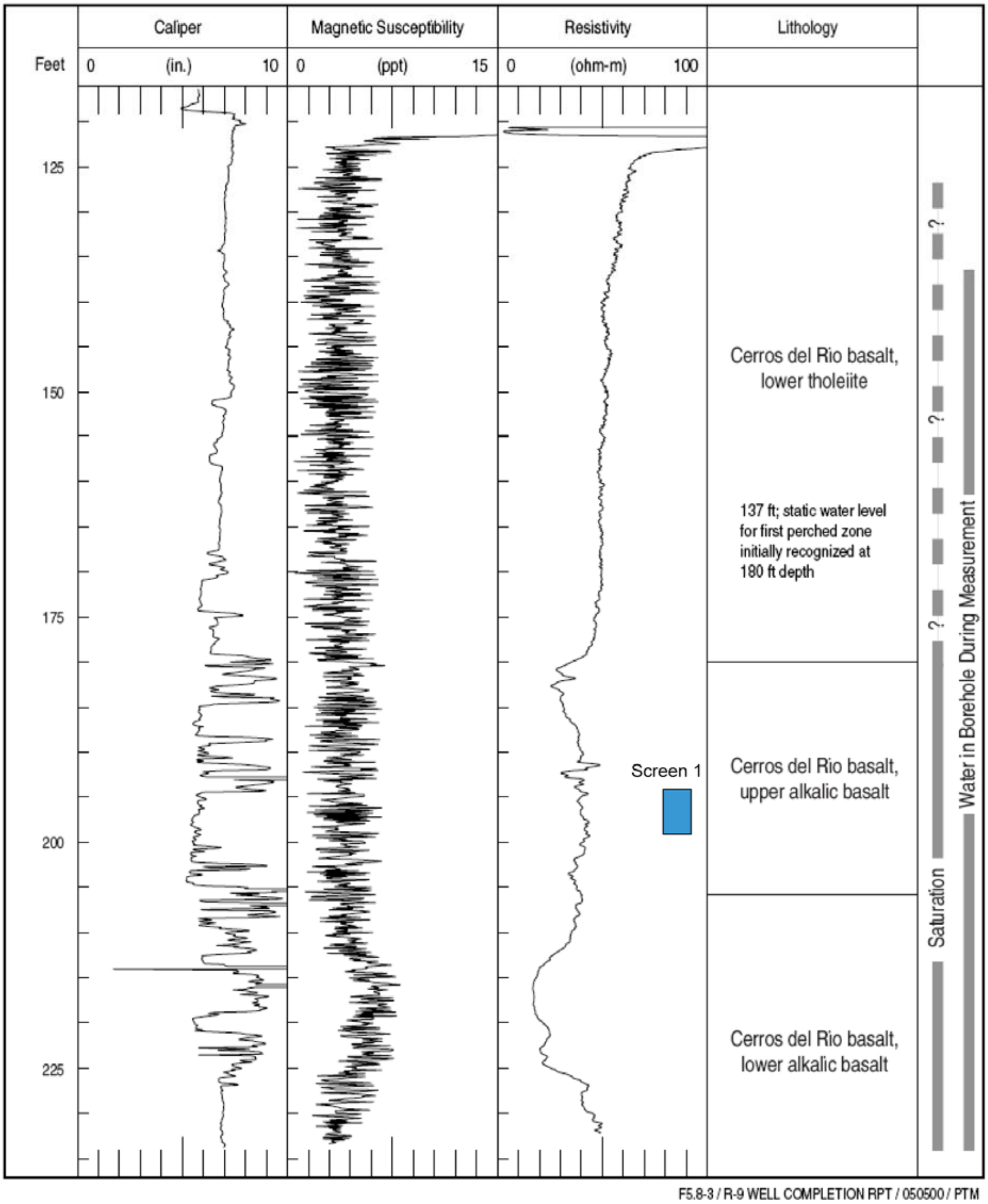
	Description	Evaluation
Additives Used During Drilling		Municipal water EZ-MUD
Annular Fill other than Filter and Transition Sands		Bentonite: 0.375-in. chips Pel Plug: refined elliptical bentonite pellets to provide a borehole annular seal Portland Type I/II cement with 1% bentonite gel, by weight



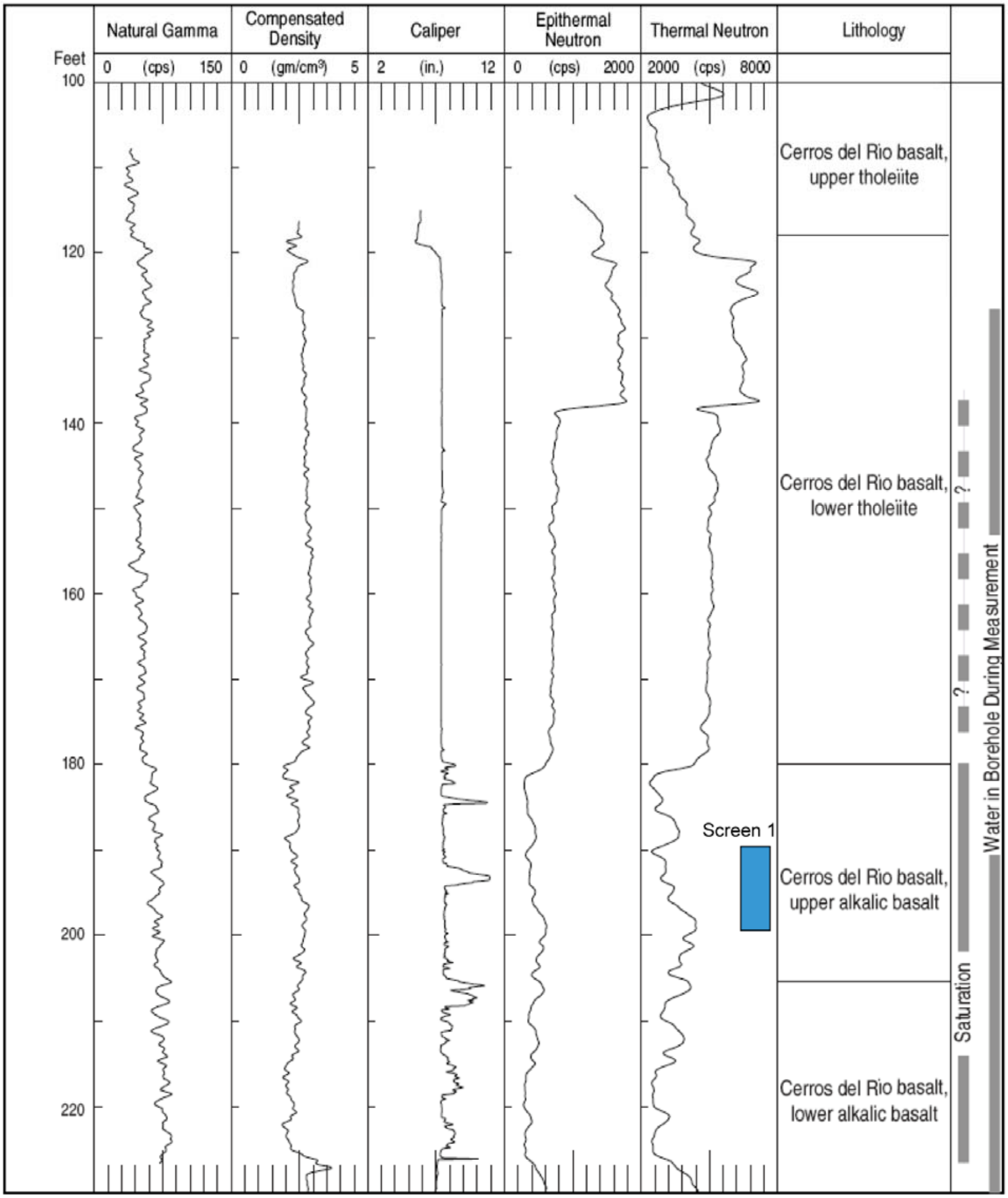
Groundwater zones identified during drilling of nearby regional well R-9



As-built completion diagram of well R-9i

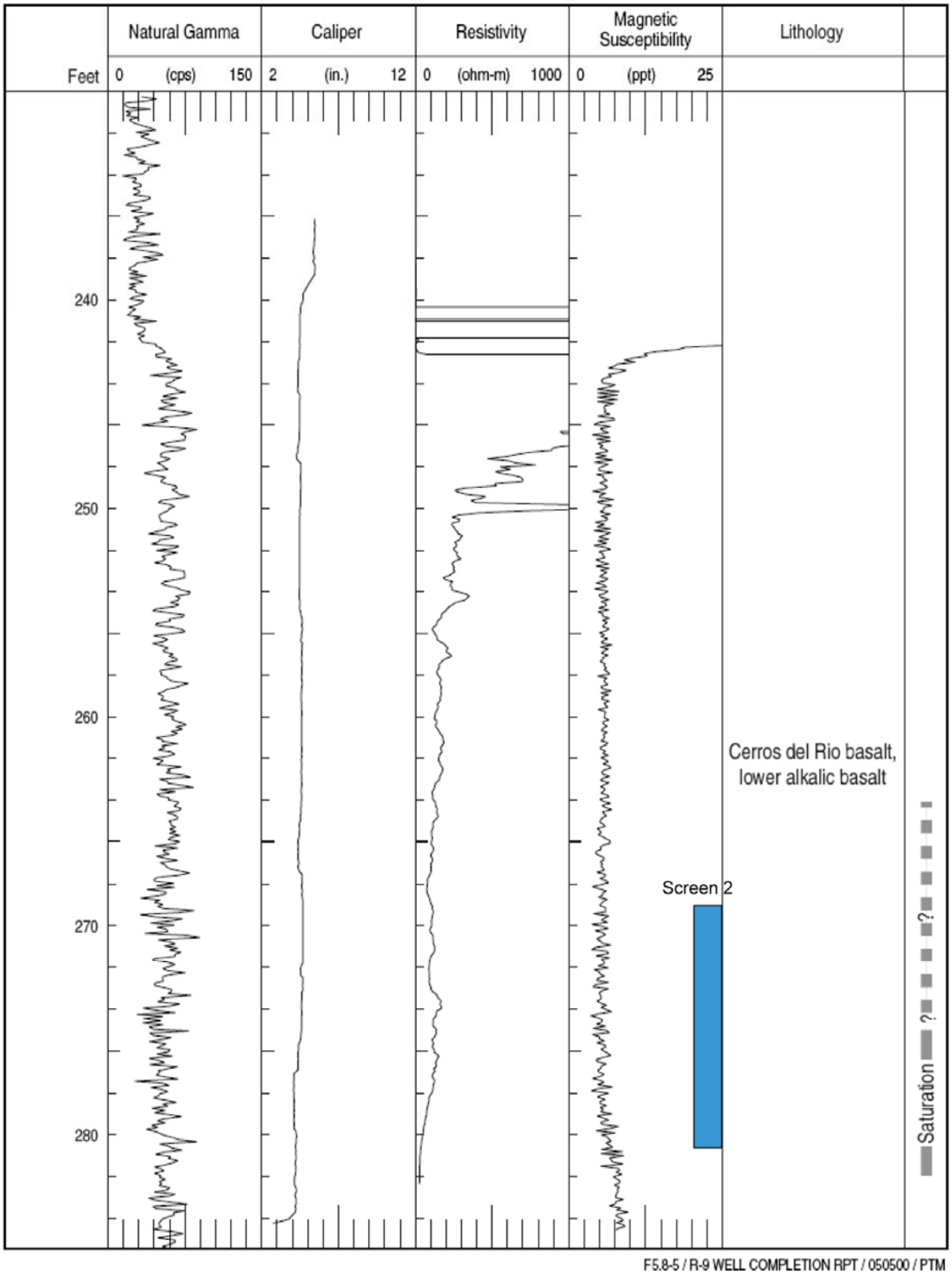


Position of R-9i well screen 1 relative to geophysical data collected in adjacent R-9 borehole



F5.8-4b / R-9 WELL COMPLETION RPT / 050500 / PTM

Position of R-9i well screen 1 relative to geophysical data collected in adjacent R-9 borehole (continued)



Position of R-9i well screen 2 relative to geophysical data collected in adjacent R-9 borehole

R-12 Well

R-12 Well

	Description	Evaluation
Drilling Method	R-12 was drilled using a combination of reverse-circulation air-rotary methods in open hole and with casing advance to 847 ft followed by reverse-circulation fluid-assisted air-rotary drilling in open hole to TD at 886 ft.	R-12 was drilled in two stages. During stage 1 from March 10, 1998, to June 8, 1998, the borehole was drilled to a depth of 847 ft using reverse-circulation air-rotary methods in open hole and with casing advance. A perched groundwater system was encountered from depths of 443 to 519 ft in the lower part of the Cerros del Rio basalt and in the underlying old alluvium. Three drill-casing strings (14 in., 10 in., and 8 in.) were used to isolate the perched groundwater and to advance the borehole to the top of the regional groundwater system that was encountered at a depth of 805 ft. A temporary PVC well was installed inside the three drill casings to better understand water-level data and to evaluate contaminants in the regional groundwater system prior to installation of a permanent well. After a period of data acquisition, the temporary well was removed and the borehole was deepened slightly during stage 2 drilling so that a well with a 30-ft well screen and 20-ft sump could be installed in the regional zone of saturation upgradient of supply well PM-1. A permanent well was installed with two screens in the perched zone and one screen in the regional aquifer. A Westbay sampling system was installed to isolate the three screens and to collect water samples. When stage 2 drilling activities to deepen the borehole began October 25, 1999, problems were encountered retrieving the PVC well casing and advancing the borehole with the 8-in. drill system. Because of the clay-rich nature of the deep sedimentary deposits at this site, both the PVC casing and the 8-in. drill casing were effectively rock-locked by shifting ground and could not be easily removed. After considerable effort, all but the lower 50 ft of the PVC well were removed, which was subsequently drilled out. A more serious problem developed during efforts to advance the 8-in. drill casing. While attempting to advance the casing, the shoe on which the down-the-hole hammer strikes became detached from the bottom of the 8-in.-casing string. Cement was introduced to the bottom of the hole so that the 8-in. drill shoe could be retrieved with the 8-in.-drill casing. Eventually, the borehole was deepened to 886 ft, and the well was installed by January, 21, 2000. Drilling from 847- to 886-ft depth was accomplished by reverse-circulation fluid-assisted air-rotary drilling methods. Circulation of cuttings was primarily accomplished using air and municipal water mixed with additives. After the borehole was deepened, a well with two screens in perched zones and one screen in the regional aquifer was installed. During well installation, drill casing was extracted as the filter pack and annular fill were installed around the well. The 14-in.-drill casing could not be retracted from its original landed depth of 450 ft, and it was grouted in place. The use of cement to assist retrieval of the 8-in. drill shoe and the use of drilling additives during stage 2 drilling are possibly important considerations when evaluating groundwater data collected from screen 3 at R-12.

	Description	Evaluation
General Well Characteristics	R-12 is a three-screen well constructed of 4.3-in.-I.D./5-in.-O.D. low-carbon steel casing from the surface to 354-ft depth and 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing from 354 to 869 ft.	Low-carbon steel casing was used in the vadose zone above the perched groundwater zones and thus does not affect groundwater chemistry of the three well screens. Use of stainless-steel casing in the region of perched groundwater and in the regional groundwater system prevents corrosion of well materials in the vicinity of well screens.
Well Screen Construction	The well screen is constructed of 4.5-in.-I.D./5.1-in.-O.D. 304 stainless-steel wire wrap with 0.010-in. slots in the upper and lower screens and 0.005-in. slots in the middle screen.	Wire-wrapped screen is considered the optimum design for promoting the free flow of water during well development and sampling. The wire wrap on the R-12 well screen contains 0.010-in. slots in the upper and lower screens and 0.005-in. slots in the middle screen, primarily to minimize the intake of fine-grained aquifer material into the well during sampling. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The quality of groundwater data from screens 1 and 2 following well rehabilitation in September and October 2006 is much improved; this suggests that the 0.005-in. and 0.010-in. slot screens can be properly developed and yield representative water samples. The 0.010-in. slots in the regional aquifer screen probably do not inhibit proper development, but other factors, discussed below, compromise groundwater data collected from this well screen. In December 2007, the regional aquifer well screen (screen 3) was abandoned, and a Baski packer with dual pump sampling was installed at screens 1 and 2.
Screen Length and Placement	Screen 1 is submerged in perched water within Cerros del Rio basalt and extends from 459 to 467.5 ft (length of 8.5 ft). Screen 2 is submerged in perched water within old alluvium and extends from 504.5 to 508 ft (length of 3.5 ft). The current water level in screens 1 and 2 is about 427 ft bgs. Screen 3 was abandoned in December 2007.	The screen lengths and their placements were selected with the following goals in mind: • Provide a monitoring point straddling the regional aquifer at the Laboratory boundary (with the abandonment of screen 3, this function is no longer available at R-12, but is now satisfied by the installation of well R-36) • Install a sentry well upgradient of municipal supply well PM-1 (with the abandonment of screen 3, this function is no longer available at R-12, but is now satisfied by the installation of well R-36) • Install a well screen in the upper part of the perched system within a permeable part of the Cerros del Rio basalt (screen 1) • Install a well screen in the lower part of the perched system within permeable sediments of the old alluvium (screen 2)

	Description	Evaluation
Screen Length and Placement (continued)		Screen 1 was placed in perched groundwater within Cerros del Rio basalt at a depth below where groundwater was first noted in the borehole (443-ft depth) and where cuttings sampled indicated the basalt was fractured. Perched zone water quickly rose to 424 ft when it was first encountered, indicating either that it was confined or that suitable interconnected fractures did not extend into the upper part of the perched zone at this location. For either hydrologic interpretation, it was necessary to place the well screen in fractured basalts that would yield groundwater. Screen 2 targeted the lower part of the perched zone within the old alluvium that contained sandy axial river gravels made up of well-rounded quartzite, granite, gneiss, and intermediate volcanics. These deposits are poorly cemented and were selected for their high permeability.
Filter Pack Materials and Placement	The filter packs and their placements are discussed for the three well screens in the column to the right.	The primary filter pack for screen 1 is made up of 20/40 sand from 453 to 481 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 447 to 453 ft and 481 to 486 ft, respectively. The primary filter pack extends 6 ft above and 13.5 ft below the well screen. This filter pack length allows groundwater to be drawn from a larger volume of the basalt where the distribution of water-producing fractures is poorly known. The primary filter pack for screen 2 is made up of 30/70 sand from 495 to 522 ft. A secondary filter pack was not used in screen 2. The primary filter pack extends 9.5 ft above and 14 ft below the well screen. The combination of this filter pack with a relatively short well screen allows groundwater to be drawn from throughout the interval, representing the permeable portion of the old alluvium from the base of the Cerros del Rio basalt to the top of the confining layer of silt and clay.
Sampling System	Baski packer with dual-pump system	A Baski packer with dual-pump system was installed at screens 1 and 2 in December 2007. This system uses a packer to isolate the two screen intervals and a dedicated pump within each interval to provides discrete groundwater samples; no valves or associated control lines are used in the dual-pump system. This sampling system is a relatively high-flow system capable of pumping rates adequate for conventional purging and sampling. Purging and sampling with the Baski system allow water to be drawn more deeply from within formation materials surrounding the well screen in comparison to low-flow systems. There is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. The Baski packer system incorporates separate gage tubes that provide access to each screen zone using conventional transducer equipment and manual measurement methods

	Description	Evaluation
Other Issues that Could Affect the Performance of the Well	Well Development	After R-12 was installed, development took place in the open well casing without the use of packers to isolate each of the well screens. Consequently, jetting with municipal water and the free flow of water from the perched zone were the only effective development that occurred in the upper two well screens. The limited success of this development approach is reflected by the high TOC concentrations measured in the first characterization samples collected after February 2000. The upper two well screens were redeveloped as part of a well rehabilitation program in September and October 2006. This rehabilitation effort resulted in a more thorough development of screens 1 and 2, but over 623,000 gal. of perched zone water flowed out of screens 1 and 2 and accumulated in screen 3 before it was isolated by installation of a packer. This large amount of water could not be easily removed from screen 3 through normal pumping development, and screen 3 was abandoned in December 2007. Monitoring of the regional aquifer that formerly took place in screen 3 at R-12 now takes place at well R-36 that was installed in February 2008.
Additives Used		Municipal water during drilling and well construction EZ-MUD QUIK-FOAM TORKEASE
Annular fill other than Filter and Transition Sands		Bentonite was placed above and below the filter packs to isolate the well screens and to seal off the perched zones from the regional aquifer as well as unsaturated portions of the vadose zone. The upper 70 ft of the well was cemented in place to provide a surface seal, and cement was placed between 580 and 583 ft to provide a stable platform for annular materials above.

Characterization Well R-12:

Location: TA-72, Sandia Canyon near the eastern Lab boundary

Ground surface elevation: 6501 ft asl
NAD 83 Survey coordinates (center top of protective box):
- x: 1647424.2 y: 1767913.4
- z: 6499.6 ft asl

Drilling: air rotary with casing advance/fluid-assisted air rotary
- Phase 1 Start date: 3/10/98
- Phase 1 End date: 6/8/98
- Phase 2 Start date: 10/25/99
- Phase 2 End date: 1/10/00

Borehole drilled to 886 ft

Data collection:
- Total core collected: 11.4 % of R-12; 26.4% for this location when core from SCOI-3 included.
- Hydrologic properties:
  - Moisture content/matric potential (112/111)
  - Pore water anions (73) and isotopes (4)
  - Samples for hydraulic properties analyses:
    - 1 from Cerros del Rio basalt
    - 1 from Puye Fm
    - 2 from Old Alluvium
- Field Hydraulic Testing: none
- Cores/cuttings submitted for geochemical and contaminant characterization: (14)
- Groundwater samples submitted for geochem and cont. characterization: (4)
- Geologic properties:
  - Mineralogy, petrography, and chemistry (23)
- Borehole logs:
  - Lithologic (0-847 ft)
  - Video (0-182 ft)
  - Caliper (inside 10-3/4 in casing)
  - Natural gamma (0-640 ft; cased)

Contaminants Detected in Borehole Samples:
- Perched groundwater: uranium (?), nitrate, ammonia, tritium, chloride
- Regional groundwater: tritium, uranium (?), nitrogen isotopes indicate sewage influence
  - Cuttings/Core: $Pu^{239/240}$, Am^{241} (?)

Compilation of data collection and analyses results: LA-UR-00-3785

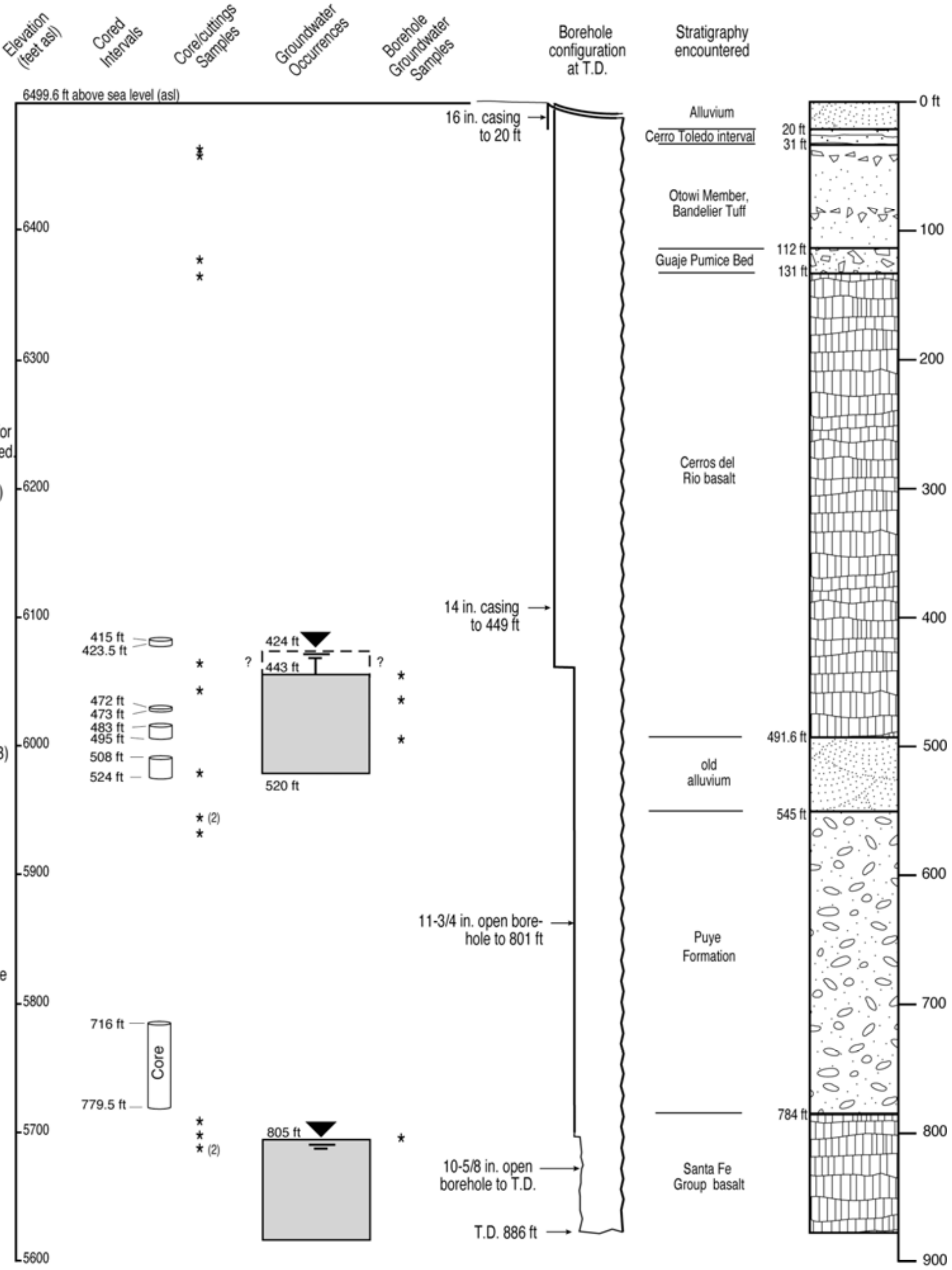
Well construction:
- Drilling Completed: 1/10/00
- Well Installed: 1/24/00
- Well Developed: 2/6/00
- Westbay Installed: 3/21/00

Casing: 4.3-in I.D. mild steel to 354 ft; 4.5-in I.D. stainless steel from 354 ft to 869 ft

Number of Screens: 3
4.5-in I.D. ss; 0.010-in slot for screens #1 and #3; 0.005-in for screen #2

Screen placements:
- Screen #1 - 459 ft to 467.5 ft
- Screen #2 - 504.5 ft to 508 ft
- Screen #3 - 801 ft to 839 ft

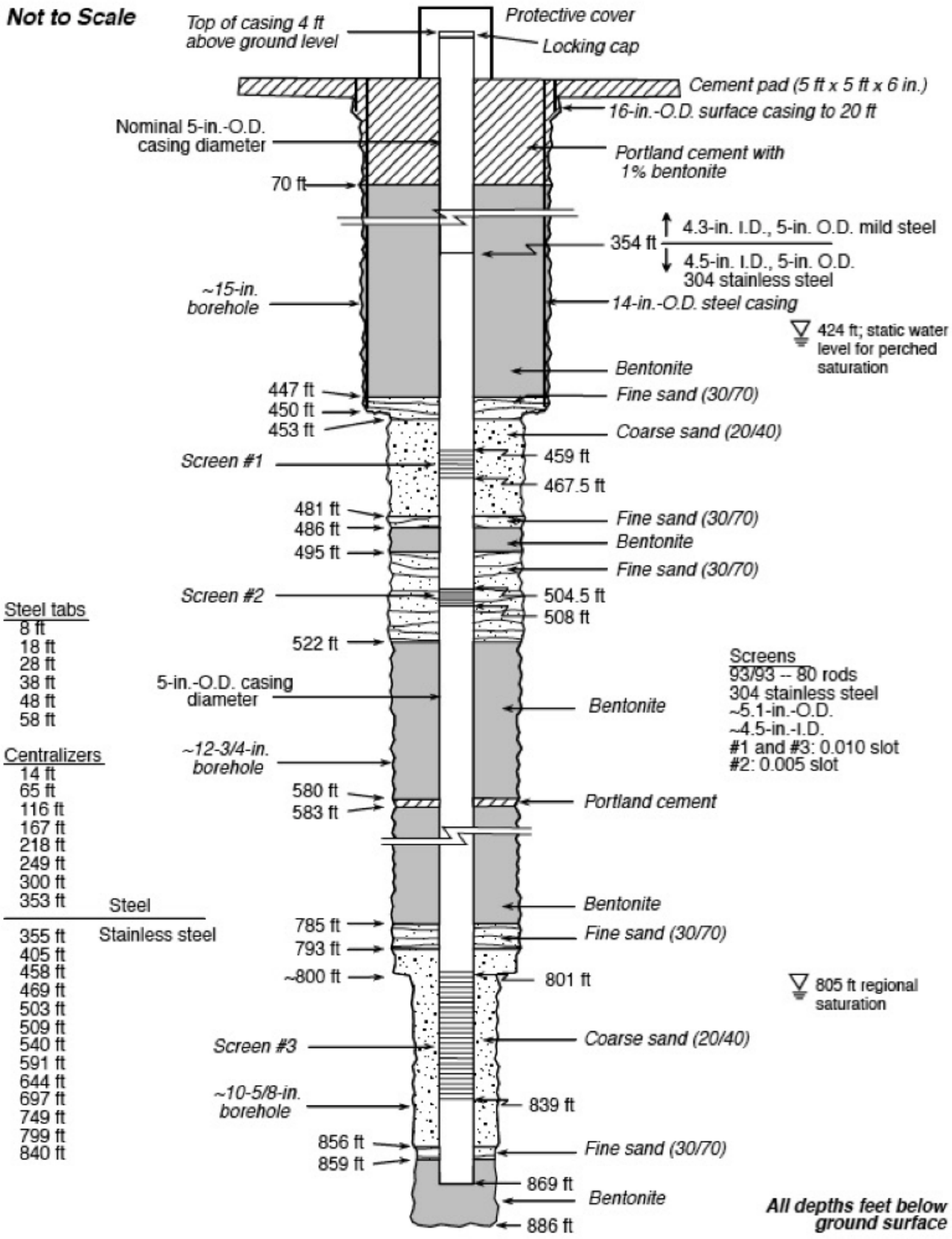
Well development consisted of jetting and pumping each screen and pumping the sump.



Groundwater occurrences were determined by recognition first water produced while drilling with air. Static water levels were determined after the borehole was rested. During Phase I drilling, the upper perched zone was isolated from the lower vadose zone by landing 10-3/4 in. casing in clay-rich deposits at 520.5 ft and drilling ahead with 8-5/8 in. casing-advance drill system.

Geologic contacts determined by examination of cuttings and core, interpretation of natural gamma logs, and analysis of geologic samples by petrography and rock chemistry.

Construction, stratigraphic, and hydrologic information for well R-12



Note: Depths for screens are for actual screen intervals, not joints.

F8.1-2 / R-12 WELL COMPLETION RPT / 082400 / PTM

As-built completion diagram of well R-12

R-35a and R-35b Wells

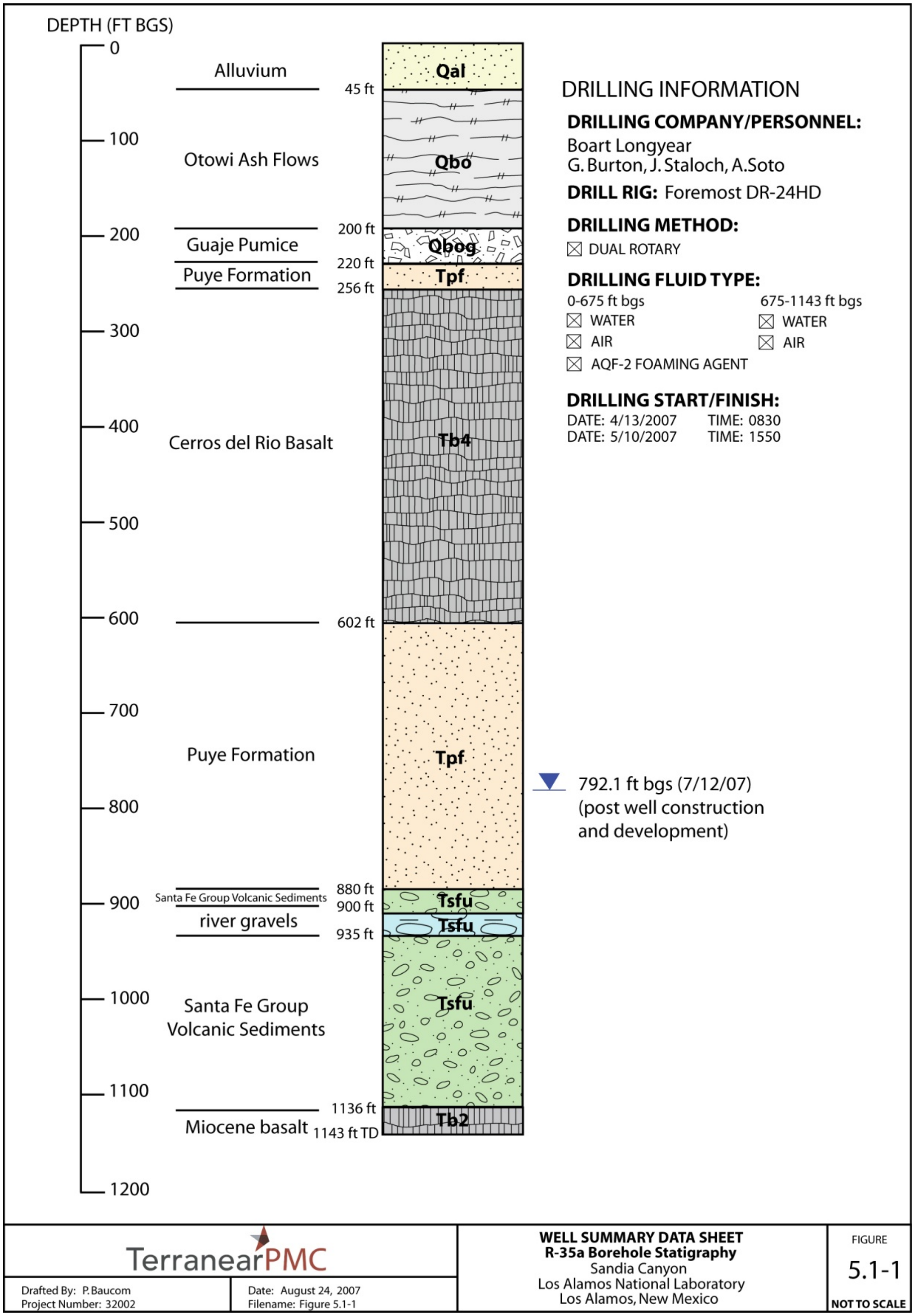
R-35a and R-35b Wells

	Description	Evaluation
Drilling Method	R-35a was drilled to a 765-ft depth using fluid-assisted air-rotary methods with nested casing advance (16-in. casing to 262-ft depth, 12-in. casing to 940 ft, 10-in. casing to TD at 1143 ft). Both tricone bits and down-the-hole hammers were used. R-35b was also drilled using fluid-assisted air-rotary methods with nested casing advance (16-in. casing to 266-ft depth, 10-in. casing to TD at 892 ft). Both tricone bits and down-the-hole hammers were used.	No core was collected at either R-35a or R-35b. Some bucket collections of the total cuttings stream were made within Puye Formation fanglomerates and Santa Fe Group sediments at R-35a. Drilling of the R-35a and b set of wells was conducted in three stages. First, R-35b was drilled to the top of the Cerros del Rio lavas at 266-ft depth, where examination for perched water was conducted (results were negative). Second, R-35a was drilled to TD of 1143 ft. Third, the drill rig returned to R-35b to reach TD of 892 ft. R-35a was drilled using air rotary with tricone and down-the-hole hammer bits. Fluid additives were limited to municipal water and AQF-2 foaming agent to 676-ft depth; only municipal water was used from 676 ft to the water table at 786 ft, and no fluids were added from 786 ft to TD at 1143 ft. R-35a was designed as a single-screen well. R-35b was drilled using air rotary with tricone and down-the-hole hammer bits. Fluid additives were limited to municipal water and AQF-2 foaming agent to 603-ft depth; only municipal water was used from 603 ft to the water table at 788 ft, and no fluids were added from 788 ft to TD at 892 ft. R-35b was designed as a single-screen well.
General Well Characteristics	R-35a and R-35b are both single-screen wells constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The rod-based wire-wrapped screens are constructed of 4.46-in.-I.D./5.27-in.-O.D. 304 stainless steel with stainless-steel wire wrap having 0.020-in. slots.	Rod-based screen provides extensive, uniformly distributed openings for access to the filter pack during development. Also, the 0.020-in. slots in the R-35a and R-35b screens allow greater water movement during development than 0.010-in. slots.
Screen Length and Placement	The screen at R-35a is 49.1 ft long, placed from 1013.1- to 1062.2-ft depth. The top of this screen is 220 ft below the water table (793.1-ft depth). The top of the screen at R-35a is 43 ft below the top of the louvers at production well PM-3, which is ~500 ft to the east.	Puye Formation fanglomerates are from 602- to 880-ft depth; the pumiceous unit of the upper Santa Fe Group is from 880- to 900-ft depth; Santa Fe Group sands and gravels are from 900- to 1141-ft depth; Miocene basalt is from 1141 ft to R-35a TD at 1143 ft. At R-35a, a video log was run by the Laboratory in open hole with the 16-in. casing pulled back above the Cerros del Rio lavas from 265- to 666-ft depth, with no indications of perched water. The Laboratory's induction tool was run from 265- to 670-ft depth, and the gamma tool was run from surface to 668-ft depth.

	Description	Evaluation
Screen Length and Placement (continued)	The screen at R-35b is 23.1 ft long, placed from 825.4- to 848.5-ft depth. The top of the upper screen is 36 ft below the water table (789.4-ft depth).	Schlumberger logging tools were run in R-35a to 1150-ft depth with casing in place. The tools used were TLD, NGS, ECS, and CHFR. A preliminary ELAN by Schlumberger was used to refine screen placement at R-35a. At R-35b, two video logs were run by the Laboratory in open hole with the 16-in. casing pulled back above the Cerros del Rio lavas, on April 11, 2007, from 269- to 585-ft depth where foam had accumulated, and on April 12, 2007, to 603 ft after defoamer had been added, with no indication of perched water. The Laboratory's induction tool was run from 269- to 611-ft depth. The Laboratory's gamma tool was run twice, from surface to 611-ft depth on April 12, 2007, and from surface to 901-ft depth on May 22, 2007. Schlumberger logging tools were not run in R-35b. **R-35a screen placement:** The driving goal of screen placement at R-35a is to provide a monitoring point for chromium contamination that may be moving at depth from upgradient sources toward the production louvers at well PM-3. Elevated chromium was not observed in any of the borehole water samples collected during drilling of R-35a, but above background concentrations of molybdenum, chlorine, sulfate, and nitrate indicated that anthropogenic sources may be reaching this site. The elevated molybdenum concentrations have not been replicated in samples from the completed well. The screen at R-35a was located with the following goals in mind: A monitoring point is provided at a depth within the range of louvers at production well PM-3, which is ~500 ft to the east. The screen of 1013.1 to 1062.2 ft targets the zone that includes some of the highest molybdenum concentrations as measured in borehole screening samples collected at depths opposite the louvers at PM-3. Molybdenum concentrations in this interval are variable, ranging from 14 to 90 ppb or µg/L, but these values are not replicated in the completed well. The screen depth of 1013.1 to 1062.2 ft targets the zone below 1000-ft depth where both driller observations and Schlumberger analysis indicate that flow is enhanced opposite the louvers at PM-3. **R-35b screen placement:** The driving goal of screen placement at R-35b is to provide a monitoring point for chromium contamination that may be moving near the top of regional saturation from western sources. Elevated chromium was not observed in any of the water samples collected during drilling of R-35b, but elevated molybdenum concentrations in borehole screening samples indicated that anthropogenic sources were reaching this site. The elevated molybdenum concentrations have not been replicated in samples from the completed well, and additional data from samples collected over a longer time period are needed. The screen at R-35b was located with the following goals in mind: Sufficient depth was provided beneath the top of regional saturation for aggressive screen development and sufficient screen length to allow future sampling despite drawdown of the regional aquifer over the life of the well.

	Description	Evaluation
Screen Length and Placement (continued)		The screen depth of 825.4 to 848.5 ft targets the zone that includes some of the highest molybdenum concentrations observed in sampling during the drilling of either R-35a or R-35b. Molybdenum concentrations in this interval range to >100 ppb or µg/L, but these values are not replicated in the completed well and additional data are needed. The screen depth of 825.4 to 848.5 ft targets two gravel zones at 820–830 ft and 835–840 ft where driller observations suggest that flow first increases below the top of regional saturation and Schlumberger analysis at nearby R-35a indicates that flow is enhanced.
Filter Pack Materials and Placement	The primary filter packs are made up of 10/20 sand. Secondary sand collars are made up of 20/40 sand. At R-35a, the primary filter pack is at 1007.2 to 1066.4 ft, and the upper secondary sand filter pack is at 1005.2 to 1007.2 ft. There is no lower secondary sand filter pack. At R-35b, the primary filter pack is at 820.1 to 854.6 ft, and the upper secondary sand filter pack is at 817.2 to 820.1 ft. There is no lower secondary sand filter pack.	At R-35a, the primary filter pack extends 5.9 ft above the screen openings and 4.2 ft below. At R-35b, the primary filter pack extends 5.3 ft above the screen openings and 6.1 ft below.
Sampling System	Submersible Pump	Both R-35a and R-35b are installed with submersible pumps. Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allows water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well		Approximately 1200 gal. of high-solids bentonite grout loss to the formation was recorded at the R-35a location. Although a small amount of bentonite (~2 gal.) was recovered from the well sump, it is assumed that the majority of this lost material entered a permeable zone or zones within the aquifer. These losses are thought to have occurred primarily at or near the depths of 940 ft and 850 ft bgs. Conditions recorded in the field and the Laboratory natural gamma log support this determination.

	Description	Evaluation
Additives Used		**R-35a** Municipal water added during drilling: 23,200 gal. (~11,000 gal. returned to cuttings pit) Municipal water added during well construction (19,000 gal.) Baroid AQF-2 foaming agent (215 gal.). Additive use was limited to intervals >100 ft above the regional aquifer. **R-35b** Municipal water added during drilling: 11,400 gal. (~2,500 gal. returned to cuttings pit) Municipal water added during well construction (11,400 gal.) Baroid AQF-2 foaming agent (204 gal.). Additive use was limited to intervals >100 ft above the regional aquifer.
Annular Fill other than Filter and Transition Sands		**R-35a** Bentonite seal: 569.9 ft3 chips and 443.8 ft3 high-solids grout Surface seal of cement slurry (240.6 ft3) **R-35b** Bentonite seal: 543 ft3 chips and 82.9 ft3 high-solids grout Surface seal of cement slurry (298.8 ft3)
Water Produced on Development and Testing		**R-35a** Well development (32,032 gal.) Aquifer testing (33,400 gal.) **R-35b** Well development (21,090 gal.) Aquifer testing (36,000 gal.)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL:
Boart Longyear
G. Burton, J. Staloch, A.Soto

DRILL RIG: Foremost DR-24HD

DRILLING METHOD:
☒ DUAL ROTARY

DRILLING FLUID TYPE:

0-675 ft bgs	675-1143 ft bgs
☒ WATER	☒ WATER
☒ AIR	☒ AIR
☒ AQF-2 FOAMING AGENT	

DRILLING START/FINISH:
DATE: 4/13/2007 TIME: 0830
DATE: 5/10/2007 TIME: 1550

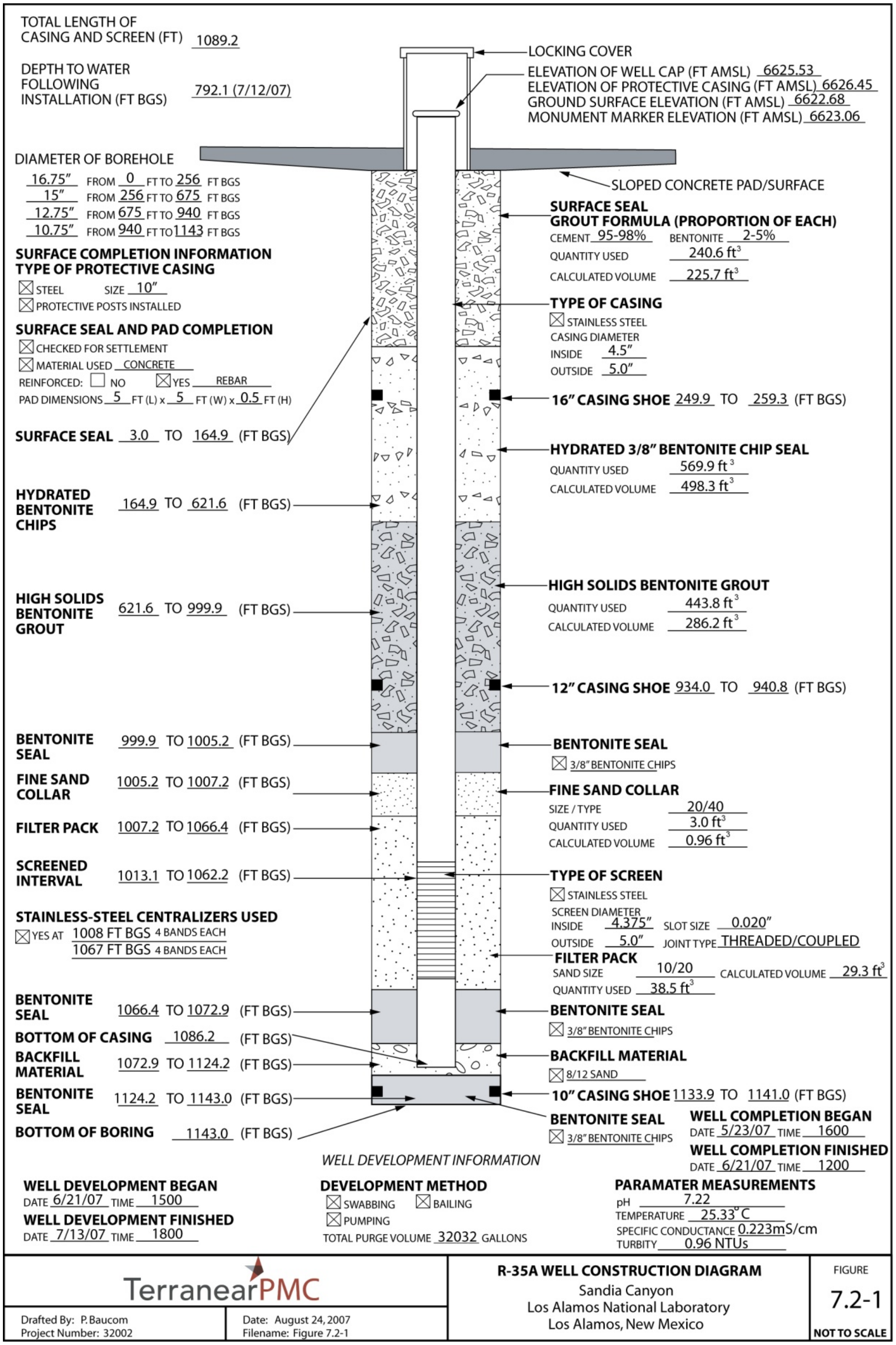
Drafted By: P. Baucom
Project Number: 32002

Date: August 24, 2007
Filename: Figure 5.1-1

WELL SUMMARY DATA SHEET
R-35a Borehole Statigraphy
Sandia Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
5.1-1
NOT TO SCALE

Borehole summary data sheet, regional well R-35a



TOTAL LENGTH OF CASING AND SCREEN (FT) 1089.2

DEPTH TO WATER FOLLOWING INSTALLATION (FT BGS) 792.1 (7/12/07)

LOCKING COVER

ELEVATION OF WELL CAP (FT AMSL) 6625.53

ELEVATION OF PROTECTIVE CASING (FT AMSL) 6626.45

GROUND SURFACE ELEVATION (FT AMSL) 6622.68

MONUMENT MARKER ELEVATION (FT AMSL) 6623.06

DIAMETER OF BOREHOLE

16.75" FROM 0 FT TO 256 FT BGS

15" FROM 256 FT TO 675 FT BGS

12.75" FROM 675 FT TO 940 FT BGS

10.75" FROM 940 FT TO 1143 FT BGS

SLOPED CONCRETE PAD/SURFACE

SURFACE COMPLETION INFORMATION

TYPE OF PROTECTIVE CASING

☒ STEEL SIZE 10"

☒ PROTECTIVE POSTS INSTALLED

SURFACE SEAL AND PAD COMPLETION

☒ CHECKED FOR SETTLEMENT

☒ MATERIAL USED CONCRETE

REINFORCED: ☐ NO ☒ YES REBAR

PAD DIMENSIONS 5 FT (L) x 5 FT (W) x 0.5 FT (H)

SURFACE SEAL

GROUT FORMULA (PROPORTION OF EACH)

CEMENT 95-98% BENTONITE 2-5%

QUANTITY USED 240.6 ft^3

CALCULATED VOLUME 225.7 ft^3

TYPE OF CASING

☒ STAINLESS STEEL

CASING DIAMETER

INSIDE 4.5"

OUTSIDE 5.0"

16" CASING SHOE 249.9 TO 259.3 (FT BGS)

SURFACE SEAL 3.0 TO 164.9 (FT BGS)

HYDRATED 3/8" BENTONITE CHIP SEAL

QUANTITY USED 569.9 ft^3

CALCULATED VOLUME 498.3 ft^3

HYDRATED BENTONITE CHIPS 164.9 TO 621.6 (FT BGS)

HIGH SOLIDS BENTONITE GROUT

QUANTITY USED 443.8 ft^3

CALCULATED VOLUME 286.2 ft^3

HIGH SOLIDS BENTONITE GROUT 621.6 TO 999.9 (FT BGS)

12" CASING SHOE 934.0 TO 940.8 (FT BGS)

BENTONITE SEAL 999.9 TO 1005.2 (FT BGS)

BENTONITE SEAL

☒ 3/8" BENTONITE CHIPS

FINE SAND COLLAR 1005.2 TO 1007.2 (FT BGS)

FINE SAND COLLAR

SIZE / TYPE 20/40

QUANTITY USED 3.0 ft^3

CALCULATED VOLUME 0.96 ft^3

FILTER PACK 1007.2 TO 1066.4 (FT BGS)

SCREENED INTERVAL 1013.1 TO 1062.2 (FT BGS)

TYPE OF SCREEN

☒ STAINLESS STEEL

SCREEN DIAMETER

INSIDE 4.375" SLOT SIZE 0.020"

OUTSIDE 5.0" JOINT TYPE THREADED/COUPLED

STAINLESS-STEEL CENTRALIZERS USED

☒ YES AT 1008 FT BGS 4 BANDS EACH

1067 FT BGS 4 BANDS EACH

FILTER PACK

SAND SIZE 10/20 CALCULATED VOLUME 29.3 ft^3

QUANTITY USED 38.5 ft^3

BENTONITE SEAL 1066.4 TO 1072.9 (FT BGS)

BENTONITE SEAL

☒ 3/8" BENTONITE CHIPS

BOTTOM OF CASING 1086.2 (FT BGS)

BACKFILL MATERIAL 1072.9 TO 1124.2 (FT BGS)

BACKFILL MATERIAL

☒ 8/12 SAND

BENTONITE SEAL 1124.2 TO 1143.0 (FT BGS)

10" CASING SHOE 1133.9 TO 1141.0 (FT BGS)

BOTTOM OF BORING 1143.0 (FT BGS)

BENTONITE SEAL

☒ 3/8" BENTONITE CHIPS

WELL COMPLETION BEGAN

DATE 5/23/07 TIME 1600

WELL COMPLETION FINISHED

DATE 6/21/07 TIME 1200

WELL DEVELOPMENT INFORMATION

WELL DEVELOPMENT BEGAN

DATE 6/21/07 TIME 1500

WELL DEVELOPMENT FINISHED

DATE 7/13/07 TIME 1800

DEVELOPMENT METHOD

☒ SWABBING ☒ BAILING

☒ PUMPING

TOTAL PURGE VOLUME 32032 GALLONS

PARAMATER MEASUREMENTS

pH 7.22

TEMPERATURE 25.33° C

SPECIFIC CONDUCTANCE 0.223mS/cm

TURBITY 0.96 NTUs

TerranearPMC

Drafted By: P. Baucom

Project Number: 32002

Date: August 24, 2007

Filename: Figure 7.2-1

R-35A WELL CONSTRUCTION DIAGRAM

Sandia Canyon

Los Alamos National Laboratory

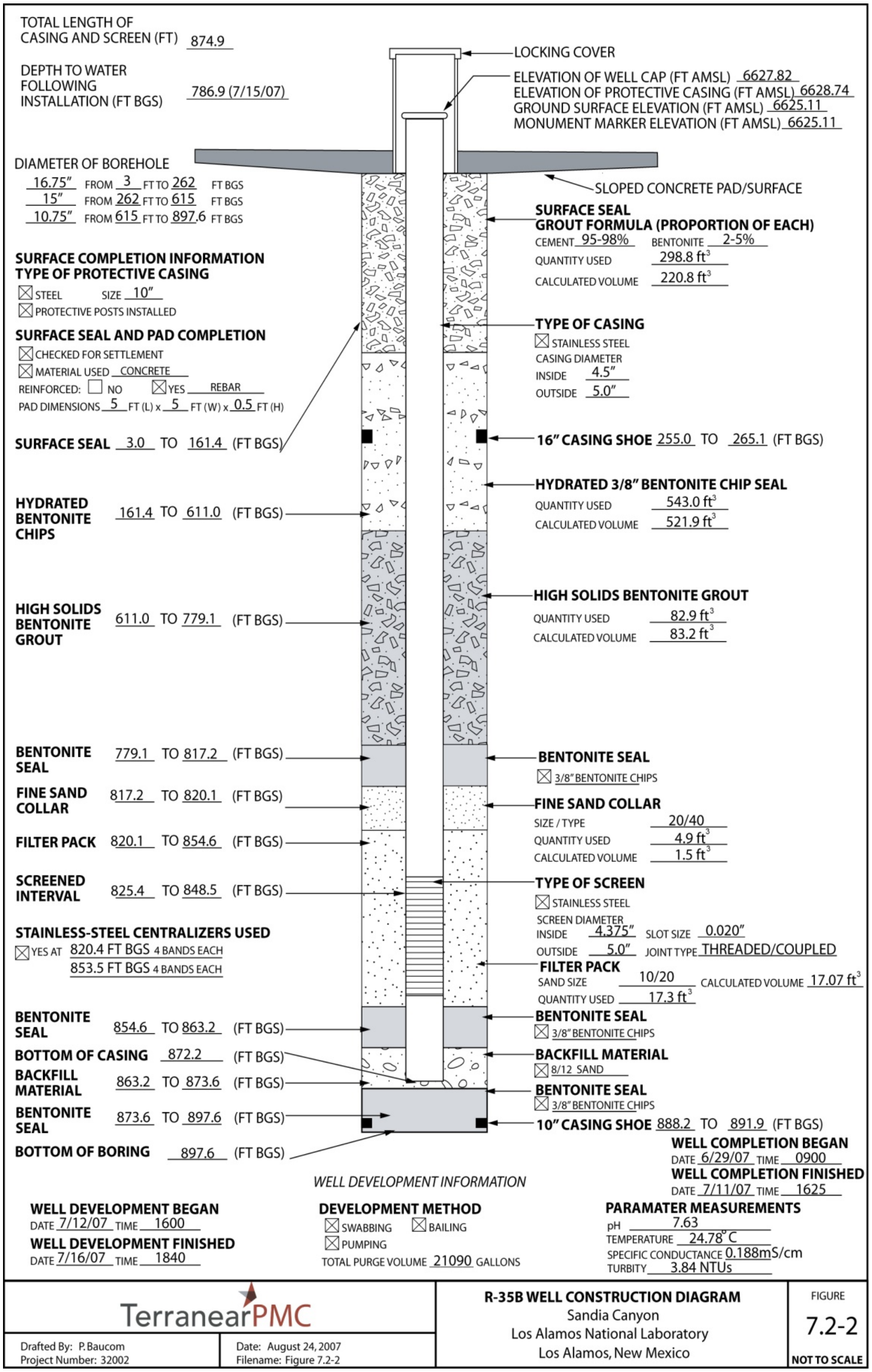
Los Alamos, New Mexico

FIGURE

7.2-1

NOT TO SCALE

As-built well completion diagram for well R-35a



TOTAL LENGTH OF CASING AND SCREEN (FT) 874.9

DEPTH TO WATER FOLLOWING INSTALLATION (FT BGS) 786.9 (7/15/07)

DIAMETER OF BOREHOLE
16.75" FROM 3 FT TO 262 FT BGS
15" FROM 262 FT TO 615 FT BGS
10.75" FROM 615 FT TO 897.6 FT BGS

SURFACE COMPLETION INFORMATION
TYPE OF PROTECTIVE CASING
☒ STEEL SIZE 10"
☒ PROTECTIVE POSTS INSTALLED

SURFACE SEAL AND PAD COMPLETION
☒ CHECKED FOR SETTLEMENT
☒ MATERIAL USED CONCRETE
REINFORCED: ☐ NO ☒ YES REBAR
PAD DIMENSIONS 5 FT (L) x 5 FT (W) x 0.5 FT (H)

SURFACE SEAL 3.0 TO 161.4 (FT BGS)

HYDRATED BENTONITE CHIPS 161.4 TO 611.0 (FT BGS)

HIGH SOLIDS BENTONITE GROUT 611.0 TO 779.1 (FT BGS)

BENTONITE SEAL 779.1 TO 817.2 (FT BGS)

FINE SAND COLLAR 817.2 TO 820.1 (FT BGS)

FILTER PACK 820.1 TO 854.6 (FT BGS)

SCREENED INTERVAL 825.4 TO 848.5 (FT BGS)

STAINLESS-STEEL CENTRALIZERS USED
☒ YES AT 820.4 FT BGS 4 BANDS EACH
853.5 FT BGS 4 BANDS EACH

BENTONITE SEAL 854.6 TO 863.2 (FT BGS)

BOTTOM OF CASING 872.2 (FT BGS)

BACKFILL MATERIAL 863.2 TO 873.6 (FT BGS)

BENTONITE SEAL 873.6 TO 897.6 (FT BGS)

BOTTOM OF BORING 897.6 (FT BGS)

LOCKING COVER

ELEVATION OF WELL CAP (FT AMSL) 6627.82
ELEVATION OF PROTECTIVE CASING (FT AMSL) 6628.74
GROUND SURFACE ELEVATION (FT AMSL) 6625.11
MONUMENT MARKER ELEVATION (FT AMSL) 6625.11

SLOPED CONCRETE PAD/SURFACE

SURFACE SEAL
GROUT FORMULA (PROPORTION OF EACH)
CEMENT 95-98% BENTONITE 2-5%
QUANTITY USED 298.8 ft^3
CALCULATED VOLUME 220.8 ft^3

TYPE OF CASING
☒ STAINLESS STEEL
CASING DIAMETER
INSIDE 4.5"
OUTSIDE 5.0"

16" CASING SHOE 255.0 TO 265.1 (FT BGS)

HYDRATED 3/8" BENTONITE CHIP SEAL
QUANTITY USED 543.0 ft^3
CALCULATED VOLUME 521.9 ft^3

HIGH SOLIDS BENTONITE GROUT
QUANTITY USED 82.9 ft^3
CALCULATED VOLUME 83.2 ft^3

BENTONITE SEAL
☒ 3/8" BENTONITE CHIPS

FINE SAND COLLAR
SIZE / TYPE 20/40
QUANTITY USED 4.9 ft^3
CALCULATED VOLUME 1.5 ft^3

TYPE OF SCREEN
☒ STAINLESS STEEL
SCREEN DIAMETER
INSIDE 4.375" SLOT SIZE 0.020"
OUTSIDE 5.0" JOINT TYPE THREADED/COUPLED

FILTER PACK
SAND SIZE 10/20 CALCULATED VOLUME 17.07 ft^3
QUANTITY USED 17.3 ft^3

BENTONITE SEAL
☒ 3/8" BENTONITE CHIPS

BACKFILL MATERIAL
☒ 8/12 SAND

BENTONITE SEAL
☒ 3/8" BENTONITE CHIPS

10" CASING SHOE 888.2 TO 891.9 (FT BGS)

WELL COMPLETION BEGAN
DATE 6/29/07 TIME 0900
WELL COMPLETION FINISHED
DATE 7/11/07 TIME 1625

WELL DEVELOPMENT INFORMATION

WELL DEVELOPMENT BEGAN
DATE 7/12/07 TIME 1600
WELL DEVELOPMENT FINISHED
DATE 7/16/07 TIME 1840

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
☒ PUMPING
TOTAL PURGE VOLUME 21090 GALLONS

PARAMATER MEASUREMENTS
pH 7.63
TEMPERATURE 24.78° C
SPECIFIC CONDUCTANCE 0.188mS/cm
TURBITY 3.84 NTUs

TerranearPMC

Drafted By: P. Baucom
Project Number: 32002

Date: August 24, 2007
Filename: Figure 7.2-2

R-35B WELL CONSTRUCTION DIAGRAM
Sandia Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
7.2-2
NOT TO SCALE

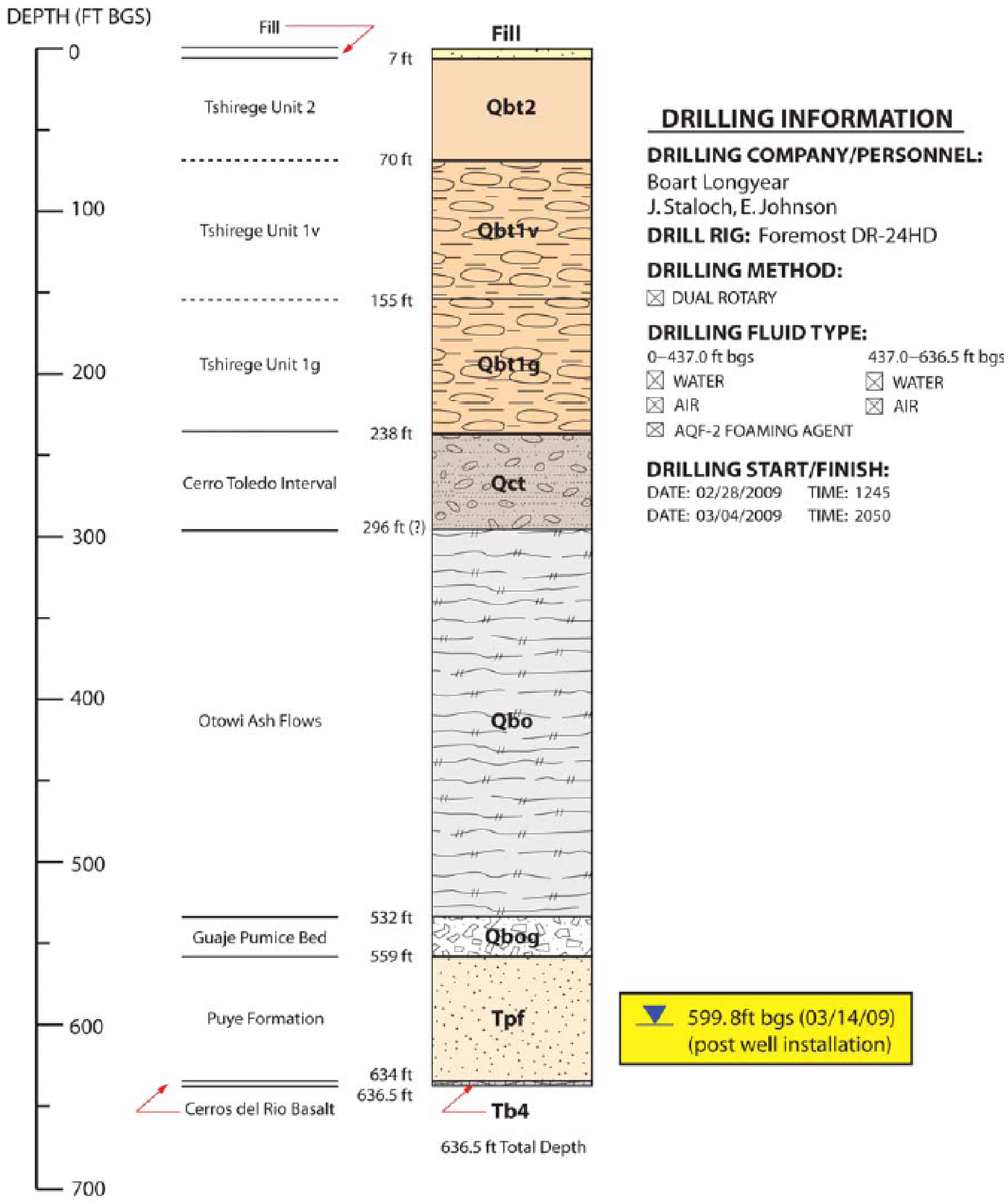
As-built well completion diagram for well R-35b

TA-53i Well

TA-53i Well

	Description	Evaluation
Drilling Method	TA-53i was drilled using fluid-assisted air-rotary casing advance methods.	TA-53i was drilled by dual-rotary air-drilling methods using a Foremost DR-24HD drill rig. The borehole reached a total depth of 636.5 ft by advancing 16-in. and 12-in. drill casing. Drilling fluids, other than air, used within the vadose zone included municipal water and a mixture of municipal water with Baroid AQF-2 foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of the foaming agent was terminated at 437.0 ft bgs, 163.5 ft above the perched groundwater horizon. No additives other than municipal water were used for drilling below this depth (437.0 ft bgs).
General Well Characteristics	TA-53i is a single-screen well constructed of 5-in.-I.D./5.56-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 5-in. I.D./5.88 O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The TA-53i well screen construction (0.020-in. wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well and the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 600 to 610 ft and has a length of 10 ft. The top of the well screen is about 0.5 ft above the current water level of 600.5 ft below the surface (Koch and Schmeer 2010, 108926).	TA-53i is designed to provide water-quality and water-level data for the perched groundwater downgradient of TA-21, and the screen lengths and placements were selected with the following goals in mind: • Define the extent of perched-intermediate groundwater and contamination observed in Los Alamos Canyon at wells LADP-3, LAOI-3.2, LAOI-3.2a, and R-6i • Determine whether perched groundwater beneath the mesa communicates with perched groundwater zones observed to the south in Sandia Canyon (e.g., wells SCI-1 and SCI-2). • Monitor water levels to detect whether perched-intermediate groundwater responds to seasonal infiltration beneath Los Alamos Canyon Perched groundwater was encountered within the upper portion of the Puye Formation immediately above the Cerros del Rio basalt. A video log was run in the TA-53i borehole after the 12-in. drill casing was retracted to 615 ft, 21.5 ft above the bottom of the borehole. No water entry was observed over the open section of the borehole. The 12-in casing was then pulled back a total of 103 ft to 532.0 ft bgs to better allow water to enter the borehole, and the second video log revealed standing water at 600.0 ft bgs. The screen length and placement for TA-53i are appropriate for the conditions encountered at this location and meet the goals defined in the bullets above.

	Description	Evaluation
Filter Pack Materials and Placement	The primary filter pack consists of 10/20 sand from 598.2 to 612.2 ft. A secondary filter pack of 20/40 sand was placed above and below the primary filter pack from 594.6 to 598.2 ft and 612.2 to 613.2 ft, respectively.	The primary filter pack extends 1.8 ft above and 2.2 ft below the well screen. Placement of the filter pack is within the optimum design for the well screen.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well	None	n/a
Additives Used During Drilling		Air Municipal water used during drilling (6900 gal.) Baroid AQF-2 foaming agent (38 gal.)
Annular Fill other than Filter and Transition Sands		Bentonite seal: bentonite chips/pellets (213.2 ft3) Cement grout surface seal (592.6 ft3) Municipal water used during well construction (11,910 gal.) Water removed during well development (2600 gal.) Water removed during aquifer testing (2463 gal.)



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL:
Boart Longyear
J. Staloch, E. Johnson

DRILL RIG: Foremost DR-24HD

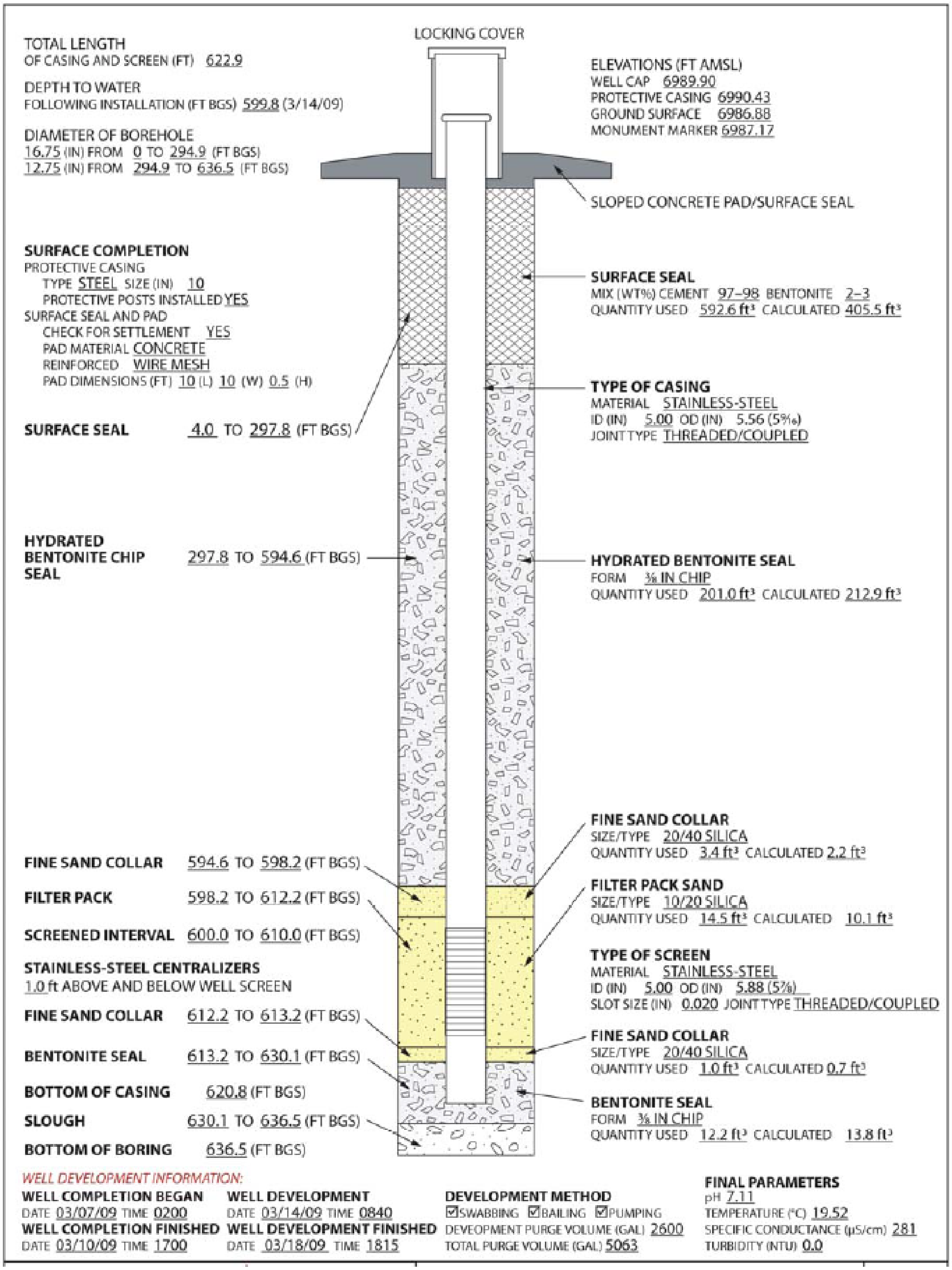
DRILLING METHOD:
☒ DUAL ROTARY

DRILLING FLUID TYPE:

0–437.0 ft bgs	437.0–636.5 ft bgs
☒ WATER	☒ WATER
☒ AIR	☒ AIR
☒ AQF-2 FOAMING AGENT	

DRILLING START/FINISH:
DATE: 02/28/2009 TIME: 1245
DATE: 03/04/2009 TIME: 2050

Borehole summary data sheet, intermediate well TA-53i



TOTAL LENGTH
OF CASING AND SCREEN (FT) 622.9

DEPTH TO WATER
FOLLOWING INSTALLATION (FT BGS) 599.8 (3/14/09)

DIAMETER OF BOREHOLE
16.75 (IN) FROM 0 TO 294.9 (FT BGS)
12.75 (IN) FROM 294.9 TO 636.5 (FT BGS)

ELEVATIONS (FT AMSL)
WELL CAP 6989.90
PROTECTIVE CASING 6990.43
GROUND SURFACE 6986.88
MONUMENT MARKER 6987.17

SURFACE COMPLETION
PROTECTIVE CASING
TYPE STEEL SIZE (IN) 10
PROTECTIVE POSTS INSTALLED YES
SURFACE SEAL AND PAD
CHECK FOR SETTLEMENT YES
PAD MATERIAL CONCRETE
REINFORCED WIRE MESH
PAD DIMENSIONS (FT) 10 (L) 10 (W) 0.5 (H)

SURFACE SEAL
MIX (WT%) CEMENT 97–98 BENTONITE 2–3
QUANTITY USED 592.6 ft³ CALCULATED 405.5 ft³

TYPE OF CASING
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.56 (5 9/16)
JOINT TYPE THREADED/COUPLED

SURFACE SEAL 4.0 TO 297.8 (FT BGS)

HYDRATED BENTONITE CHIP SEAL 297.8 TO 594.6 (FT BGS)

HYDRATED BENTONITE SEAL
FORM 3/8 IN CHIP
QUANTITY USED 201.0 ft³ CALCULATED 212.9 ft³

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED 3.4 ft³ CALCULATED 2.2 ft³

FILTER PACK SAND
SIZE/TYPE 10/20 SILICA
QUANTITY USED 14.5 ft³ CALCULATED 10.1 ft³

TYPE OF SCREEN
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.88 (5 7/8)
SLOT SIZE (IN) 0.020 JOINT TYPE THREADED/COUPLED

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED 1.0 ft³ CALCULATED 0.7 ft³

BENTONITE SEAL
FORM 3/8 IN CHIP
QUANTITY USED 12.2 ft³ CALCULATED 13.8 ft³

FINE SAND COLLAR 594.6 TO 598.2 (FT BGS)
FILTER PACK 598.2 TO 612.2 (FT BGS)
SCREENED INTERVAL 600.0 TO 610.0 (FT BGS)
STAINLESS-STEEL CENTRALIZERS
1.0 ft ABOVE AND BELOW WELL SCREEN
FINE SAND COLLAR 612.2 TO 613.2 (FT BGS)
BENTONITE SEAL 613.2 TO 630.1 (FT BGS)
BOTTOM OF CASING 620.8 (FT BGS)
SLOUGH 630.1 TO 636.5 (FT BGS)
BOTTOM OF BORING 636.5 (FT BGS)

WELL DEVELOPMENT INFORMATION:

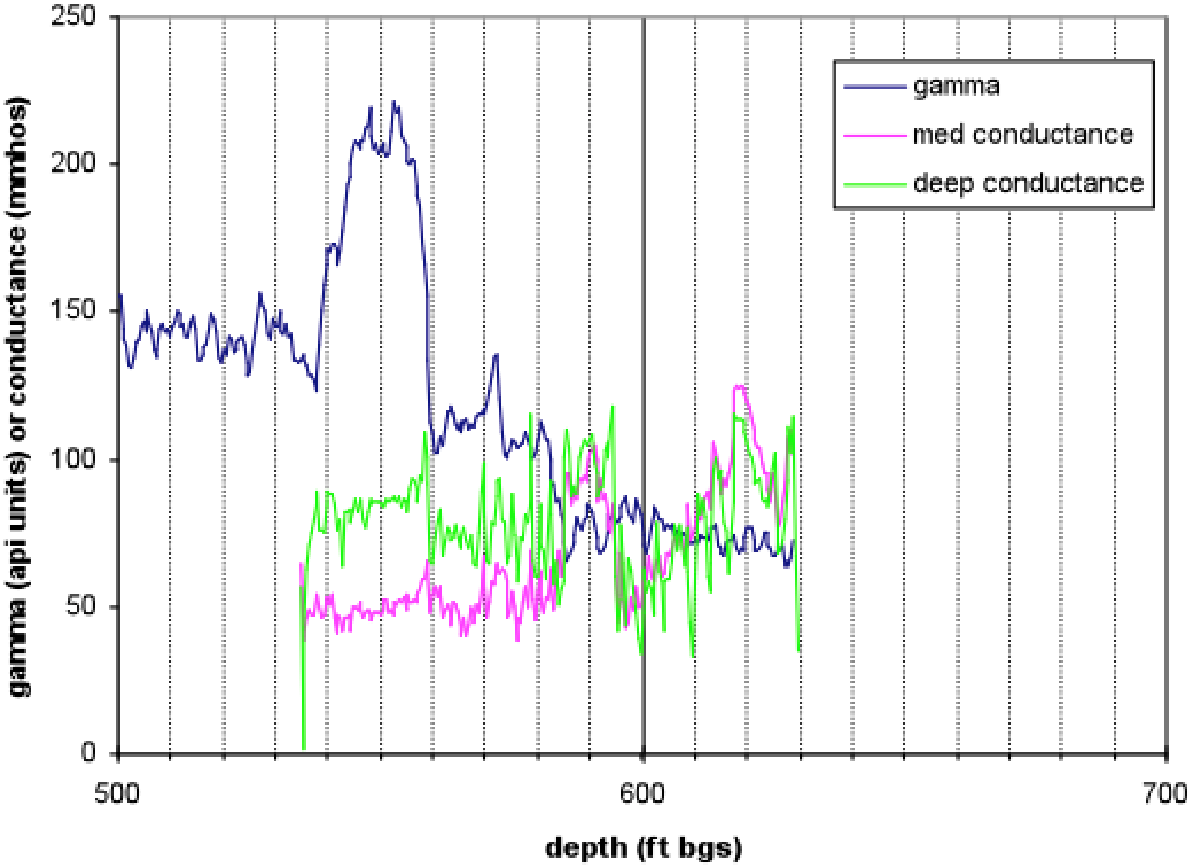
WELL COMPLETION BEGAN
DATE 03/07/09 TIME 0200
WELL COMPLETION FINISHED
DATE 03/10/09 TIME 1700

WELL DEVELOPMENT
DATE 03/14/09 TIME 0840
WELL DEVELOPMENT FINISHED
DATE 03/18/09 TIME 1815

DEVELOPMENT METHOD
☑SWABBING ☑BAILING ☑PUMPING
DEVEOPMENT PURGE VOLUME (GAL) 2600
TOTAL PURGE VOLUME (GAL) 5063

FINAL PARAMETERS
pH 7.11
TEMPERATURE (°C) 19.52
SPECIFIC CONDUCTANCE (µS/cm) 281
TURBIDITY (NTU) 0.0

Well schematic, intermediate well TA-53i



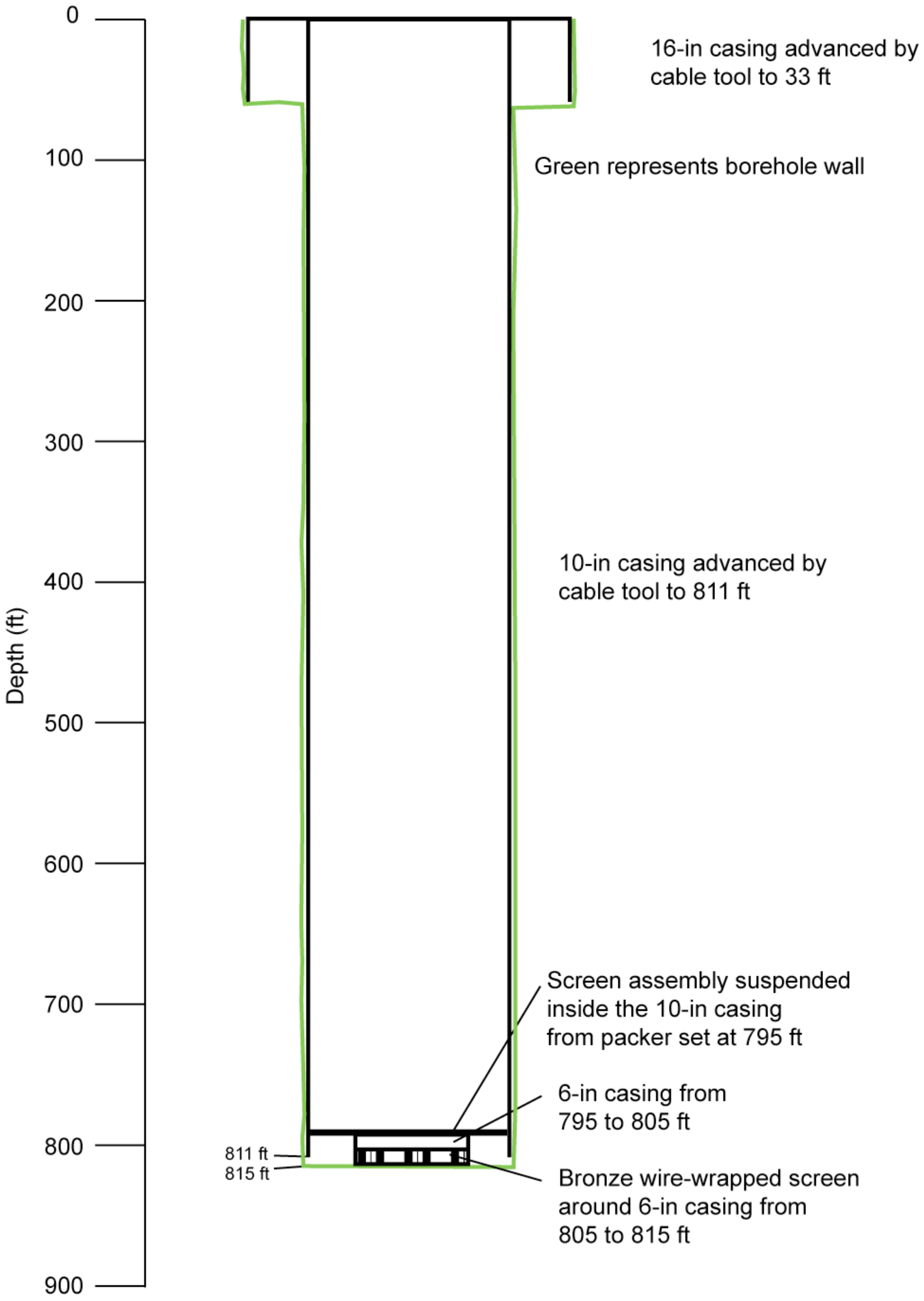
Combined geophysical logs for the lower portion of the TA-53i borehole

TW-3 Well

TW-3 Well

	Description	Evaluation
Drilling Method	TW-3 was drilled using a cable-tool method.	In 1949, TW-3 was drilled to a depth of 815 ft using the cable-tool method (Black and Veatch 1950, 008417; John et al. 1966, 008796; Purtymun 1995, 045344; Purtymun and Swanton 1998, 099096). The casing diameter is 16 in. to a depth of 33 ft and 10 in. from 33 to 811 ft. Open hole was drilled from 811 to 815 ft.
General Well Characteristics	TW-3 is a single-screen well. A 16-in. casing was set to a depth of 33 ft to seal out surface water. A 10-in.-I.D. steel casing was advanced inside the 16-in. casing to a depth of 811 ft. Open hole was drilled from 811 to 815 ft. Ten feet of 6-in.-I.D. steel casing was hung inside the 10-in. casing from 795 to 805 ft with a packer making a seal between the two casings at 795 ft. Ten feet of 6-in. Layne Western, Inc., well screen was suspended from 805 to 815 ft beneath the 6-in. casing.	The types of well materials used to construct TW-3 are not specified in reports documenting its installation. Use of carbon-steel drive and well casings was common practice during the time this was installed, and a well of this age is likely to be highly corroded. Furthermore, there is no annular fill outside the drive casings, although by nature cable-tool drilling usually results in a minimal annulus. The lack of annular fill for most of the length of the well means that the annulus between the well and borehole may act as a preferential pathway for movement of alluvial groundwater to the regional aquifer. Persistence of low-level tritium in groundwater from TW-3, coupled with the absence of contaminants in the properly constructed upgradient well R-6, suggests that contaminants may be leaking from the surface to the regional aquifer through pathways associated with the annulus of TW-3. Although no perched water was noted in 1949 when TW-3 was drilled, new shallow wells LAOI-3.2 and LAOI-3.2a (completed in 2005) sample perching horizons in the Guaje Pumice Bed and in the upper Puye Formation that have elevated tritium content, providing a likely source for contaminant flow along the annulus of TW-3. Because of its age, construction, and possible contribution to contamination in the regional aquifer, TW-3 should be plugged and abandoned as soon as possible.
Well Screen Construction	TW-3 was constructed with a bronze wire-wrapped well screen.	Wire-wrapped well screens are generally considered preferable to the pipe-based slotted screens for minimizing the amount of formation material drawn into the well during sampling. There is no information about the slot sizes of the well screen in reports describing the installation of this well. The 6-in. well screen overlaps the bottom of the 10-in. casing, and 4 ft of the well screen extends into open borehole below the bottom of the 10-in. casing.
Screen Length and Placement	The well screen extends from about 805 to 815 ft and has a length of 10 ft. The top of the well screen where it exits the 10-in. casing (811 ft) is submerged, approximately 24 ft below the current water table (currently about 787 ft below the surface).	TW-3 was installed primarily to provide a monitoring point for the regional aquifer below Los Alamos Canyon where contaminants derived from such sources as TA-21 and Manhattan Project–era buildings in the townsite could be entering the regional aquifer. The regional aquifer monitoring function of TW-3 is superseded by the installation of wells R-6 and R-8.

	Description	Evaluation
Filter Pack Materials and Placement	There is no record of a filter pack being installed at TW-3.	Over time, the open hole occupied by the well screen probably filled in with formation materials. This natural filter pack likely helps to minimize the amount of formation material drawn into the well during sampling.
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can be pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn from more deeply within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues that Could Affect the Performance of the Well	Corrosion of carbon-steel casing	Corrosion of carbon-steel casing could reduce the structural stability of the well string and affect the quality of groundwater sampled by the well. The geochemical evaluation of groundwater is a means for assessing corrosion of well materials (see Appendix B).
Additives Used	Probably none	Cable-tool drilling does not introduce drilling additives, except for a small amount of municipal water.
Annular Fill other than Filter and Transition Sands	There is no record of annular fill being installed at TW-3.	Most likely, no annular materials were introduced outside the 16-in. and 10-in. casings.



TW-3 well casing and screen construction

A-2.0 VAPOR-MONITORING WELLS AT TA-21

Vapor-monitoring wells have been installed at Material Disposal Area (MDA) T and MDA V according to various New Mexico Environment Department– (NMED-) approved work plans. Monitoring data have been collected from shortly following completion of the vapor wells to the present. Depending on the installation date, between two and over eight quarters of data have been collected and reported for MDA T, and three quarters of data have been collected and reported at MDA V.

A-2.1 Well Installation

Air-rotary and/or hollow-stem auger (HSA) drilling methods with appropriate casings and drill strings were used to advance boreholes to total depth (TD) below the ground surface. After TD was reached, the casing (or HSA) was pulled up and the borehole backfilled with a combination of 0.25-in.-diameter stainless-steel tubing, bentonite pellets, and silica sand to create the desired sampling intervals.

A typical pore-gas vapor-monitoring well (Figure A-2.1-1) is equipped with multiple sampling ports consisting of a nominal 0.5-in.-diameter, 6-in.-long stainless-steel well screen connected to sample tubing extending to the ground surface. Up to nine sampling ports are installed at the elevations presented in Table A-2.1-1. The sample tubing consists of 0.25-in.-diameter stainless-steel connected with Swagelok fittings. Five-foot-thick sampling intervals are filled with 10/20 silica sand. Bentonite chips were tremied into the borehole and hydrated to isolate the sampling intervals. This process included the following general steps:

(1) Measure and record the TD of the borehole after slough is removed.

(2) Add bentonite pellets, hydrate using potable water, and measure and record the depth.

(3) Add approximately 2.5 ft of 10/20 silica sand to support the stainless-steel screen and measure and record the depth. The maximum silica sand interval is approximately 5 ft but may be adjusted based on the particular characteristics of the subsurface.

(4) Lower the sampling port and enough stainless-steel tubing and screen to reach top of silica sand and measure and record the depth.

(5) Add another 2.5 ft of 10/20 silica sand and measure and record the depth.

(6) Add enough bentonite pellets to reach the next screen location, measure and record the depth, and hydrate the pellets.

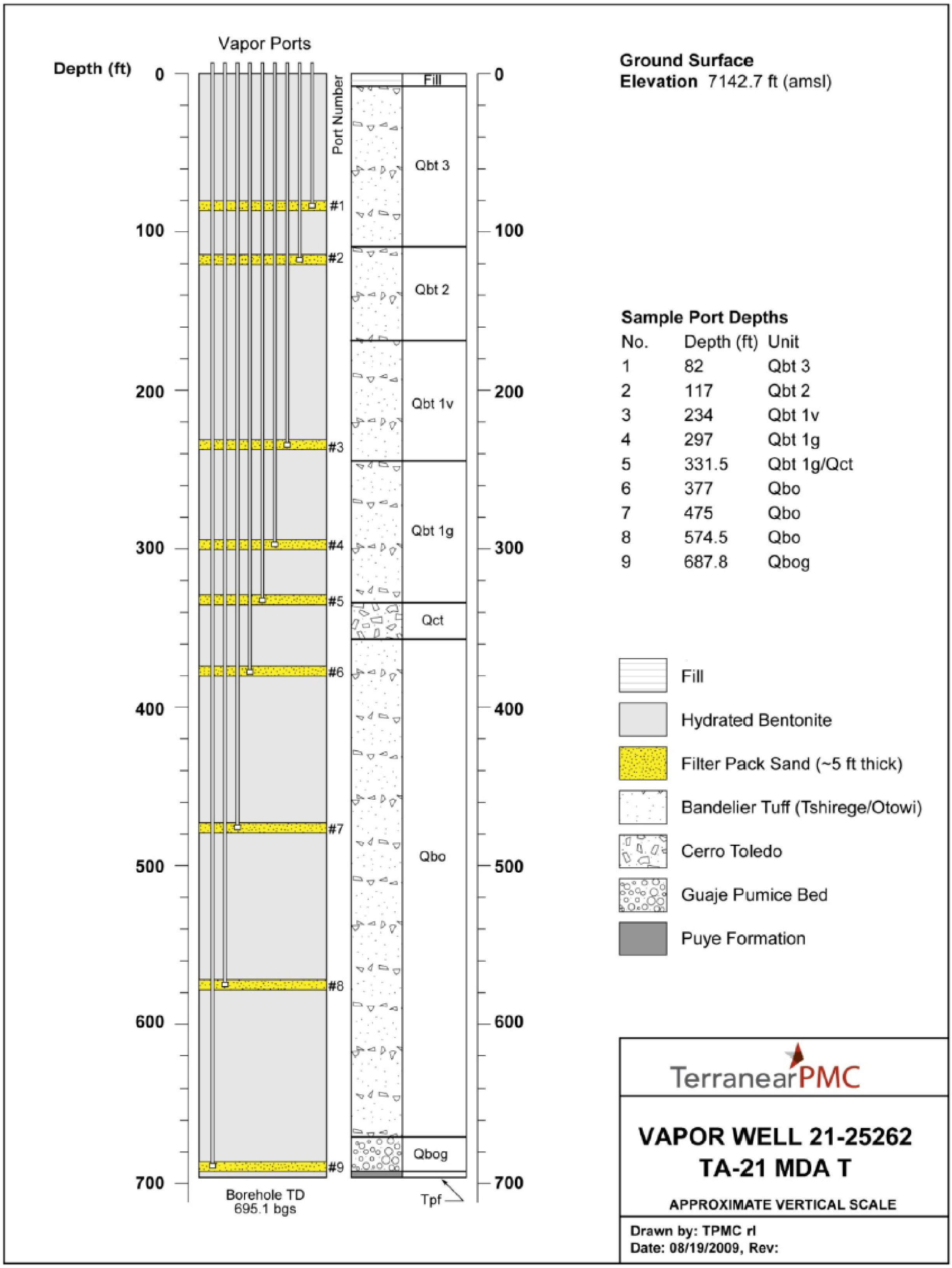
(7) Label the top of each stainless-steel tube to identify each screen and depth of screen.

(8) Repeat steps 3 through 7 until the ground surface is reached.

(9) Install a stainless-steel cap to contain the ends of the stainless-steel tubing.

(10) Complete a cement surface, including a locking steel cap.

It should be noted that in order to overcome difficulties of installing the individual ports and riser pipes in the deepest borehole at MDA T, all ports were attached to a 2-in.-diameter steel riser pipe lowered into the cased borehole prior to installing the intervals of sand pack and bentonite seals.



Sample Port Depths

No.	Depth (ft)	Unit
1	82	Qbt 3
2	117	Qbt 2
3	234	Qbt 1v
4	297	Qbt 1g
5	331.5	Qbt 1g/Qct
6	377	Qbo
7	475	Qbo
8	574.5	Qbo
9	687.8	Qbog

Figure A-2.1-1 Example vapor-monitoring well design, well 21-25262

Table A-2.1-1

Summary of TA-21 Existing and Planned Vapor-Monitoring Well Locations, Port Elevations, and Port Depths

Formation Name or Symbol	MDA T Location 21-603058 Surface Elev. 7135 ft		MDA T Location 21-25264 Surface Elev. 7126 ft		MDA T Location 21-25262 Surface Elev. 7143 ft		MDA T Location 21-607955 Surface Elev. 7130 ft		Planned MDA T Location Near Bldg. 21-257[a]		MDA T Location 21-603059 Surface Elev. 7141 ft		MDA V Location 21-24524 Surface Elev. 7167 ft	
	Elevation (ft)	**Depth (ft bgs)**	**Elevation (ft)**	**Depth (ft bgs)**	**Elevation (ft)**	**Depth (ft bgs)**	**Elevation (ft)**	**Depth (ft bgs)**	**Elevation (ft)**	**Depth (ft bgs)**	**Elevation (ft)**	**Depth (ft bgs)**	**Elevation (ft)**	**Depth (ft bgs)**
Qbt 3	7065	70	7056	70	7064	79	7064	66	TBD[b]	79	7061	80	7122	45
Qbt 2	—[c]	—	—	—	7029	114	7029	101	TBD	114	7026	115[d]	7042	125
Qbt 2	6972	163d	6973	153	—	—	—	—	—	—	6951	190		
Qbt 1v	—	—	—	—	6954	189	6954	176	TBD	189	6909	232	6992	175
Qbt 1g	6915.5	219.5	6901	225	6909	234	6909	221	TBD	234	6846	295	6907	260
Tsankawi Pumice Bed	—	—	—	—	6853	290	6853	277	TBD	290	—	—	6864.5	302.5
Qct	6793	342	6800	326	6800	343	6800	330	TBD	375	6766	375	6837	330
Qct[e]	—	—	6766	360	—	—	—	—	—	—	—	—	—	—
Qbof	—	—	—	—	6668	475	6668	462	TBD	475	—		6787	380
Qbof	—	—	—	—	6568	575	6568	562	TBD	575	—	—	—	—
Guaje Pumice Bed (Qbob)	—	—	—	—	6468	675	6468	662	TBD	675	—	—	6487	680
Puye (Tpf)	—	—	—	—	—	—	6330	800	—	—	—	—	6452	715
Puye (Tpf)	—	—	—	—	—	—	6180	950	—	—	—	—	—	—

[a] The number and depth of sampling ports are tentative pending results of DP Site Aggregate Area Phase II sampling and data analysis.

[b] TBD = To be determined.

[c] — = No port installed/proposed at this formation.

[d] Ports do not produce sufficient pore gas to yield a sample; this is likely due to the welded nature of the bedrock tuff. Operability is checked during each sampling event.

[e] An additional port was installed in the bottom of the borehole at an elevation of 6766 ft as required by the Compliance Order on Consent.

A-3.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Allen, S.P., and R.J. Koch, March 2007. "Groundwater Level Status Report for Fiscal Year 2006, Los Alamos National Laboratory," Los Alamos National Laboratory report LA-14331-PR, Los Alamos, New Mexico. (Allen and Koch 2007, 095268)

Black and Veatch, October 1950. "Report on Ground Water Observation Wells, Los Alamos, New Mexico," Black and Veatch Consulting Engineers, Kansas City, Missouri. (Black and Veatch 1950, 008417)

John, E.C., E.A. Enyart, and W.D. Purtymun (Comps.), October 1966. "Records of Wells, Test Holes, Springs, and Surface-Water Stations in the Los Alamos Area, New Mexico," U.S. Geological Survey Open-File Report, Albuquerque, New Mexico. (John et al. 1966, 008796)

Koch, R.J., and S. Schmeer, March 2010. "Groundwater Level Status Report for 2009, Los Alamos National Laboratory," Los Alamos National Laboratory report LA-14416-PR, Los Alamos, New Mexico. (Koch and Schmeer 2010, 108926)

LANL (Los Alamos National Laboratory), October 2006. "Mortandad Canyon Investigation Report," Los Alamos National Laboratory document LA-UR-06-6752, Los Alamos, New Mexico. (LANL 2006, 094161)

LANL (Los Alamos National Laboratory), May 2007. "Well Screen Analysis Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-2852, Los Alamos, New Mexico. (LANL 2007, 096330)

Purtymun, W.D., January 1995. "Geologic and Hydrologic Records of Observation Wells, Test Holes, Test Wells, Supply Wells, Springs, and Surface Water Stations in the Los Alamos Area," Los Alamos National Laboratory report LA-12883-MS, Los Alamos, New Mexico. (Purtymun 1995, 045344)

Purtymun, W.D., and A.S. Swanton, February 5, 1998. "Engineering, Geology, and Construction Data of Twenty-Five Test Holes and Test Wells on and Adjacent to the Pajarito Plateau," draft, Los Alamos National Laboratory, Los Alamos, New Mexico. (Purtymun and Swanton 1998, 099096)

Appendix B

Geochemical Performance of Network Wells

B-1.0 PURPOSE

This appendix presents the results obtained in the evaluation of the representativeness of water-quality samples from proposed network monitoring wells for Technical Area 21 (TA-21).

- Perched-intermediate groundwater: LADP-3, LAOI(a)-1.1, LAOI-3.2, LAOI-3.2a, LAOI-7, R-6i, R-9i screens 1 and 2, R-12 screens 1 and 2, and TA-53i
- Regional groundwater: R-6, R-7 screen 3, R-8 screens 1 and 2, and R-9

The objective of the evaluation is to determine whether the screened intervals in these wells are capable of providing samples that are representative of predrilling conditions for chemicals of potential concern (COPCs) originating from TA-21 sources, focusing on contaminants historically released from the Solid Waste Management Unit 21-011(k) former outfall: cesium-137, 1,4-dioxane, nitrate, perchlorate, strontium-90, and tritium (section 3.1.1; Table B-1.0-1).

The evaluation is conducted following the approach described in the "Well Screen Analysis Report, Revision 2" (hereafter, WSAR Rev. 2) (LANL 2007, 096330). After summarizing the evaluation outcomes for individual screens in Section B-2.0, the rest of the appendix provides background information about the process applied and presents the water-quality data used to derive the evaluation results.

This appendix summarizes previous evaluations of water-quality samples for the majority of these wells that were documented in Appendix B of the "Los Alamos and Pueblo Canyons Groundwater Monitoring Well Network Evaluation and Recommendations, Revision 1" (hereafter the LA/Pueblo Network Evaluation Rev. 1) (LANL 2008, 101330) and in Appendix F of the "2009 Interim Facility-Wide Groundwater Monitoring Plan" (hereafter, the 2009 IFGMP) (LANL 2009, 106115), which covers data for samples collected in 2008. This appendix also updates those evaluations with more recent data collected since January 2009.

B-2.0 RESULTS OF GEOCHEMICAL PERFORMANCE EVALUATION

Evaluation results are summarized below in terms of the present-day status of each screen interval with respect to its recovery from residual effects of drilling, construction, or rehabilitation activities and its present-day capability to meet geochemical monitoring objectives for the TA-21 monitoring well network. This capability is expressed qualitatively by assignment of each screen to one of three categories:

- Meets geochemical monitoring objectives unconditionally—provides representative samples for all of the COPCs listed in Table B-1.0-1
- Meets geochemical monitoring objectives conditionally—currently provides representative samples for some or all of the COPCs listed in Table B-1.0-1. Classified as conditional for at least one of two reasons:
    - The post-development data record spans less than 2 yr, so this screen is classified as conditionally meeting monitoring objectives, subject to the results of future data.
    - Data may have the potential to be biased high for some constituents and biased low for others at the present time, but this limitation is expected to be resolved within a reasonable time frame as geochemical conditions in the screen interval continue to improve.

- Does not meet geochemical monitoring objectives—cannot provide representative samples for the majority of the COPCs listed in Table B-1.0-1, and conditions do not show clear signs of improving within a reasonable time frame

The capability of each screen to provide representative water samples for specific COPCs is tabulated in Table B-1.0-1 based on evaluation outcomes summarized in Table B-2.0-1, taking into consideration the potential effects of residual conditions on COPC data reliability (Table B-2.0-2). Site-specific groundwater conditions for each screened interval are also considered in the evaluation process. Water-quality indicators that are present as local contaminants in screened intervals, or that consistently exceed test threshold values for other reasons unrelated to residual effects of drilling, construction, or rehabilitation activities, may have limited applicability for the evaluation of the representativeness of water-quality samples from these screens. These constituents are identified in Table B-2.0-3, along with average concentrations obtained for recent samples.

B-2.1 Well Screens in Perched-Intermediate Aquifers

LADP-3 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted the possible presence of nitrate-reducing conditions and slightly elevated total organic carbon (TOC) concentrations. These conditions are likely to be representative of predrilling groundwater conditions because no drilling additives were used.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- In addition to TOC, other water-quality indicators that consistently exceed upper test threshold values in recent samples include boron, chloride, chromium, sodium, sulfate, tritium, and uranium. Of these, all but sulfate also exceed upper tolerance limits (UTLs) (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the “Groundwater Background Investigation Report, Revision 3” (hereafter, the GBIR Rev. 3) (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

LAOI(a)-1.1 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) did not find any obvious drilling-related conditions. Total iron concentrations and turbidities in some samples are higher than typically observed in groundwater from the perched-intermediate zone in the absence of drilling effects or steel corrosion. However, this well is constructed of polyvinyl chloride casing, so indicators used to detect steel corrosion are not relevant. These conditions are assumed to be representative of predrilling groundwater and not an artifact of residual drilling products because no drilling products were used for this borehole.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- No water-quality indicators other than total iron concentrations and turbidity consistently exceed upper test threshold values at this location.

- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

LAOI-3.2 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted the possible presence of manganese-reducing conditions since the well's installation in the 1990s, steadily improving throughout this period and showing oxidizing levels in the past couple of years. Calcium concentrations were also observed to be consistently above the upper test threshold value used for this indicator. The cause is uncertain, and it is likely that this condition is representative of the groundwater at this location and not related to drilling effects because no drilling products were used for this borehole.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- Water-quality indicators that consistently exceed test threshold values in recent samples include calcium, chloride, perchlorate, sodium, sulfate, tritium, and uranium. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

LAOI-3.2a meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted the presence of manganese-reducing conditions since the well's installation in the 1990s, steadily improving throughout this period and showing oxidizing levels in the past couple of years. Calcium concentrations were observed to be consistently above the upper test threshold value used for this indicator. The cause is uncertain, and it is likely that this condition is representative of the groundwater at this location and not related to drilling effects because no drilling products were used for this borehole.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- Water-quality indicators that consistently exceed test threshold values in recent samples include calcium, chloride, chromium, perchlorate, sodium, sulfate, tritium, and uranium. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

LAOI-7 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) found no obvious drilling- or construction-related conditions.

- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- Water-quality indicators that consistently exceed test threshold values in recent samples include boron, chloride, chromium, magnesium, perchlorate, sulfate, and tritium. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

R-6i meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted that calcium, dissolved iron, and sodium concentrations were elevated above the upper test threshold values used for these indicators.
- In recent samples, dissolved iron concentrations decreased to background levels. Otherwise, the evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- Water-quality indicators that consistently exceed test threshold values in recent samples include boron, calcium, chloride, chromium, fluoride, nitrate, perchlorate, sodium, sulfate, and tritium. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

R-9i screen 1 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted the following conditions:
  - ❖ TOC concentrations are consistently elevated above the test threshold value used for this indicator. However, all other residual organic indicators passed their respective tests, and the stability of the elevated TOC concentrations suggests that they are representative of the groundwater at this location and not related to drilling effects.
  - ❖ The possible presence of manganese-reducing conditions may be related to the elevated TOC concentrations. Because nitrate was not detected in the groundwater sample collected from this depth interval in the R-9 borehole during drilling, it is assumed that reducing conditions in this screen may be representative of predrilling groundwater conditions and not an artifact of residual drilling products.
  - ❖ Calcium and magnesium are slightly elevated above the upper test threshold values used for these indicators. The cause is uncertain, but the stability of the elevated concentrations suggests that they are representative of the groundwater at this location and not related to drilling effects.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.

- Water-quality indicators that consistently exceed test threshold values in recent samples include boron, calcium, chloride, fluoride, magnesium, manganese, nickel, sodium, sulfate, TOC, tritium, and uranium. Although not used as a water-quality indicator, molybdenum is also notably elevated above background groundwater concentrations for this trace metal. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). Nitrate and perchlorate are consistently near or below detection limits. These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1. Because of the groundwater's reducing condition at this location, concentrations of some redox-sensitive COPCs such as nitrate and perchlorate might fall below the range of natural background; such low concentrations and nondetects are nonetheless representative data.

<u>R-9i screen 2</u> meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted that manganese-reducing conditions for this screen have been slowly but consistently improving since sampling began in 2000. An approach to oxidizing conditions was evidenced by detectable concentrations of redox-sensitive nitrate and perchlorate in samples collected in 2008. Reducing conditions at this location are likely to be representative of predrilling groundwater conditions and not an artifact of residual drilling products.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- Water-quality indicators that consistently exceed test threshold values in recent samples include chloride, fluoride, perchlorate, phosphate, manganese, sulfate, tritium, and uranium. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

<u>R-12 screen 1</u> meets geochemical monitoring objectives conditionally.

- Rehabilitation and conversion of well R-12 to a dual-screen well was completed in 2008. Evaluation of postconversion samples in the 2009 IFGMP (LANL 2009, 106115) noted the presence of residual effects of drilling products, including residual organic chemicals, iron-reducing conditions, and carbonate-mineral disequilibria. Nonetheless, drilling-related conditions in the screen interval improved significantly relative to those that dominated before rehabilitation activities.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) substantiates the trends noted in the 2009 IFGMP. The majority of water-quality indicators show stable concentrations. Elevated concentrations of ammonia and TOC may reflect the degradation of residual organic products following rehabilitation activities. Manganese-reducing conditions may also be present, although nitrate and perchlorate are generally detected above detection limits.

- Water-quality indicators that consistently exceed test threshold values in recent samples include boron, calcium, chloride, fluoride, manganese, sodium, sulfate, and tritium. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions may be representative of groundwater at this location, subject to the evaluation of post-rehabilitation data spanning a longer period of time.
- This screen is currently capable of providing representative data for some of the COPCs listed in Table B-1.0-1. Because of the groundwater's reducing condition at this location, concentrations of some redox-sensitive COPCs such as cesium-137, nitrate, and perchlorate might be biased low. These conditions and the capability of the screen to provide representative data will continue to be reevaluated as additional data become available.

R-12 screen 2 meets geochemical monitoring objectives unconditionally.

- Rehabilitation and conversion of well R-12 to a dual-screen well was completed in 2008. Evaluation of postconversion samples in the 2009 IFGMP (LANL 2009, 106115) did not note any obvious drilling- or construction-related conditions. Possible manganese-reducing conditions at this location are likely to be representative of predrilling groundwater conditions and not an artifact of residual drilling products.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) substantiates the evaluations in the 2009 IFGMP.
- Water-quality indicators that consistently exceed test threshold values in recent samples include boron, chloride, fluoride, manganese, perchlorate, sulfate, and tritium. Of these, all but chloride and sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

TA-53i meets geochemical monitoring objectives conditionally.

- TA-53i is a relatively new well that was developed in March 2009; the postdevelopment data record spans less than a year. Residual organic drilling products are present in the screen interval, based on elevated concentrations of acetone and TOC, and conditions may be slightly nitrate-reducing (Table B-2.0-1). However, overall geochemical trends are steadily improving, and it is expected that the screen will fully recover from drilling and construction effects within a reasonable time frame.
- Water-quality indicators that consistently exceed test threshold values in recent samples include boron, calcium, chloride, chromium, magnesium, perchlorate, sodium, strontium, sulfate, tritium, and uranium. Although not used as water-quality indicators, bromide and molybdenum are also notably elevated above background concentrations. Of these, all but sulfate also exceed UTLs (or their equivalent) calculated for perched-intermediate groundwater in Table 4.2-2 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for most, if not all, COPCs listed in Table B-1.0-1. These conditions and the capability of the screen to provide representative data will continue to be reevaluated as additional data become available.

B-2.2 Well Screens in the Regional Aquifer

R-6 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) did not note any obvious drilling- or construction-related conditions.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted in the most recent samples.
- No water-quality indicators consistently exceed test threshold values in recent samples.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

R-7 screen 3 meets geochemical monitoring objectives conditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted the presence of sulfate- or iron-reducing conditions and carbonate-mineral disequilibria.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports. Persistent effects of drilling include iron-reducing conditions, residual organic chemicals, and carbonate-mineral disequilibria.
- Of the COPCs listed in Table B-1.0-1, this screen is currently capable of providing representative data for tritium and 1,4-dioxane.

R-8 screen 1 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted the possible presence of nitrate-reducing conditions. However, the reliability of the data indicating this condition was suspect.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) did not find any evidence for nitrate-reducing conditions nor for any other obvious drilling- or construction-related conditions.
- Fluoride is the only water-quality indicator that consistently exceeds its test threshold value in recent samples. Fluoride also exceeds the UTL calculated for regional groundwater in Table 4.2-3 of the GBIR Rev. 3 (LANL 2007, 095817). This condition is considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

R-8 screen 2 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted that chloride and barium are elevated above the upper test threshold values used for these indicators. The cause of these trends is unknown but does not appear to be related to residual effects of drilling. Water samples from this screen consistently show elevated pH values (8.6 to 9.5), which likely affects the applicability of some test threshold values used to identify residual drilling effects.

- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the elevated barium concentration. Chloride and pH values fall within their respective background ranges.
- Barium is the only water-quality indicator that consistently exceeds its test threshold value in recent samples. Barium also exceeds the UTL calculated for regional groundwater in Table 4.2-3 of the GBIR Rev. 3 (LANL 2007, 095817).This condition is considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

R-9 meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the LA/Pueblo Network Evaluation Rev. 1 (LANL 2008, 101330) and the 2009 IFGMP (LANL 2009, 106115) noted that barium and magnesium concentrations are elevated above the upper threshold values used for these indicators. The cause is uncertain, but the stability of the elevated concentrations suggests that they are representative of the groundwater at this location and not related to drilling effects.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) reaffirms the results of previous reports, with no obvious drilling- or construction-related conditions noted.
- Water-quality indicators that consistently exceed test threshold values in recent samples include barium, boron, chloride, magnesium, perchlorate, uranium, and tritium. Of these, all but tritium and uranium also exceed UTLs (or their equivalent) calculated for regional groundwater in Table 4.2-3 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

R-35a meets geochemical monitoring objectives conditionally.

- Water-quality evaluations conducted for the 2009 IFGMP (LANL 2009, 106115) noted persistently elevated concentrations of barium, chloride, and magnesium. The cause is unknown.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) substantiates the trends observed in the 2009 IFGMP.
- Water-quality indicators that consistently exceed test threshold values in recent samples include barium, chloride, and magnesium. These constituents also exceed UTLs (or their equivalent) calculated for regional groundwater in Table 4.2-3 of the GBIR Rev. 3 (LANL 2007, 095817). It is unclear at this time whether these conditions are representative of groundwater at this location.
- This screen is currently capable of providing representative data for COPCs listed in Table B-1.0-1, with the possible exception of cesium-137. The capability of the screen to provide representative data will continue to be reevaluated as additional data become available and as the conceptual model is refined for this part of the flow system.

R-35b meets geochemical monitoring objectives unconditionally.

- Water-quality evaluations conducted for the 2009 IFGMP (LANL 2009, 106115) did not note any obvious drilling- or construction-related conditions.
- The evaluation of water-quality samples collected since January 2009 (Table B-2.0-1) substantiates the evaluations in the 2009 IFGMP.
- Water-quality indicators that consistently exceed test threshold values in recent samples include magnesium, nitrate, and perchlorate. These constituents also exceed UTLs (or their equivalent) calculated for regional groundwater in Table 4.2-3 of the GBIR Rev. 3 (LANL 2007, 095817). These conditions are considered to be representative of groundwater at this location.
- This screen is currently capable of providing representative data for all COPCs listed in Table B-1.0-1.

TW-3 does not meet geochemical monitoring objectives.

- Persistent sulfate- or iron-reducing conditions and iron-corrosion products are present. Total iron concentrations consistently exceed the upper test threshold value used to detect the possible presence of steel corrosion. Zinc concentrations and turbidities are also higher than is typically observed in groundwater from the regional aquifer and are also likely attributable to corrosion of carbon-steel well components.
- Variable low tritium activities (8 to 15 pCi/L) are detected.
- Of the COPCs listed in Table B-1.0-1, this screen is currently capable of providing representative data for tritium and 1,4-dioxane. However, because of possible annular leakage, the sample itself may not be representative of regional groundwater at this location (Appendix A).

B-3.0 APPROACH

The evaluation summarized above was conducted following the general approach described in Section 4 of the WSAR Rev. 2 (LANL 2007, 096330). Analytical data are compared against threshold values for about 30 geochemical indicator species, which serve as test criteria for identifying the presence of residual drilling effects. The threshold values are defined based on concentrations measured in background samples assumed to be representative of water quality in perched-intermediate groundwater or in the regional aquifer, as reported in the “Groundwater Background Investigation Report, Revision 2” (LANL 2007, 094856). The test criteria are used to identify samples that appear to be unreliable and/or are not representative of predrilling groundwater chemistry because of residual effects of drilling fluids. The residual effects are classified into six categories (LANL 2007, 096330).

- Category A—Residual inorganic constituents from drilling, construction, and development products
- Category B—Residual organic components from drilling products
- Category C—Modification of in situ redox conditions
- Category D—Modification of surface-active mineral surfaces with the effect of enhancing adsorption, such as onto drilling clays
- Category E—Disturbance of the carbonate-mineral system
- Category F—Corrosion of steel well components

- General Indicator Category—A seventh category includes geochemical parameters for which values may fall outside the range of background groundwater concentrations. These excursions generally cannot be attributed with confidence to any single cause and hence are used primarily for corroborative purposes during the evaluation. Parameters in this category include alkalinity, chromium, perchlorate, pH, nitrate, tritium, turbidity, and zinc.
- An important caveat for the evaluation protocol is the recognition that the test threshold values serve as screening levels, not as invariable and strict guidelines. Significantly, upper threshold values for several test indicators are purposefully set at levels less than the UTLs for local groundwater background, in order to improve the effectiveness of the screening protocol for identifying potential geochemical trends that bear closer examination. One side effect of this approach is the increased potential for "false negatives." These apparent failed tests require careful review by a user who is knowledgeable about site-specific conditions. Documentation of the rationale used to determine why a failed outcome is not applicable is also required to ensure consistency and transparency for the evaluation protocol.

B-4.0 ANALYSIS OF RESIDUAL EFFECTS OF DRILLING

Table B-4.0-1 presents the analytical data used for the evaluation, grouped by category of drilling effects. For example, all of the tests to evaluate redox conditions are grouped together in Category C. Data are repeated if they are used in more than one category, as is the case for barium, sulfate, uranium, and other analytes. In Table B-4.0-1, data cells are color-coded to provide a visual indicator of the test outcomes. Pink-shaded cells indicate a failing outcome, and yellow-shaded cells indicate an outcome that is either indeterminate or not applicable. Unshaded cells indicate passing outcomes or that no data are available for this test.

Table B-4.0-2 also provides a visual synopsis of the evaluation results, showing pass/fail outcomes for each test. This table is used to document the reason that a particular test outcome was considered indeterminate or not applicable.

B-5.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), May 2007. "Groundwater Background Investigation Report, Revision 3," Los Alamos National Laboratory document LA-UR-07-2853, Los Alamos, New Mexico. (LANL 2007, 095817)

LANL (Los Alamos National Laboratory), February 2007. "Groundwater Background Investigation Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-0755, Los Alamos, New Mexico. (LANL 2007, 094856)

LANL (Los Alamos National Laboratory), May 2007. “Well Screen Analysis Report, Revision 2,” Los Alamos National Laboratory document LA-UR-07-2852, Los Alamos, New Mexico. (LANL 2007, 096330)

LANL (Los Alamos National Laboratory), February 2008. “Los Alamos and Pueblo Canyons Groundwater Monitoring Well Network Evaluation and Recommendations, Revision 1,” Los Alamos National Laboratory document LA-UR-08-1105, Los Alamos, New Mexico. (LANL 2008, 101330)

LANL (Los Alamos National Laboratory), May 2009. “2009 Interim Facility-Wide Groundwater Monitoring Plan,” Los Alamos National Laboratory document LA-UR-09-1340, Los Alamos, New Mexico. (LANL 2009, 106115)

National Library of Medicine, June 11, 2007. “1,4-Dioxane,” online search results from the Hazardous Substances Data Bank (HSDB) on TOXNET (Toxicology Data Network), http://toxnet.nlm.nih.gov/. (National Library of Medicine 2007, 096556)

Table B-1.0-1
Capability of Screen to Provide Reliable and Representative Samples for Selected COPCs

Well	Port Depth (ft)	Tritium	Nitrate	Perchlorate	Cesium-137	Strontium-90	Dioxane[1,4-]
Perched-Intermediate Groundwater							
LADP-3	316	■[a]	■	■	■	■	■
LAOI(a)-1.1	295	■	■	■	■	■	■
LAOI-3.2	153	■	■	■	■	■	■
LAOI-3.2a	181	■	■	■	■	■	■
LAOI-7	240	■	■	■	■	■	■
R-6i	602	■	■	■	■	■	■
R-9i screen 1	199	■	■	■	■	■	■
R-9i screen 2	279	■	■	■	■	■	■
R-12 screen 1	459	■	■–[b]	■–	■?[c]	■	■
R-12 screen 2	504	■	■	■	■	■	■
TA-53i	600	■	■	■	■	■	■
Regional Aquifer							
R-6	1205	■	■	■	■	■	■
R-7 screen 3	915	■	—[d]	—	—	—	■
R-8 screen 1	711	■	■	■	■	■	■
R-8 screen 2	825	■	■	■	■	■	■
R-9	684	■	■	■	■	■	■
R-35a	1013	■	■	■	■?	■	■
R-35b	825	■	■	■	■	■	■
TW-3	805	■	—	—	—	■?	■

Source: Derived from information provided in section B-2.0.

[a] ■ = Screen can provide reliable and representative sample for this COPC.

[b] ■– = Screen has provided one or more recent samples in which this analyte was detected, but measured concentrations may be biased low due to residual effects of drilling.

[c] ■? = Screen probably can provide reliable and representative sample for this COPC, but there is uncertainty associated with this judgment.

[d] — = Screen cannot provide reliable and representative sample for this COPC.

Table B-2.0-1
Summary of Evaluation Outcomes for Water-Quality Samples, 2009–2010

Location	Port Depth (ft bgs)	Date	Passed[a]	Failed[a]	% Passed	Cat A—Residual Inorganics Present	Cat B—Residual Organics Present	Cat C—Redox Stage[b]	Cat D—Enhanced Adsorption	Cat E—Carbonate System Disturbed	Cat F—Steel Corrosion Present	General Category[c]	Residual Conditions Present[d]	Notes[e]
LADP-3	316	09-Jan-09	28	2	93	—	—	NO_3	—	—	—	■	—	A1, A2, B1, C1, E1, G1, G2
LADP-3	316	15-Jul-09	26	1	96	—	—	NO_3	—	—	—	■	—	A1, A2, B1, C1, G1, G2
LADP-3	316	07-Jan-10	26	0	100	—	—	NO_3	—	—	—	—	—	A1, A2, B1, C1
LAOI(a)-1.1	295	7-Jul-09	31	3	91	—	—	NO_3	—	—	—	■	—	A2, C1, G4, G5
LAOI(a)-1.1	295	13-Jan-10	33	1	97	—	—	—	—	—	—	■	—	G4
LAOI-3.2	153	8-Jul-09	26	1	96	—	—	—	—	—	—	■	—	A1, A2, E1, G1
LAOI-3.2	153	8-Jan-10	11	1	92	—	—	—	—	—	—	■	—	A1, A2, B1, G1
LAOI-3.2a	181	8-Jul-09	24	2	92	—	—	—	—	—	—	■	—	A1, A2, E2, G1
LAOI-3.2a	181	8-Jan-10	25	2	93	—	—	—	—	—	—	■	—	A1, A2, B1, E2, G1, G2
LAOI-7	240	13-Jul-09	31	1	97	—	—	—	—	—	—	■	—	A1, A2, E2, G1, G2
LAOI-7	240	14-Jan-10	27	1	96	—	—	—	—	—	—	■	—	A1, B1, E2, G1
R-6i	602	14-Jul-09	27	2	93	—	—	—	—	—	—	■	—	A1, A2, E2, G1, G2
R-9i screen 1	199	8-Jul-09	18	7	72	—	—	Fe-Mn	—	—	—	■	—	A1, A2, B1, C1, E2, G1
R-9i screen 2	279	8-Jul-09	24	4	75	—	—	NO_3	—	—	—	■	—	A1, A2, C1, E2, G1, G2
R-12 screen 1	459	20-Feb-09	20	7	74	—	■	Fe-Mn	—	—	—	■	B, C	A1, A2, E2, G1
R-12 screen 1	459	05-Aug-09	20	5	80	—	■	Fe-Mn	—	—	—	■	B, C	A1, A2, E2, G1
R-12 screen 1	459	12-Nov-09	22	5	81	—	■	Fe-Mn	—	—	—	■	B, C	A1, A2, E2
R-12 screen 2	504	11-Feb-09	25	2	93	—	■	Fe-Mn	—	—	—	■	B	A1, A2, C1, G1
R-12 screen 2	504	29-Apr-09	26	2	93	—	■	Fe-Mn	—	—	—	■	B	A1, A2, C1, G1
R-12 screen 2	504	05-Aug-09	26	2	93	—	—	Fe-Mn	—	—	—	■	—	A1, A2, C1, G1
R-12 screen 2	504	12-Nov-09	26	2	93	—	—	Fe-Mn	—	—	—	■	—	A1, A2, C1, G1

Table B-2.0-1 (continued)

Location	Port Depth (ft bgs)	Date	Passed[a]	Failed[a]	% Passed	Cat A—Residual Inorganics Present	Cat B—Residual Organics Present	Cat C—Redox Stage[b]	Cat D—Enhanced Adsorption	Cat E—Carbonate System Disturbed	Cat F—Steel Corrosion Present	General Category[c]	Residual Conditions Present[d]	Notes[e]
TA-53i	600	21-May-09	23	16	59	—	■	—	—	—	—	■	B	A1, A2, E2, G1, G2
TA-53i	600	20-Jul-09	26	14	65	—	■	—	—	—	—	■	B	A1, A2, E2, G1, G2
TA-53i	600	30-Nov-09	26	13	67	—	—	—	—	—	—	■	—	A1, A2, B1, E2, G1, G2
TA-53i	600	7-Jan-10	22	13	63	—	—	—	—	—	—	■	—	A1, A2, B1, E2, G1, G2
R-6	1205	14-Jul-09	36	1	97	—	—	NO_3	—	—	—	—	—	A2, C1
R-6	1205	8-Jan-10	37	0	100	—	—	—	—	—	—	—	—	A2
R-7 screen 3	915	13-Jan-09	23	10	70	—	■	Fe-Mn	—	■	—	■	B, C, E	G1
R-7 screen 3	915	20-Jul-09	19	10	66	—	■	SO_4	—	■	—	—	B, C, E	—
R-8 screen 1	711	20-Jul-09	30	1	97	—	—	—	—	—	—	■	—	A2, G2
R-8 screen 2	825	9-Jul-09	32	6	84	—	—	NO_3	—	—	—	■	—	A2, C1, E2, G2
R-9	684	13-Jul-09	32	1	97	—	—	—	—	—	—	■	—	A1, E2, G1
R-35a	1013	4-Feb-09	35	1	97	—	—	—	—	■	—	■	E	A2
R-35a	1013	28-Apr-09	32	6	84	—	—	NO_3	—	■	—	■	C, E	A2
R-35a	1013	3-Aug-09	33	6	85	—	—	—	—	■	—	■	E	A2, G2
R-35a	1013	4-Nov-09	34	6	85	—	—	—	—	■	—	■	E	A2
R-35a	1013	11-Feb-10	33	4	89	—	—	—	—	—	—	■	—	A2, G2
R-35b	825	2-Feb-09	35	0	100	—	—	—	—	—	—	—	—	A2, E2, G2
R-35b	825	27-Apr-09	32	4	89	—	—	—	—	—	—	—	—	A2, G2
R-35b	825	4-Aug-09	32	5	86	—	—	—	—	—	—	—	—	A2, E2, G2
R-35b	825	3-Nov-09	32	5	86	—	—	—	—	—	—	—	—	A2, E2, G2
R-35b	825	11-Feb-10	30	0	100	—	—	—	—	—	—	—	—	A2, E2, G2
TW-3	805	12-Jan-10	17	6	74	—	—	Fe-Mn	—	—	■	■	C, F	E2, G1, G2, G3

Table B-2.0-1 (continued)

Source: Test outcomes are based on the detailed evaluations documented in section B-4.0.

Notes:

■ = This condition is inferred as likely to be present in the screen interval as a residual effect of drilling, construction, or rehabilitation activities. The criteria for designating a condition as being present are summarized in WSAR Rev. 2 (LANL 2007, 096330, Table 6-1 footnotes).

— = This condition does not appear to be present in the screen interval as a residual effect of drilling, construction, or rehabilitation activities.

[a] Number of DQM test outcomes includes all pass/fail test outcomes (including those in the general indicator category).

[b] Redox test outcomes: Fe/Mn = iron- or manganese-reducing; NO_3 = nitrate-reducing; SO_4 = sulfate-reducing. The entry” —“ in this column indicates the presence of oxic conditions.

[c] General indicator category consists of water-quality data used for information purposes: field parameters (pH, carbonate alkalinity, turbidity); common plume indicators (tritium, nitrate, perchlorate, chromium); strongly sorbing metal (zinc).

[d] Residual effects of drilling, construction, or rehabilitation activities present: letters A through F indicate categories of drilling effects that may be present in the water-quality sample; “—” indicates that no residual effects of drilling, construction, or rehabilitation appear to be present and that any “fail” outcomes listed for the water-quality sample are more likely attributable to some cause other than drilling, as documented by applicable notes in the adjacent column.

[e] Applicable notes. Each identifier for a note consists of a test category letter (A through G) followed by a sequential number.

A1 The elevated analyte concentration which would cause a fail outcome in this category is associated with local contamination and is not a residual effect of drilling, construction, or rehabilitation activities.

A2 Based upon geochemical trends at this location, the elevated analyte concentration that would causing a fail outcome in this category is not considered to be a residual effect of drilling, construction, or rehabilitation activities but rather arises from some other source (e.g., local background, local contaminant, statistical outlier).

B1 Based upon geochemical trends at this location, the elevated analyte concentration that would cause a fail outcome in this category is not considered to be a residual effect of drilling, construction, or rehabilitation activities but rather arises from some other source (e.g., local background, local contaminant, statistical outlier).

C1 Based upon geochemical trends at this location, the apparent presence of reducing conditions in this sample is not a residual effect of drilling, construction, or rehabilitation activities but rather arises from some other source (e.g., local background, local contaminant, statistical outlier).

E1 The elevated analyte concentration that would cause a fail outcome in this category is associated with local contamination and is not a residual effect of drilling, construction, or rehabilitation activities.

E2 Based upon geochemical trends at this location, the elevated analyte concentration that would causing a fail outcome in this category is not considered to be a residual effect of drilling, construction, or rehabilitation activities but rather arises from some other source (e.g., local background, local contaminant, statistical outlier).

F1 Based upon geochemical trends at this location, the elevated metal concentration which would cause a fail outcome in this category (total iron, total chromium, or nickel) is not considered to be a residual effect of drilling, construction, or rehabilitation activities but rather arises from some other source (e.g., local background, local contaminant, steel component of sampling system, statistical outlier).

G1 Fail outcome because either pH or carbonate alkalinity is outside its background range.

G2 Fail outcome because the concentration of one or more constituents included in the general indicator category (e.g., tritium, chromium, nitrate, perchlorate) is detected above its background range but has not been identified as a local contaminant at this location.

G3 Fail outcome because dissolved zinc (a surrogate indicator for strongly adsorbing metals) is elevated above its background range.

G4 Fail outcome because sample turbidity is high.

G5 Fail outcome because total iron concentration is elevated, but there is no other indicator of metal corrosion.

Table B-2.0-2
Effects of Residual Drilling Impacts on Selected COPCs

Analyte	Outside Range of Background pH or Alkalinity[a]	Category A	Category B	Category C				Category D					Category E	Category F
		Residual Inorganics	Residual Organics	SO4	Fe	Mn	NO3	Sr	U	Ba	Zn	None[b]	Carbonate-Mineral Disequilibria	Steel Corrosion
Tritium	—[c]	—	—	—	—	—	—	—	—	—	—	—	—	—
Nitrate	—	■[d]	—	■	■	■	■	—	—	—	—	—	—	—
Perchlorate[e]	—	—	—	■	■	■	■–[f]	—	—	—	—	—	—	—
Cesium-137	—	—	—	■	■	■	—	—	—	—	■	—	—	■
Strontium-90	—	—	—	—	—	—	—	■	—	■	—	—	—	—
Dioxane[1,4-][g]	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Source: Compiled from WSAR Rev. 2 (LANL 2007, 096330, Tables A-1, A-2, A-3, and A-8).

[a] An entry in this column signifies only that the analyte's speciation may differ significantly from that expected under pH and alkalinity conditions that are characteristic of native groundwater, such that assumptions about the analyte's behavior in the presence of a residual drilling effect from drilling may not be valid.

[b] An entry in this column signifies that the analyte may adsorb onto residual bentonite but that a suitable indicator species is not available to judge whether or not this effect is present.

[c] — = The reliability or representativeness of this analyte is not affected by this residual effect of drilling.

[d] ■ = Analytical data for this analyte may not be reliable or representative of predrilling conditions if this residual effect of drilling is present.

[e] Perchlorate is indicated as being affected by manganese-reducing conditions in WSAR Rev. 2, (LANL 2007, 096330, Table A-1), and in fact, is used as an indicator for that condition. However, based on trends observed in some local monitoring wells, perchlorate concentrations may also be biased low in the presence of nitrate-reducing conditions.

[f] ■– = This analyte will be detected, if present, but its concentration may be biased low if this residual effect of drilling is present.

[g] 1,4-Dioxane was not included in WSAR Rev. 2 (LANL 2007, 096330, Appendix A). The evaluation tabulated above is based on information for this analyte from the National Library of Medicine's TOXNET database (National Library of Medicine 2007, 096556), which indicates that this chemical is highly soluble, is not expected to adsorb onto clays or minerals, and is very slow to biodegrade under either aerobic or anaerobic conditions.

Table B-2.0-3
Site-Specific Concentrations of Constituents That May Limit Their Applicability as Test Indicators

	Category A—Residual Inorganic Indicators				Category C—Redox Indicators			Category E—Carbonate System Indicators					General Category	
Location	B µg/L	Cl mg/L	Na mg/L	SO_4 mg/L	Mn µg/L	ClO_4 µg/L	NO_3-N mg/L	Ba µg/L	Ca mg/L	Mg mg/L	Sr µg/L	U µg/L	^3H pCi/L	Cr µg/L
Perched-Intermediate Groundwater														
Test threshold values (upper limits)	16	3.6	13	4.3	14	0.5	2.7	72	18	6.2	155	0.72	17	2.4
LADP-3	18	33	24	7	—[a]	(0.1)[b]	(0.1)	—	—	—	—	0.8	110	11
LAOI(a)-1.1	16	—	—	—	—	(0.2)	—	—	—	—	—	—	—	—
LAOI-3.2	—	17	18	5	—	5	2.8	—	22	—	—	1.5	2600	—
LAOI-3.2a	—	21	16	9	—	3	2.0	—	23	—	—	1.6	2200	4
LAOI-7	16	28	—	11	—	0.6	—	—	—	8	—	—	800	4
R-6i	19	16	21	9	—	7	4.4	—	23	—	—	—	3400	3
R-9i screen 1	29	38	23	13	200	(0.2)	(0.2)	—	20	7	—	0.8	110	—
R-9i screen 2	18	12	—	14	28	2	—	—	18	—	—	1.5	110	—
R-12 screen 1	44	14	14	7	160	—	—	—	25	—	—	—	75	—
R-12 screen 2	23	6	—	8	39	1	—	—	—	—	—	—	50	—
TA-53i	24	26	15	16	—	0.6	—	—	33	7	180	0.9	600	7
Regional Groundwater														
Test threshold values (upper limits)	42	3.8	29	6.3	14	0.5	0.8	70	25	4.9	180	1.6	1	6.7
R-6	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-7 screen 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-8 screen 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-8 screen 2	—	—	—	—	—	—	—	170	—	—	—	—	—	—
R-9	46	6	—	—	—	1	—	180	—	7	—	1.7	8	—
R-35a	—	6	—	—	—	—	—	—	—	6	—	—	—	—
R-35b	—	—	—	—	—	0.55	1.2	—	—	5	—	—	—	—
TW-3	—	—	—	—	—	—	—	—	—	—	—	—	5	—

Notes: Average concentrations for a test indicator are shown in this table for those locations at which a test consistently fails due to site-specific conditions unrelated to residual effects of drilling, construction, or rehabilitation. Averages are based on data available for post-development or post-rehabilitation samples collected between 2008 and February 2010. Site-specific conditions include the presence of local contamination or natural variations in background water quality that fall outside the range established by the test threshold.

[a] — = The constituent is not known to be present as a contaminant, and background water quality is expected to fall within the range of the test; or else these conditions are indeterminate with the information available at this time.

[b] Values in parentheses indicate average concentrations for test indicators that are consistently below the minimum threshold value (not shown in this table) due to site-specific conditions unrelated to residual effects of drilling, construction, or rehabilitation.

Table B-4.0-1
Test Indicators Used to Evaluate Water-Quality Data for Residual Effects of Drilling

Location	Date	Category A Residual Inorganics						Category B Residual Organics				Category C										
												SO4-reducing			Fe/Mn-reducing						NO3-reducing	
		B µg/L	Cl mg/L	Na mg/L	SO4 mg/L	F mg/L	PO4-P mg/L	Acetone µg/L	NH3-N mg/L	TKN mg/L	TOC mg/L	SO4 mg/L	S mg/L	ORP mV	V µg/L	Fe µg/L	Mn µg/L	ClO4 µg/L	U µg/L	Cr µg/L	NO3-N mg/L	DO mg/L
Threshold type and value • Intermediate • Regional aquifer		<UL 16 42	<UL 3.6 3.8	<UL 13 29	<UL 4.3 6.3	<UL 0.23 0.53	<UL 0.08 0.09	<UL 5 5	<UL 0.05 0.05	<UL 0.35 0.35	<UL 1.1 1.1	>LL 1.1 1.7	<UL 0.01 0.01	>LL 0 0	>LL 0.5 3.8	<UL 103 103	<UL 14 14	>LL 0.22 0.22	>LL 0.10 0.16	>LL 0.5 0.9	>LL 0.22 0.15	>LL 2 2
Perched-Intermediate Groundwater																						
LADP-3	09-Jan-09	14	35.3	23	7.7	0.20	0.07	—	< 0.05	< 0.1	1.5	7.7	—	333	1.6	29	< 10	0.13	0.96	9.6	0.10	8.0
LADP-3	15-Jul-09	22	31.3	23	7.1	0.32	0.10	< 10	< 0.05	< 0.1	1.3	7.1	—	261	1.9	< 100	< 10	0.14	0.71	11.4	0.07	8.3
LADP-3	07-Jan-10	15	32.0	22	7.0	0.35	0.07	< 10	0.04	< 0.1	1.3	7.0	—	366	1.9	< 100	< 10	0.16	0.61	14.9	0.18	5.0
LAOI(a)-1.1	7-Jul-09	16	1.3	9	3.3	0.26	0.05	< 10	0.03	0.04	< 1	3.3	—	419	1.7	< 100	< 10	0.20	0.36	< 10	0.11	6.2
LAOI(a)-1.1	13-Jan-10	< 50	1.2	9	3.5	0.10	0.07	< 10	0.05	< 0.1	< 1	3.5	—	260	1.2	< 100	< 10	0.21	0.23	< 10	0.49	8.3
LAOI-3.2	8-Jul-09	17	14.9	21	4.0	0.25	0.07	< 10	0.03	0.04	0.3	4.0	—	217	< 5	< 100	10	4.45	1.42	< 10	2.18	8.7
LAOI-3.2a	8-Jul-09	< 50	20.4	17	9.0	0.19	0.08	< 10	< 0.05	< 0.1	0.3	9.0	—	508	< 5	< 100	< 10	2.85	1.69	< 10	1.75	8.2
LAOI-3.2a	8-Jan-10	< 50	20.9	16	8.9	0.23	0.07	< 10	0.06	< 0.1	1.2	8.9	—	—	< 5	< 100	< 10	2.96	1.84	3.1	1.85	4.9
LAOI-7	13-Jul-09	19	27.3	11	11.1	0.22	—	< 10	—	—	1.0	11.1	—	318	1.9	< 100	8	0.66	0.69	3.1	0.28	8.6
LAOI-7	14-Jan-10	< 50	23.6	11	10.5	0.15	—	< 10	—	—	1.2	10.5	—	436	1.7	< 100	5	0.76	0.77	< 10	0.30	7.3
R-6i	14-Jul-09	16	16.6	22	8.9	0.66	0.14	< 10	0.04	< 0.1	< 1	8.9	—	383	2.7	< 100	< 10	7.00	0.54	3.5	4.57	6.8
R-9i screen 1	8-Jul-09	24	39.0	23	13.0	0.44	0.08	< 10	< 0.05	0.08	2.9	13.0	—	—	< 5	< 100	244	< 0.2	0.75	< 10	< 0.05	4.7
R-9i screen 2	8-Jul-09	15	12.4	11	14.1	0.24	0.14	< 10	0.04	0.08	0.5	14.1	—	—	1.8	< 100	19	2.37	1.67	< 10	0.18	5.8
R-12 screen 1	20-Feb-09	47	14.9	13	7.3	0.26	0.05	< 10	0.30	0.47	1.7	7.3	—	-16	< 5	239	173	0.24	0.54	< 3	0.74	0.2
R-12 screen 1	05-Aug-09	33	12.4	15	6.2	0.40	0.09	< 10	0.15	0.14	1.2	6.2	—	-219	< 5	66	126	0.19	0.60	< 10	0.62	1.1
R-12 screen 1	12-Nov-09	44	16.8	13	7.9	0.29	0.11	< 10	0.17	0.40	1.1	7.9	—	-168	< 5	80	161	0.35	0.72	< 10	1.14	0.8
R-12 screen 2	11-Feb-09	< 50	6.4	10	8.4	0.35	0.05	< 10	0.06	0.06	0.7	8.4	—	377	4.2	< 100	42	0.99	0.50	< 3	1.14	4.6
R-12 screen 2	29-Apr-09	32	6.4	10	8.4	0.38	0.04	< 10	0.10	< 0.1	< 1	8.4	—	16	3.8	< 100	38	1.12	0.44	< 3	1.16	4.9
R-12 screen 2	05-Aug-09	< 50	5.9	11	7.5	0.42	0.06	< 10	0.02	< 0.1	0.9	7.5	—	-53	4.2	< 100	37	0.94	0.58	< 10	1.18	3.3
R-12 screen 2	12-Nov-09	16	6.1	9	7.7	0.28	0.06	< 10	0.02	0.09	0.6	7.7	—	-67	4.2	< 100	38	1.00	0.46	< 10	1.13	3.4

Table B-4.0-1 (continued)

Location	Date	Category A Residual Inorganics						Category B Residual Organics				Category C										
												SO4-reducing			Fe/Mn-reducing						NO3-reducing	
		B µg/L	Cl mg/L	Na mg/L	SO4 mg/L	F mg/L	PO4-P mg/L	Acetone µg/L	NH3-N mg/L	TKN mg/L	TOC mg/L	SO4 mg/L	S mg/L	ORP mV	V µg/L	Fe µg/L	Mn µg/L	ClO4 µg/L	U µg/L	Cr µg/L	NO3-N mg/L	DO mg/L
Threshold type & value • Intermediate • Regional aquifer		<UL 16 42	<UL 3.6 3.8	<UL 13 29	<UL 4.3 6.3	<UL 0.23 0.53	<UL 0.08 0.09	<UL 5 5	<UL 0.05 0.05	<UL 0.35 0.35	<UL 1.1 1.1	>LL 1.1 1.7	<UL 0.01 0.01	>LL 0 0	>LL 0.5 3.8	<UL 103 103	<UL 14 14	>LL 0.22 0.22	>LL 0.10 0.16	>LL 0.5 0.9	>LL 0.22 0.15	>LL 2 2
TA-53i	21-May-09	27	26.5	15	15.4	0.21	0.09	224	0.13	< 0.1	4.1	15.4	—	203	1.0	< 100	6	0.65	0.90	6.8	1.05	6.7
TA-53i	20-Jul-09	21	25.6	14	15.4	0.30	0.06	75	0.02	0.11	3.3	15.4	—	118	1.8	76	10	0.58	0.85	8.0	1.09	7.1
TA-53i	30-Nov-09	26	26.4	16	15.9	0.14	0.06	< 10	< 0.05	< 0.1	1.8	15.9	—	58	1.0	71	10	0.63	0.90	3.3	0.97	6.3
TA-53i	7-Jan-10	22	25.3	14	16.1	0.31	0.14	< 10	0.03	< 0.1	1.7	16.1	—	229	1.6	< 100	5	0.67	0.78	8.8	0.96	8.4
Regional Aquifer																						
R-6	14-Jul-09	17	2.1	13	2.4	0.43	0.14	< 10	0.03	< 0.1	< 1	2.4	—	205	9.6	< 100	< 10	0.36	0.44	5.8	< 0.13	3.5
R-6	8-Jan-10	21	2.0	12	2.4	0.65	0.07	< 10	0.02	< 0.1	0.4	2.4	—	223	9.1	51	< 10	0.30	0.37	6.0	0.31	4.7
R-7 screen 3	13-Jan-09	10	2.8	8	2.0	0.57	< 0.00	—	< 0.05	0.36	—	2.0	< 0.01	—	< 1	2051	720	< 0.2	< 0.2	< 1	< 0.00	4.0
R-7 screen 3	20-Jul-09	16	2.3	9	1.3	0.48	< 0.00	< 10	0.95	—	1.6	1.3	< 0.02	—	< 1	2043	723	< 2	< 0.2	< 1	< 0.00	—
R-8 screen 1	20-Jul-09	< 50	1.5	10	2.3	0.54	—	< 10	< 0.05	0.06	0.7	2.3	—	—	14.4	< 100	< 10	0.30	0.22	8.8	0.16	—
R-8 screen 2	9-Jul-09	37	4.1	19	4.4	0.55	0.04	< 10	< 0.05	< 0.1	< 1	4.4	—	—	10.8	< 100	< 10	0.42	0.78	6.8	0.10	7.9
R-9	13-Jul-09	48	6.0	17	5.9	0.33	0.04	< 10	< 0.03	< 0.1	< 1	5.9	—	294	11.3	< 100	2	1.03	1.71	5.1	0.71	5.1
R-35a	4-Feb-09	35	6.1	19	5.4	0.35	< 0.05	< 10	< 0.05	0.09	0.6	5.4	—	375	17.1	117	3	0.43	0.77	4.9	0.53	5.6
R-35a	28-Apr-09	40	6.4	18	5.6	0.41	0.10	< 10	0.53	< 0.1	< 1	5.6	—	296	17.6	< 100	4	0.43	0.66	3.4	0.11	3.9
R-35a	3-Aug-09	35	6.2	18	5.3	0.50	0.47	< 10	< 0.05	< 0.1	< 1	5.3	—	149	16.3	< 100	4	0.41	0.56	6.6	0.85	4.6
R-35a	4-Nov-09	41	6.3	18	5.3	0.63	0.06	< 10	0.02	0.33	0.9	5.3	—	155	16.9	< 100	4	0.40	0.62	3.6	0.53	4.7
R-35a	11-Feb-10	39	6.3	18	5.5	0.31	0.10	< 10	0.07	< 0.1	0.7	5.5	—	224	17.4	< 100	3	0.39	0.59	9.8	0.50	6.2
R-35b	2-Feb-09	27	2.8	12	3.5	0.52	0.10	< 10	< 0.05	< 0.1	0.6	3.5	—	451	14.8	< 100	4	0.54	0.33	5.1	1.31	5.4
R-35b	27-Apr-09	26	2.9	11	3.7	0.70	0.12	< 10	0.02	< 0.1	< 1	3.7	—	294	14.4	< 100	2	0.55	0.31	—	1.19	6.6
R-35b	4-Aug-09	20	2.7	12	3.5	0.66	0.04	< 10	0.06	< 0.1	0.6	3.5	—	438	14.2	< 100	2	0.53	0.33	3.8	1.09	5.8
R-35b	3-Nov-09	16	2.8	11	3.5	0.79	0.04	< 10	0.30	0.04	0.4	3.5	—	221	14.0	< 100	2	0.58	0.33	5.6	1.18	6.2
R-35b	11-Feb-10	23	2.7	11	3.6	0.48	0.09	< 10	< 0.05	< 0.1	0.9	3.6	—	262	14.5	< 100	2	0.54	0.30	< 50	1.16	7.4
TW-3	19-Jan-06	31	3.2	12	0.8	0.38	< 0.04	< 5	0.61	0.74	—	0.8	—	-152	< 1	440	175	< 0.05	< 0.05	< 1	< 0.02	0.1
TW-3	12-Jan-10	25	—	12	—	—	—	< 10	—	—	—	—	—	227	3.0	43	158	—	0.43	< 10	—	5.0

Table B-4.0-1 (continued)

Location	Date	Category D Enhanced Adsorption				Category E Carbonate System					Category F Metal Corrosion					General Indicators							
		U µg/L	Sr µg/L	Ba µg/L	Zn µg/L	Ba µg/L	Ca mg/L	Mg mg/L	Sr µg/L	U µg/L	Fe(UF) µg/L	Fe ratio	Cr(UF) µg/L	Cr ratio	Ni µg/L	Turbidity NTU	pH	Alk mg/L	3H pCi/L	Cr µg/L	NO3-N mg/L	ClO4 µg/L	Zn µg/L
Threshold type & value • **Intermediate** • **Regional aquifer**		>LL 0.10 0.16	>LL 19 44	>LL 1.4 4.6	>LL 0.5 0.6	<UL 72 70	4.6-18 9.3-25	<UL 6.2 4.9	<UL 155 180	<UL 0.72 1.6	<UL 500 500	<UL 10 10	<UL 10 10	<UL 5 5	<UL 50 50	<UL 5 5	6.1-8.8 7.0-8.7	<UL 52 106	<UL 17 1	<UL 2.4 6.7	<UL 2.7 0.8	<UL 0.5 0.5	<UL 40 40
Intermediate perched groundwater																							
LADP-3	09-Jan-09	0.96	109	27	3	27	16	4.8	109	0.96	26	—	11.0	1	1	2	6.7	64	106	9.6	0.10	0.13	3
LADP-3	15-Jul-09	0.71	92	24	4	24	13	4.1	92	0.71	58	—	10.7	1	1	1	6.6	53	114	11.4	0.07	0.14	4
LADP-3	07-Jan-10	0.61	94	24	< 10	24	13	4.1	94	0.61	< 100	—	13.4	—	1	1	6.3	46	85	14.9	0.18	0.16	< 10
LAOI(a)-1.1	7-Jul-09	0.36	71	10	5	10	6.5	1.5	71	0.36	754	—	< 10	—	< 2	52	6.7	47	0	< 10	0.11	0.20	5
LAOI(a)-1.1	13-Jan-10	0.23	41	8	15	8	5.9	1.7	41	0.23	450	—	< 10	—	< 2	127	6.6	39	11	< 10	0.49	0.21	15
LAOI-3.2	8-Jul-09	1.42	115	49	6	49	20	5.2	115	1.42	< 100	—	< 10	—	< 2	2	6.4	82	1830	< 10	2.18	4.45	6
LAOI-3.2a	8-Jul-09	1.69	159	18	3	18	25	5.4	159	1.69	< 100	—	2.7	—	1	1	5.5	77	1680	< 10	1.75	2.85	3
LAOI-3.2a	8-Jan-10	1.84	153	19	< 10	19	25	5.3	153	1.84	< 100	—	3.3	1	1	1	6.4	76	2140	3.1	1.85	2.96	< 10
LAOI-7	13-Jul-09	0.69	95	28	8	28	17	7.4	95	0.69	146	—	4.2		2	2	5.4	54	776	3.1	0.28	0.66	8
LAOI-7	14-Jan-10	0.77	94	26	8	26	18	7.7	94	0.77	286	—	< 10	—	2	3	6.7	52	952	< 10	0.30	0.76	8
R-6i	14-Jul-09	0.54	111	23	7	23	22	4.0	111	0.54	< 100	—	3.5	1	1	1	6.9	68	3230	3.5	4.57	7.00	7
R-9i screen 1	8-Jul-09	0.75	128	59	13	59	22	7.8	128	0.75	83	—	4.1	—	92	1	7.6	60	111	< 10	< 0.05	< 0.2	13
R-9i screen 2	8-Jul-09	1.67	96	25	5	25	20	5.9	96	1.67	< 100	—	< 10	—	5	1	8.8	64	118	< 10	0.18	2.37	5
R-12 screen 1	20-Feb-09	0.54	106	42	< 10	42	24	5.4	106	0.54	235	1	< 3	—	2	1	7.9	81	73	< 3	0.74	0.24	< 10
R-12 screen 1	05-Aug-09	0.60	109	37	< 10	37	23	4.8	109	0.60	114	2	< 10	—	2	1	8.2	79	74	< 10	0.62	0.19	< 10
R-12 screen 1	12-Nov-09	0.72	118	48	< 10	48	27	5.7	118	0.72	84	1	< 10	—	2	1	7.9	85	76	< 10	1.14	0.35	< 10
R-12 screen 2	11-Feb-09	0.50	69	20	< 10	20	17	3.9	69	0.50	< 100	—	< 3	—	1	0	8.1	59	67	< 3	1.14	0.99	< 10
R-12 screen 2	29-Apr-09	0.44	67	12	3	12	18	4.0	67	0.44	< 100	—	< 3	—	< 2	0	8.1	59	50	< 3	1.16	1.12	3
R-12 screen 2	05-Aug-09	0.58	72	12	< 10	12	17	4.0	72	0.58	< 100	—	< 10	—	1	1	8.3	59	52	< 10	1.18	0.94	< 10
R-12 screen 2	12-Nov-09	0.46	68	12	< 10	12	18	3.9	68	0.46	< 100	—	< 10	—	1	1	8.1	59	54	< 10	1.13	1.00	< 10
TA-53i	21-May-09	0.90	168	45	15	45	33	6.8	168	0.90	224	—	13.5	2	11	4	6.9	87	575	6.8	1.05	0.65	15
TA-53i	20-Jul-09	0.85	176	43	15	43	33	6.7	176	0.85	105	1	8.4	1	16	3	7.0	89	581	8.0	1.09	0.58	15
TA-53i	30-Nov-09	0.90	189	40	12	40	34	7.2	189	0.90	154	2	15.3	5	22	3	6.6	85	760	3.3	0.97	0.63	12
TA-53i	7-Jan-10	0.78	182	39	9	39	33	7.0	182	0.78	322	—	17.8	2	22	4	6.6	85	527	8.8	0.96	0.67	9

Table B-4.0-1 (continued)

Location	Date	Category D Enhanced Adsorption				Category E Carbonate System					Category F Metal Corrosion					General Indicators							
		U µg/L	Sr µg/L	Ba µg/L	Zn µg/L	Ba µg/L	Ca mg/L	Mg mg/L	Sr µg/L	U µg/L	Fe(UF) µg/L	Fe ratio	Cr(UF) µg/L	Cr ratio	Ni µg/L	Turbidity NTU	pH	Alk mg/L	3H pCi/L	Cr µg/L	NO3-N mg/L	ClO4 µg/L	Zn µg/L
Threshold type & value		>LL	>LL	>LL	>LL	<UL		<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL	<UL		<UL	<UL	<UL	<UL	<UL	<UL
• Intermediate		0.10	19	1.4	0.5	72	4.6-18	6.2	155	0.72	500	10	10	5	50	5	6.1-8.8	52	17	2.4	2.7	0.5	40
• Regional aquifer		0.16	44	4.6	0.6	70	9.3-25	4.9	180	1.6	500	10	10	5	50	5	7.0-8.7	106	1	6.7	0.8	0.5	40
Regional Aquifer																							
R-6	14-Jul-09	0.44	65	20	< 10	20	14	3.9	65	0.44	< 100	—	5.3	1	1	1	8.1	70	0	5.8	< 0.13	0.36	< 10
R-6	8-Jan-10	0.37	63	21	3	21	16	4.3	63	0.37	< 100	—	7.3	1	< 2	1	8.0	67	0	6.0	0.31	0.30	3
R-7 screen 3	13-Jan-09	< 0.2	38	102	13	102	8.3	3.1	38	< 0.2	1797	1	< 1	—	2	2	6.9	64	0	< 1	< 0.00	< 0.2	13
R-7 screen 3	20-Jul-09	< 0.2	36	97	4	97	8.1	3.0	36	< 0.2	2284	1	< 1	—	2	—	7.1	70	0	< 1	< 0.00	< 2	4
R-8 screen 1	20-Jul-09	0.22	99	24	4	24	17	2.6	99	0.22	< 100	—	6.7	1	< 2	—	8.3	68	0	8.8	0.16	0.30	4
R-8 screen 2	9-Jul-09	0.78	164	183	7	183	22	5.0	164	0.78	< 100	—	5.8	1	1	4	8.6	96	0	6.8	0.10	0.42	7
R-9	13-Jul-09	1.71	176	186	—	186	22	6.9	176	1.71	< 100	—	5.4	1	< 2	0	7.9	111	9	5.1	0.71	1.03	—
R-35a	4-Feb-09	0.77	161	324	18	324	22	5.6	161	0.77	96	1	13.9	3	7	1	7.7	105	0	4.9	0.53	0.43	18
R-35a	28-Apr-09	0.66	178	339	15	339	24	5.4	178	0.66	75	—	9.9	1	10	1	7.6	106	0	3.4	0.11	0.43	15
R-35a	3-Aug-09	0.56	161	328	12	328	22	5.7	161	0.56	81	—	25.9	4	16	2	7.4	104	0	6.6	0.85	0.41	12
R-35a	4-Nov-09	0.62	165	334	12	334	23	6.1	165	0.62	125	—	20.7	6	17	1	7.6	103	0	3.6	0.53	0.40	12
R-35a	11-Feb-10	0.59	156	68	11	68	22	5.7	156	0.59	< 100	—	29.2	3	17	1	7.6	102	0	9.8	0.50	0.39	11
R-35b	2-Feb-09	0.33	69	37	38	37	16	5.1	69	0.33	< 100	—	5.7	1	1	1	7.5	71	0	5.1	1.31	0.54	38
R-35b	27-Apr-09	0.31	66	35	26	35	15	4.6	66	0.31	32	—		1	1	1	7.5	73	0	—	1.19	0.55	26
R-35b	4-Aug-09	0.33	72	37	33	37	16	5.1	72	0.33	< 100	—	3.7	1	1	3	7.3	75	0	3.8	1.09	0.53	33
R-35b	3-Nov-09	0.33	64	38	26	38	16	5.1	64	0.33	< 100	—	5.8	1	1	1	7.5	71	0	5.6	1.18	0.58	26
R-35b	11-Feb-10	0.30	64	37	30	37	15	5.0	64	0.30	< 100	—	< 50	—	< 10	1	7.5	70	0	< 50	1.16	0.54	30
TW-3	19-Jan-06	< 0.05	64	29	64	29	14	4.6	64	< 0.05	6130	14	2.4	—	1	9	7.7	77	15	< 1	< 0.02	< 0.05	64
TW-3	12-Jan-10	0.43	70	40	101	40	16	5.3	70	0.43	247	6	< 10	—	1	3	6.8	—	3	< 10	—	—	101

Notes: — = No data; LL = lower limit; UL = upper limit; NTU = nephelometric turbidity units; TKN = total Kjeldahl nitrogen; ORP = oxygen-reduction potential; UF = unfiltered.
Test outcomes are color-coded as follows, with reasons provided in Table B-4.0-2:
Unshaded = Passing outcome. Test indicator meets threshold condition.
Pink-shading = Failing outcome. Test indicator does not meet threshold condition due to residual effect of drilling, construction, or rehabilitation.
Gray shading = Test outcome is indeterminate.
Yellow shading = Test outcome is not applicable.

Table B-4.0-2
Documentation of Rationale for Test Outcomes

Location	Date	Category A Residual Inorganics						Category B Residual Organics				Category C										
												SO4-reducing			Fe/Mn-reducing						NO3-reducing	
		B	Cl	Na	SO4	F	PO4-P	Acetone	NH3-N	TKN	TOC	SO4	S	ORP	V	Fe	Mn	ClO4	U	Cr	NO3-N	DO
LADP-3	09-Jan-09	P	NA-CP	NA-CP	NA-CP	P	P	—	P	P	NA-TRND	P	—	P	P	P	P	NA-TRND	P	P	NA-TRND	P
LADP-3	15-Jul-09	NA-TRND	NA-CP	NA-CP	NA-CP	NA-TRND	NA-TRND	IN-DL	P	P	NA-TRND	P	—	P	P	P	P	NA-TRND	P	P	NA-TRND	P
LADP-3	07-Jan-10	P	NA-CP	NA-CP	NA-CP	NA-TRND	P	IN-DL	P	P	NA-TRND	P	—	P	P	P	P	NA-TRND	P	IN-VDL	NA-TRND	P
LAOI(a)-1.1	7-Jul-09	NA-TRND	P	P	P	NA-TRND	P	IN-DL	P	P	P	P	—	P	P	P	P	NA-TRND	P	IN-DL	F	P
LAOI(a)-1.1	13-Jan-10	IN-DL	P	P	P	P	P	IN-DL	P	P	P	P	—	P	P	P	P	NA-TRND	P	IN-DL	P	P
LAOI-3.2	8-Jul-09	NA-TRND	NA-CP	NA-TRND	P	NA-TRND	P	IN-DL	P	P	P	P	—	P	IN-DL	P	P	P	P	IN-DL	P	P
LAOI-3.2a	8-Jul-09	IN-DL	NA-CP	NA-TRND	NA-CP	P	P	IN-DL	P	P	P	P	—	P	IN-DL	P	P	P	P	IN-DL	P	P
LAOI-3.2a	8-Jan-10	IN-DL	NA-CP	NA-TRND	NA-CP	P	P	IN-DL	NA-TRND	P	NA-TRND	P	—	—	IN-DL	P	P	P	P	P	P	P
LAOI-7	13-Jul-09	NA-TRND	NA-CP	P	NA-CP	P	—	IN-DL	—	—	P	P	—	P	P	P	P	P	P	P	P	P
LAOI-7	14-Jan-10	IN-DL	NA-CP	P	NA-CP	P	—	IN-DL	—	—	NA-TRND	P	—	P	P	P	P	P	P	IN-DL	P	P
R-6i	14-Jul-09	NA-TRND	NA-CP	NA-CP	NA-CP	NA-TRND	NA-TRND	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-9i screen 1	8-Jul-09	NA-CP	NA-CP	NA-CP	NA-CP	NA-TRND	NA-TRND	IN-DL	P	P	NA-TRND	P	—	—	IN-DL	P	NA-TRND	NA-TRND	P	IN-DL	NA-TRND	P
R-9i screen 2	8-Jul-09	P	NA-CP	P	NA-CP	NA-TRND	NA-TRND	IN-DL	P	P	P	P	—	—	P	P	NA-TRND	P	P	IN-DL	NA-TRND	P

Table B-4.0-2 (continued)

Location	Date	Category A Residual Inorganics						Category B Residual Organics				Category C										
												SO4-reducing			Fe/Mn-reducing						NO3-reducing	
		B	Cl	Na	SO4	F	PO4-P	Acetone	NH3-N	TKN	TOC	SO4	S	ORP	V	Fe	Mn	ClO4	U	Cr	NO3-N	DO
R-12 screen 1	20-Feb-09	NA-CP	NA-CP	NA-CP	NA-CP	NA-TRND	P	IN-DL	F	F	F	P	—	NA-LTD	IN-DL	F	F	P	P	IN-DL	P	F
R-12 screen 1	05-Aug-09	NA-CP	NA-CP	NA-CP	NA-CP	NA-TRND	NA-TRND	IN-DL	F	P	F	P	—	NA-LTD	IN-DL	P	F	F	P	IN-DL	P	F
R-12 screen 1	12-Nov-09	NA-CP	NA-CP	NA-CP	NA-CP	NA-TRND	NA-TRND	IN-DL	F	F	P	P	—	NA-LTD	IN-DL	P	F	P	P	IN-DL	P	F
R-12 screen 2	11-Feb-09	IN-DL	NA-CP	P	NA-CP	NA-TRND	P	IN-DL	P	P	P	P	—	P	P	P	NA-TRND	P	P	IN-DL	P	P
R-12 screen 2	29-Apr-09	NA-TRND	NA-CP	P	NA-CP	NA-TRND	P	IN-DL	P	P	P	P	—	P	P	P	NA-TRND	P	P	IN-DL	P	P
R-12 screen 2	05-Aug-09	IN-DL	NA-CP	P	NA-CP	NA-TRND	P	IN-DL	P	P	P	P	—	NA-LTD	P	P	NA-TRND	P	P	IN-DL	P	P
R-12 screen 2	12-Nov-09	NA-TRND	NA-CP	P	NA-CP	NA-TRND	P	IN-DL	P	P	P	P	—	NA-LTD	P	P	NA-TRND	P	P	IN-DL	P	P
TA-53i	21-May-09	NA-CP	NA-CP	NA-TRND	NA-CP	P	NA-TRND	F	F	P	F	P	—	P	P	P	P	P	P	P	P	P
TA-53i	20-Jul-09	NA-CP	NA-CP	NA-TRND	NA-CP	NA-TRND	P	F	P	P	F	P	—	P	P	P	P	P	P	P	P	P
TA-53i	30-Nov-09	NA-CP	NA-CP	NA-TRND	NA-CP	P	P	IN-DL	P	P	NA-TRND	P	—	P	P	P	P	P	P	P	P	P
TA-53i	7-Jan-10	NA-CP	NA-CP	NA-TRND	NA-CP	NA-TRND	NA-TRND	IN-DL	P	P	NA-TRND	P	—	P	P	P	P	P	P	P	P	P
R-6	14-Jul-09	P	P	P	P	P	NA-TRND	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	NA-TRND	P
R-6	8-Jan-10	P	P	P	P	NA-TRND	P	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-7 screen 3	13-Jan-09	P	P	P	P	NA-TRND	P	—	P	F	—	P	P	—	F	F	F	F	IN-DL	IN-DL	F	P
R-7 screen 3	20-Jul-09	P	P	P	P	P	P	IN-DL	F	—	F	F	IN-DL	—	F	F	F	IN-DL	IN-DL	IN-DL	F	—

Table B-4.0-2 (continued)

Location	Date	Category A Residual Inorganics						Category B Residual Organics				Category C										
												SO4-reducing			Fe/Mn-reducing						NO3-reducing	
		B	Cl	Na	SO4	F	PO4-P	Acetone	NH3-N	TKN	TOC	SO4	S	ORP	V	Fe	Mn	ClO4	U	Cr	NO3-N	DO
R-8 screen 1	20-Jul-09	IN-DL	P	P	P	NA-TRND	—	IN-DL	P	P	P	P	—	—	P	P	P	P	P	P	P	—
R-8 screen 2	9-Jul-09	P	NA-TRND	P	P	NA-TRND	P	IN-DL	P	P	P	P	—	—	P	P	P	P	P	P	NA-TRND	P
R-9	13-Jul-09	NA-CP	NA-CP	P	P	P	P	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35a	4-Feb-09	P	NA-TRND	P	P	P	P	IN-DL	P	P	P	P	—	P	P	F	P	P	P	P	P	P
R-35a	28-Apr-09	P	NA-TRND	P	P	P	NA-TRND	IN-DL	F	P	P	P	—	P	P	P	P	P	P	P	F	P
R-35a	3-Aug-09	P	NA-TRND	P	P	P	NA-TRND	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35a	4-Nov-09	P	NA-TRND	P	P	NA-TRND	P	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35a	11-Feb-10	P	NA-TRND	P	P	P	NA-TRND	IN-DL	F	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35b	2-Feb-09	P	P	P	P	P	NA-TRND	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35b	27-Apr-09	P	P	P	P	NA-TRND	NA-TRND	IN-DL	P	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35b	4-Aug-09	P	P	P	P	NA-TRND	P	IN-DL	NA-TRND	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35b	3-Nov-09	P	P	P	P	NA-TRND	P	IN-DL	NA-TRND	P	P	P	—	P	P	P	P	P	P	P	P	P
R-35b	11-Feb-10	P	P	P	P	P	NA-TRND	IN-DL	P	P	P	P	—	P	P	P	P	P	P	IN-DL	P	P
TW-3	19-Jan-06	P	P	P	P	P	P	P	NA-TRND	NA-TRND	—	F	—	F	F	F	F	F	F	IN-DL	F	F
TW-3	12-Jan-10	P	—	P	—	—	—	IN-DL	—	—	—	—	—	P	F	P	F	—	P	IN-DL	—	P

Table B-4.0-2 (continued)

Location	Date	Category D Enhanced Adsorption				Category E Carbonate System					Category F Metal Corrosion					General Indicators							
		U	Sr	Ba	Zn	Ba	Ca	Mg	Sr	U	Fe(UF)	Fe ratio	Cr(UF)	Cr ratio	Ni	Turbidity	pH	Alk	3H	Cr	NO3-N	ClO4	Zn
LADP-3	09-Jan-09	P	P	P	P	P	P	P	P	NA-TRND	P	—	NA-TRND	P	P	P	P	F	NA-CP	F	P	P	P
LADP-3	15-Jul-09	P	P	P	P	P	P	P	P	P	P	—	NA-TRND	P	P	P	P	F	NA-CP	F	P	P	P
LADP-3	07-Jan-10	P	P	P	IN-DL	P	P	P	P	P	P	—	IN-VDL	—	P	P	P	P	NA-CP	IN-VMB	P	P	P
LAOI(a)-1.1	7-Jul-09	P	P	P	P	P	P	P	P	P	F	—	P	—	P	F	P	P	P	IN-DL	P	P	P
LAOI(a)-1.1	13-Jan-10	P	P	P	P	P	P	P	P	P	P	—	P	—	P	F	P	P	P	IN-DL	P	P	P
LAOI-3.2	8-Jul-09	P	P	P	P	P	NA-TRND	P	P	P	P	—	P	—	P	P	P	F	NA-CP	IN-DL	P	NA-CP	P
LAOI-3.2a	8-Jul-09	P	P	P	P	P	NA-TRND	P	NA-TRND	NA-TRND	P	—	P	—	P	P	F	F	NA-CP	IN-DL	P	NA-CP	P
LAOI-3.2a	8-Jan-10	P	P	P	IN-DL	P	NA-TRND	P	P	NA-TRND	P	—	P	P	P	P	P	F	NA-CP	F	P	NA-CP	P
LAOI-7	13-Jul-09	P	P	P	P	P	P	NA-TRND	P	P	P	—	P		P	P	F	F	NA-CP	F	P	NA-CP	P
LAOI-7	14-Jan-10	P	P	P	P	P	P	NA-TRND	P	NA-TRND	P	—	P	—	P	P	P	F	NA-CP	IN-DL	P	NA-CP	P
R-6i	14-Jul-09	P	P	P	P	P	NA-TRND	P	P	P	P	—	P	P	P	P	P	F	NA-CP	F	NA-CP	NA-CP	P
R-9i screen 1	8-Jul-09	P	P	P	P	P	NA-TRND	NA-TRND	P	NA-TRND	P	—	P	—	NA-CP	P	P	F	NA-CP	IN-DL	P	P	P
R-9i screen 2	8-Jul-09	P	P	P	P	P	NA-TRND	P	P	NA-TRND	P	—	P	—	P	P	P	F	NA-CP	IN-DL	P	NA-CP	P
R-12 screen 1	20-Feb-09	P	P	P	IN-DL	P	NA-TRND	P	P	P	P	1	P	—	P	P	P	F	NA-CP	P	P	P	P
R-12 screen 1	05-Aug-09	P	P	P	IN-DL	P	NA-TRND	P	P	P	P	2	P	—	P	P	P	F	NA-CP	IN-DL	P	P	P
R-12 screen 1	12-Nov-09	P	P	P	IN-DL	P	NA-TRND	P	P	P	P	1	P	—	P	P	P	F	NA-CP	IN-DL	P	P	P

Table B-4.0-2 (continued)

		Category D Enhanced Adsorption				Category E Carbonate System					Category F Metal Corrosion					General Indicators							
Location	Date	U	Sr	Ba	Zn	Ba	Ca	Mg	Sr	U	Fe(UF)	Fe ratio	Cr(UF)	Cr ratio	Ni	Turbi-dity	pH	Alk	3H	Cr	NO3-N	ClO4	Zn
R-12 screen 2	11-Feb-09	P	P	P	IN-DL	P	P	P	P	P	P	—	P	—	P	P	P	F	NA-CP	P	P	NA-CP	P
R-12 screen 2	29-Apr-09	P	P	P	P	P	P	P	P	P	P	—	P	—	P	P	P	F	NA-CP	P	P	NA-CP	P
R-12 screen 2	05-Aug-09	P	P	P	IN-DL	P	P	P	P	P	P	—	P	—	P	P	P	F	NA-CP	IN-DL	P	NA-CP	P
R-12 screen 2	12-Nov-09	P	P	P	IN-DL	P	P	P	P	P	P	—	P	—	P	P	P	F	NA-CP	IN-DL	P	NA-CP	P
TA-53i	21-May-09	P	P	P	P	P	NA-TRND	NA-TRND	NA-TRND	NA-TRND	P	—	NA-TRND	P	P	P	P	F	NA-CP	F	P	NA-CP	P
TA-53i	20-Jul-09	P	P	P	P	P	NA-TRND	NA-TRND	NA-TRND	NA-TRND	P	P	P	P	P	P	P	F	NA-CP	F	P	NA-CP	P
TA-53i	30-Nov-09	P	P	P	P	P	NA-TRND	NA-TRND	NA-TRND	NA-TRND	P	P	NA-TRND	P	P	P	P	F	NA-CP	F	P	NA-CP	P
TA-53i	7-Jan-10	P	P	P	P	P	NA-TRND	NA-TRND	NA-TRND	NA-TRND	P	—	NA-TRND	P	P	P	P	F	NA-CP	F	P	NA-CP	P
R-6	14-Jul-09	P	P	P	IN-DL	P	P	P	P	P	P	—	P	P	P	P	P	P	P	P	P	P	P
R-6	8-Jan-10	P	P	P	P	P	P	P	P	P	P	—	P	P	P	P	P	P	P	P	P	P	P
R-7 screen 3	13-Jan-09	IN-DL	NA-RED	P	P	F	F	P	P	P	F	P	P	—	P	P	F	P	P	P	P	P	P
R-7 screen 3	20-Jul-09	IN-DL	NA-RED	P	P	F	F	P	P	P	F	P	P	—	P	—	P	P	P	P	P	IN-DL	P
R-8 screen 1	20-Jul-09	P	P	P	P	P	P	P	P	P	P	—	P	P	P	—	P	P	P	F	P	P	P
R-8 screen 2	9-Jul-09	P	P	P	P	NA-TRND	P	NA-TRND	P	NA-TRND	P	—	P	P	P	P	P	P	P	F	P	P	P
R-9	13-Jul-09	P	P	P	—	NA-TRND	P	NA-TRND	P	NA-TRND	P	P	P	P	P	P	P	F	NA-CP	P	P	NA-CP	—
R-35a	4-Feb-09	P	P	P	P	F	P	NA-TRND	P	F	P	P	NA-TRND	P	P	P	P	P	P	P	P	P	P

Table B-4.0-2 (continued)

Location	Date	Category D Enhanced Adsorption				Category E Carbonate System					Category F Metal Corrosion					General Indicators							
		U	Sr	Ba	Zn	Ba	Ca	Mg	Sr	U	Fe(UF)	Fe ratio	Cr(UF)	Cr ratio	Ni	Turbi-dity	pH	Alk	3H	Cr	NO3-N	ClO4	Zn
R-35a	28-Apr-09	P	P	P	P	F	P	NA-TRND	P	P	P	—	P	P	P	P	P	P	P	P	P	P	P
R-35a	3-Aug-09	P	P	P	P	F	P	NA-TRND	P	P	P	—	NA-TRND	P	P	P	P	P	P	P	F	P	P
R-35a	4-Nov-09	P	P	P	P	F	P	NA-TRND	P	P	P	—	NA-TRND	NA-TRND	P	P	P	P	P	P	P	P	P
R-35a	11-Feb-10	P	P	P	P	P	P	NA-TRND	P	P	P	—	NA-TRND	P	P	P	P	P	P	F	P	P	P
R-35b	2-Feb-09	P	P	P	P	P	P	NA-TRND	P	P	P	—	P	P	P	P	P	P	P	P	NA-CP	NA-TRND	P
R-35b	27-Apr-09	P	P	P	P	P	P	NA-TRND	P	P	P	—		P	P	P	P	P	P	—	NA-CP	NA-TRND	P
R-35b	4-Aug-09	P	P	P	P	P	P	NA-TRND	P	P	P	—	P	P	P	P	P	P	P	P	NA-CP	NA-TRND	P
R-35b	3-Nov-09	P	P	P	P	P	P	NA-TRND	P	P	P	—	P	P	P	P	P	P	P	P	NA-CP	NA-TRND	P
R-35b	11-Feb-10	P	P	P	P	P	P	NA-TRND	P	P	P	—	IN-DL	—	P	P	P	P	P	IN-DL	NA-CP	NA-TRND	P
TW-3	19-Jan-06	NA-RED	P	P	P	P	P	P	P	P	F	F	P	—	P	F	P	P	F	P	P	P	F
TW-3	12-Jan-10	P	P	P	P	P	P	NA-TRND	P	P	P	P	P	—	P	P	F	—	F	IN-DL	—	—	F

Notes: DO = Dissolved oxygen; TKN = total Kjeldahl nitrogen; ORP = oxygen-reduction potential.
This table documents the rationale for each of the test outcomes in Tables B-4.0-1. Test outcomes are color-coded, with supporting reasons as defined below:
P = Passing outcome. Test indicator meets threshold condition.
F (pink-shading) = Failing outcome. Test indicator does not meet threshold condition due to residual effect of drilling, construction, or rehabilitation.
IN-DL (gray shading) = Indeterminate test outcome. Value reported as a nondetect by the analytical laboratory, with a detection limit greater the test threshold value.
IN-VDL (gray shading) = Indeterminate test outcome. Value classified as a nondetect following data validation.
IN-VMB (gray shading) = Indeterminate test outcome. Value classified as a nondetect following data validation due to the presence of the analyte in the method blank.
NA-CP (yellow shading) = Test outcome is not applicable. Based upon geochemical trends at this location, the elevated analyte concentration exceeds the test threshold value because the analyte is present as a local contaminant.
NA-RED (yellow shading) = Test outcome is not applicable. Result is unreliable when sulfate- or iron-reducing conditions are present.
NA-TRND (yellow shading) = Test outcome is not applicable. Based on geochemical trends at this location, the elevated analyte concentration exceeds the test threshold value for a reason unrelated to the residual effects of drilling, construction, or rehabilitation (e.g., local background, local contaminant, statistical outlier).

Appendix C

Evaluation of Proposed Monitoring Well Locations for Detecting Potential Contaminants from Technical Area 21 in the Regional Aquifer

C-1.0 INTRODUCTION

This appendix discusses an assessment of newly proposed groundwater monitoring wells to detect potential contaminants in the regional aquifer from sources within Technical Area 21 (TA-21). The evaluation presented in this appendix addresses monitoring objective #3 presented in section 2 of this report: support an understanding of the proximal nature and extent of contamination sufficient to support investigations and the evaluation of potential corrective measures. To maximize the potential to meet this objective, proposed monitoring well locations are evaluated based on their ability to detect hypothetical plumes from TA-21 sources within the constraints regarding the hydrogeologic conditions beneath the site. Proposed monitoring well locations were placed around key sources described in section 3 of this report. The objective for the well locations is to optimize the potential for detecting contaminants soon after their arrival at the regional aquifer. The groundwater flow direction in the regional aquifer near TA-21 is constrained to some degree by surrounding wells but may vary somewhat within the immediate vicinity of TA-21. Uncertainty in the groundwater flow direction is a consideration in the well-selection process presented below.

C-2.0 CONTAMINANT TRANSPORT THROUGH THE VADOSE ZONE

Contaminant transport through the vadose zone is not explicitly considered here but is discussed in section 3 of this report. For this analysis, the contaminant transport in the vadose zone is considered to be vertical. The network efficiency is then evaluated assuming that the contaminant arrives at the regional aquifer within hypothesized arrival areas, directly below the surface sites that released contaminants to the environment. These arrival areas are referred to as potential “breakthrough locations” throughout the document and represent the high- and moderate-priority sites identified in section 3 of this report.

C-3.0 NETWORK EVALUATION OF THE REGIONAL MONITORING WELLS

A major objective of the numerical simulations is to analyze flow and contaminant transport directions near potential breakthrough locations at the regional aquifer beneath TA-21. Through this analysis, new monitoring wells are proposed to provide efficient detection in the regional aquifer of potential plumes originating from TA-21. The regional aquifer beneath and downgradient of TA-21 is within Miocene sedimentary rocks.

The simulation of contaminant transport in the regional aquifer is performed using an analytical model. The model simulates three-dimensional advective-dispersive contaminant transport in the regional aquifer from a point source (cf., Wexler 1992, 106994; Wang and Wu 2009, 109751). Previously, a similar model using a contaminant source with a given volume was applied to simulate chromium transport in the regional aquifer beneath Sandia Canyon (LANL 2007, 098938) and VOCs and tritium from Material Disposal Area (MDA) C (LANL 2010, 109260). A point-source approach was implemented here to account for irregularly shaped contaminant source areas. Various hydrogeological parameters characterize the potential contaminant transport in the regional aquifer, and a distribution of values is used for each of the parameters. In the analyses presented below, the parameters include (1) groundwater flow direction, (2) hydraulic gradient, (3) aquifer hydraulic conductivity and porosity, and (4) longitudinal and transverse dispersivities. The model parameters are listed in Table C-3.0-1.

Groundwater flow direction and magnitude are generally dictated by the shape of the regional water table (Freeze and Cherry 1979, 088742, Chapter 5; Vesselinov 2005, 090040). Although the groundwater flow direction beneath TA-21 is constrained by nearby wells, some uncertainty remains for locations immediately beneath TA-21 because of the low spatial density of wells (Figure C-3.0-1). Information about the groundwater flow direction is largely derived from wells R-2 (single screen), R-7 (screen 3), R-6 (single screen), and R-4 (single screen) (Koch and Schmeer 2010, 108926).

To determine if pumping at water-supply wells affects groundwater flow directions beneath TA-21, analyses were performed to determine if the water levels at wells R-2, R-7, R-6, and R-4 respond to pumping. Results of these analyses are shown in Figures C-3.0-2 through C-3.0-5. Responses due to pumping at local water-supply wells PM-1, PM-2, PM-3, PM-4, PM-5, O-1, O-4, G-1A, G-2A, G-3A, G-4A, and G-5A are included in the analyses. A general linear decline in water level is also included in the analyses. R-2 and R-7 water levels exhibit steady, nearly linear, water-level declines with magnitudes of 0.17 and 0.21 m/yr, respectively. The transients at these wells do not show direct correlation with water-supply pumping at wells on the Pajarito Plateau (Figures C-3.0-2 and C-3.0-3). Water levels observed at R-6 and R-4 are, however, impacted by the water-supply pumping. Both wells appear to be predominantly affected by the pumping of supply wells O-4, PM-3, and PM-4 (Figures C-3.0-4 and C-3.0-5); the other water-supply wells on the Pajarito Plateau do not seem to have an effect on the water-level transients (including those in the Guaje well field, whose analyses are not shown). Similar to R-2 and R-7, R-6 and R-4 exhibit steady water-level declines with magnitudes of 0.24 and 0.32 m/yr, respectively, in addition to the pumping-induced transients.

It is important to note that water-supply well O-4 is located close to TA-21 and to regional monitoring well R-6 (Figure C-3.0-1). O-4 is one of the most actively used wells for water supply. However, its pumping contributes only relatively small drawdown at R-6 (less than 0.1 m, Figure C-3.0-4). PM-3 and PM-4 contributions to drawdown at R-6 are larger than O-4 contributions, even though these wells are located farther from R-6. These observations suggest a complex three-dimensional structure of groundwater flow in the regional aquifer. The lack of a pronounced O-4 pumping effect on R-6 water levels indicates a vertical hydraulic separation between the deep aquifer zones pumped by O-4 and the shallow zone where R-6 water levels are monitored. The vertical hydraulic separation of O-4 from the shallow portion of the aquifer may be caused by the basalts in the upper part of the O-4 screen (see section 3.4 of this report).

Based on the current water-level data, the regional groundwater flow under TA-21 has a gradient of about 0.01 m/m with direction to the east-northeast (gradient azimuth [i.e., clockwise angle from due north] of approximately 58 degrees). Based on the observed trend of the recorded long-term water-level decline, groundwater flow directions and magnitudes are not expected to change substantially in the near future. Based on the current overall trend in water-level declines at monitoring wells R-2, R-7, R-6, and R-4 shown for the 4-yr period in Figures C-3.0-2 through C-3.0-5, within the next 10 yr, the gradients may increase to 0.011 m/m and slightly change the flow direction (gradient azimuth of approximately 57 degrees).

Sedimentary formations making up the regional aquifer are highly heterogeneous. The hydraulic conductivities estimated during single-hole pumping tests at the regional wells near TA-21 include the following: R-2, 0.5 m/d (1.5 ft/d); R-6, 2 m/d (7 ft/d); and R-4, 3.6 m/d (12 ft/d) (there are no data for hydraulic conductivity at R-7). In general, hydraulic conductivity estimates in the regional aquifer considering all monitoring wells vary between 0.3 and 20 m/d (approximately 1 to 60 ft/d) (Table C-3.0-1). The uncertainty in porosity values for the sediments within regional aquifer units is based on data from the literature (Freeze and Cherry 1979, 088742) and site-specific knowledge (Keating et al. 2001, 095399) (Table C-3.0-1). Azimuth angles from 30 to 90 degrees are considered for the advective flow direction in the simulations to account for uncertainties in contaminant transport due to aquifer property heterogeneities.

Dispersion of the contaminant plumes in the aquifer is represented in the model by longitudinal and transverse dispersivities (cf., Lichtner et al. 2002, 095397). Site-specific data supporting dispersivity values are not available. Based on data from the literature, the selected range of values is reasonable for the spatial scale of simulated contaminant transport ([on the order of hundreds of meters] Neuman 1990, 090184) and the properties of the flow medium (Table C-3.0-1).

Contaminant transport in the regional aquifer is modeled from three potential breakthrough locations (Figure C-3.0-6). The selection of the breakthrough locations is based on the mesa-top source areas where contaminants might be released in the subsurface environment; the vadose-zone transport is assumed to be vertical. The breakthrough locations are labeled “MDA T,” “DP West,” and “Drain Pipe,” (Figure C-3.0-6) and correspond to three of the four high- and moderate-priority sources identified in section 3 of this report. MDA V is not included in this regional-aquifer analysis because vapor-phase monitoring of tritium in the vadose zone is recommended for that site. The simulated plumes migrate in the regional aquifer downgradient from a series of potential point sources at 5-m spacing within each of these breakthrough locations. To estimate uncertainty in the model predictions, a Monte Carlo analysis is performed for each of the point sources. In this way, the analyses evaluate the detection capability of the monitoring wells by considering each point source within a polygon to have equal probability of being the leak point. A set of 100 uncorrelated, equally probable random realizations are generated using a Latin hypercube sampling technique. Each realization includes random selection within the acceptable range for six model parameters listed in Table C-3.0-1.

This network analysis evaluates 18 proposed regional monitoring well locations. The well locations are presented in Table C-3.0-2 and Figure C-3.0-6. All the locations are suitable for drilling based on existing information about the terrain and construction activities.

The analysis presented here is best suited for comparing proposed monitoring well locations in comparison to each other rather than for evaluating plume concentrations. For example, simulated plumes are based on a concentration at the potential point-source arrival location that does not correspond to an actual concentration because the uncertainty of the breakthrough concentration is not considered here. Therefore, the model produces concentrations at the monitoring wells that are relative to the simulated point-source concentration, and therefore do not represent predictions of contaminant concentrations. The transport within the regional aquifer of a nonsorbing conservative contaminant is simulated. No regulatory limits are used in this analysis because the predicted concentrations are relative, not absolute. Therefore, the modeling results do not indicate whether any of the hypothetical plumes are associated with concentrations that could exceed regulatory standards or detection limits. The simulations yield information about relative monitoring well detection efficiencies incorporating the distribution of hydraulic model parameters.

C-4.0 MONITORING METRICS

In the model, successfully detected plumes produce numerical concentrations (with respect to the source strength) at a proposed monitoring well greater than a designated threshold value (analyses were performed considering single monitoring wells and pairs of monitoring wells). The detection efficiency is the number of successfully detected plumes divided by the number of simulated plumes (100 parameter sets times the number of point sources in the breakthrough polygon). A metric of 95% or greater was chosen as the desired detection efficiency for this analysis. Because MDA T, DP West, and the drainlines were ranked as the mesa-top sites with the greatest potential to impact groundwater (see section 3 for discussion of ranking of sites at TA-21), emphasis was placed on having optimum detection efficiency for those areas. An additional metric is that the wells are located sufficiently close to the assumed breakthrough locations to support early detection after arrival at the regional aquifer (approximately 5 yr or less).

C-5.0 RESULTS

The efficiency of the regional monitoring wells to detect potential plumes originating from three of the four moderate- and high-priority TA-21 mesa-top sources is shown in Table C-5.0-1. The detection efficiency considers individual wells and combinations of two wells to best monitor the sources. No individual well is capable of 95% detection efficiency for all three sources. For example, MW-14 and MW-15 individually meet the criteria for MDA T, with each achieving 96% efficiency, but these wells are only 90% or less efficient for detecting the two other sources. Some combinations of two wells do provide the desired detection efficiency. For example, combinations of potential wells MW-10 and MW-14 (MW10:MW-14), MW-12 and MW-14 (MW-12:MW-14), MW-13 and MW-14 (MW-13:MW-14), and several others meet the criteria. Average travel times for the peak concentrations in breakthrough curves from the potential sources to the proposed monitoring wells are presented in Table C-5.0-2. The peak travel time from a given potential breakthrough location is an average for all of the point sources that make up that source polygon (see Figure C-3.0-6). Arrival times for initial breakthrough would be expected to be significantly faster than the peak concentration. A given monitoring well located close to the edge of a source polygon will, in fact, have a fast travel time from nearby point sources within the polygon (e.g., R-13 relative to the east end of the drainline polygon); however, the average arrival time is used to ensure no bias for breakthrough within the source polygons. Average pore velocities from the potential sources are presented in Table C-5.0-3. The pore velocity equates to the linear speed at which a tracer moves from one location to another through the narrow pores in the porous media; it is higher than the average groundwater velocity.

The combination of monitoring wells MW-10 and MW-14 is proposed for the TA-21 monitoring network. This pair of wells has a combined detection efficiency of 100%, 96%, and 98% for the MDA T, DP West, and the drainline sources, respectively. The combination MW-10:MW-14 is chosen over MW-12:MW-14 although the two combinations have identical combined detections efficiencies. Potential monitoring well MW-10 is slightly preferred over MW-12 because detection efficiencies for MW-10 are higher on its own merit, and predicted peak travel times from the three sources are shorter to MW-10 than to MW-12. Predicted travel times to MW-10 and MW-14 from MDA T are only 3.0 and 2.2 yr, respectively, and both wells are within 100 m of the MDA T boundary. If contamination were to reach the regional aquifer from MDA T, these locations and short travel times would be favorable. The travel times for peak arrival to one or the other of these wells from the three sources is less than 5 yr. Initial breakthrough would be faster. The locations of these two wells also have good potential to provide additional information to characterize the groundwater flow directions in the regional aquifer. It is proposed that well MW-14 be drilled first because it has the higher detection efficiency of the two wells for MDA T, DP West, and the drainlines and faster average peak arrival times for all three sources than MW-10. Data from MW-14 will better refine the water-table map to further constrain the groundwater flow direction beneath TA-21. This information can be used to reevaluate the location of proposed well MW-10.

C-6.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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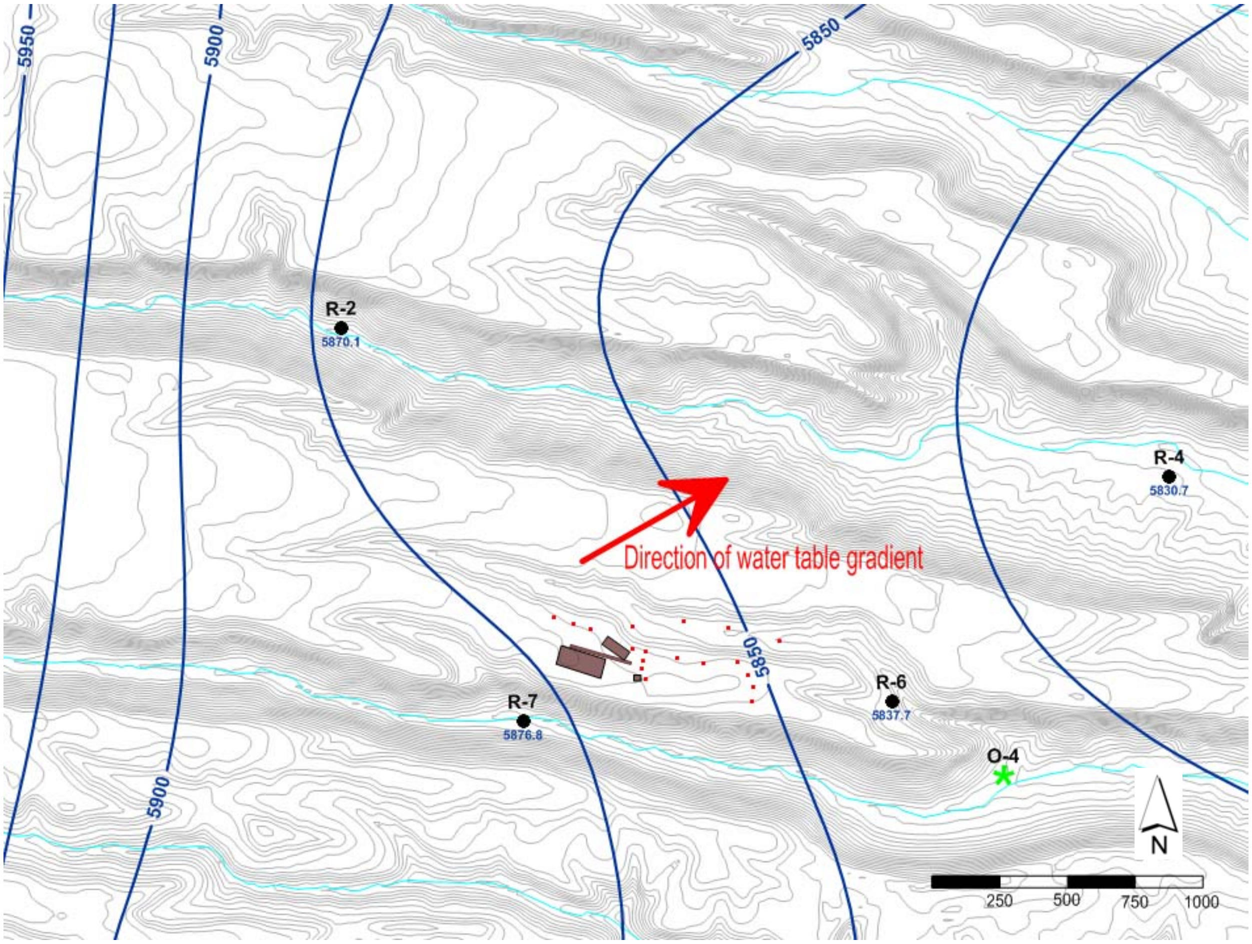
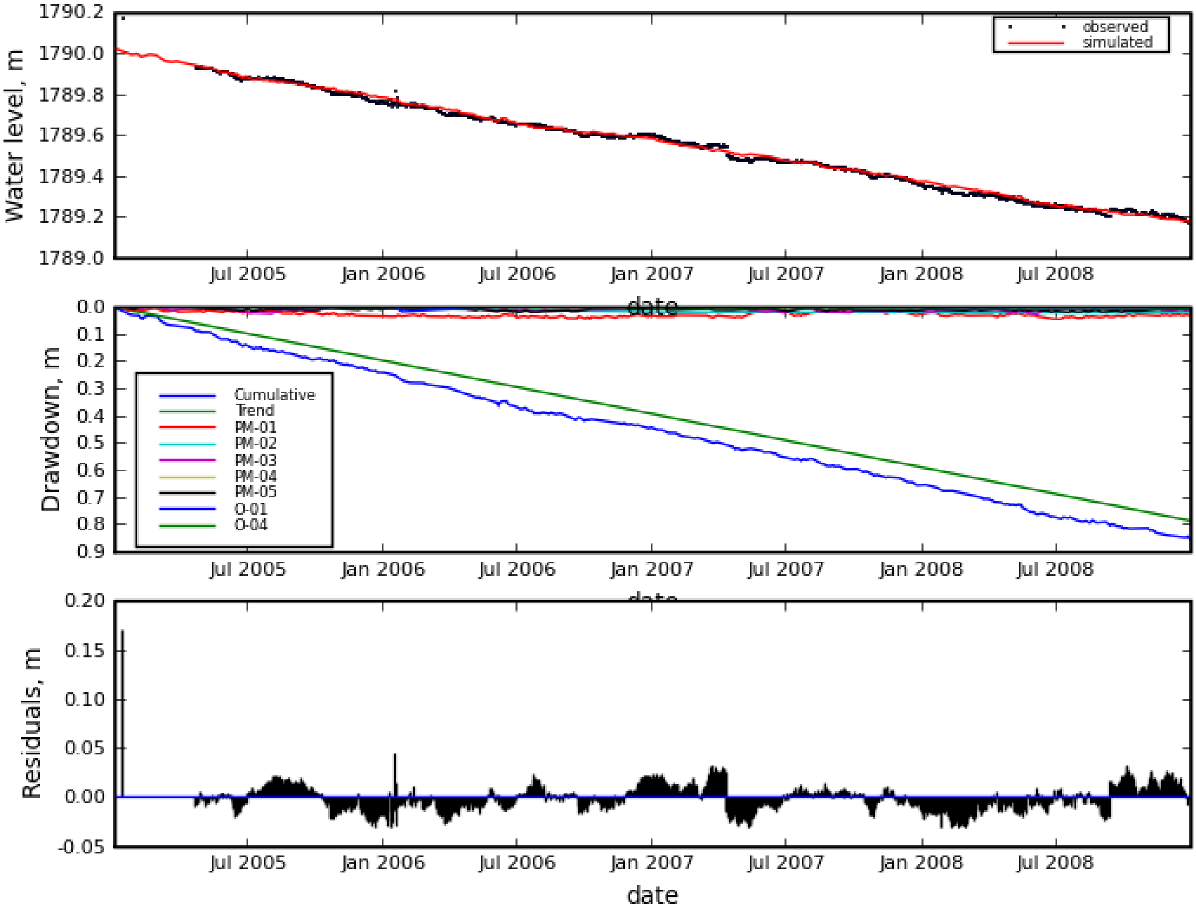


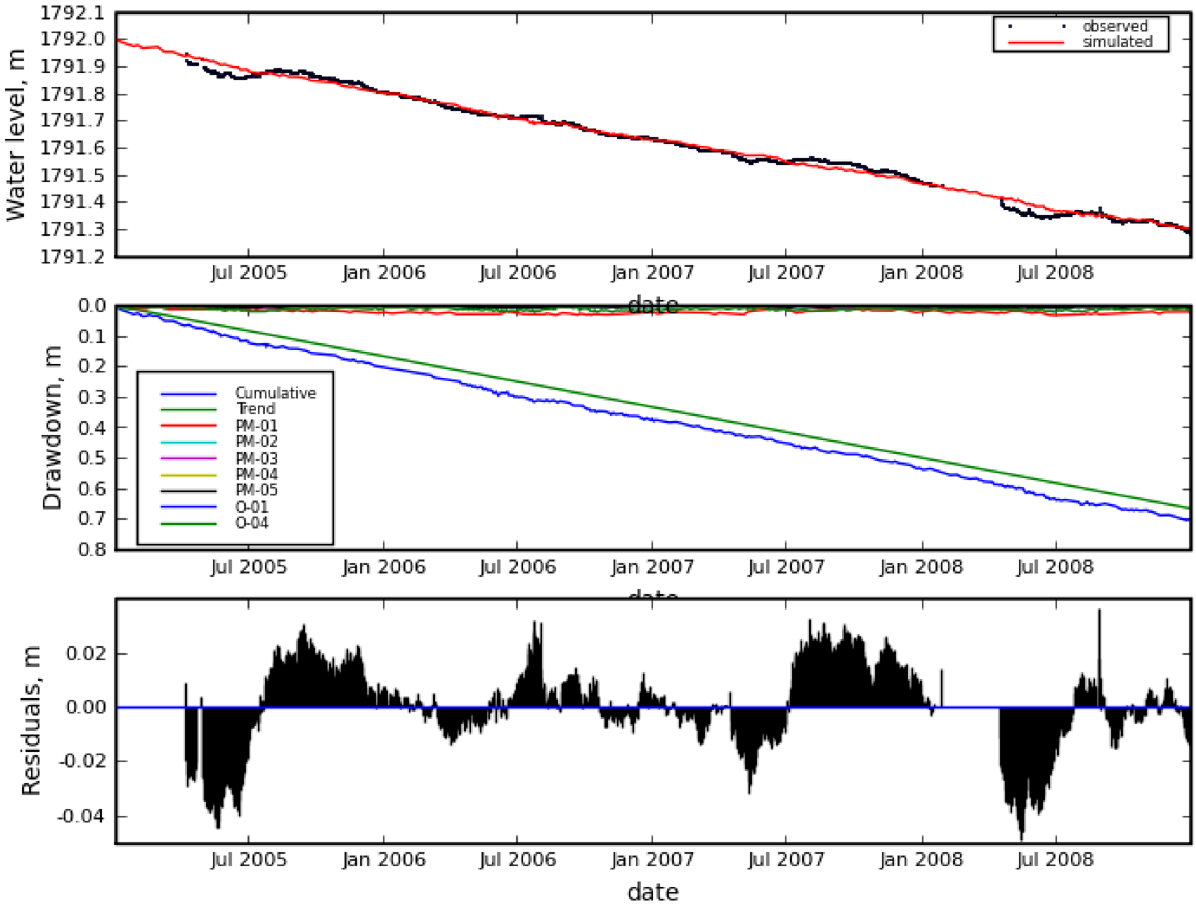
Notes: Black dots are existing regional aquifer monitoring wells; red dots are locations considered in the analysis for potential additional regional aquifer monitoring wells; the green star is a water-supply well. Brown polygons show the potential breakthrough locations of contaminants from TA-21 at the regional aquifer considered in this analysis: MDA T, DP West, and the drainlines. Blue lines and numbers indicate regional aquifer water-table elevations (based on March 2009 water-level data from the 2010 General Facility Information document [LANL 2010, 109084]). Scale bar units are in meters.

Figure C-3.0-1 Moderate- and high-priority TA-21 sources and potential new regional wells considered in the network evaluation; nearby regional monitoring wells; and water-table gradient



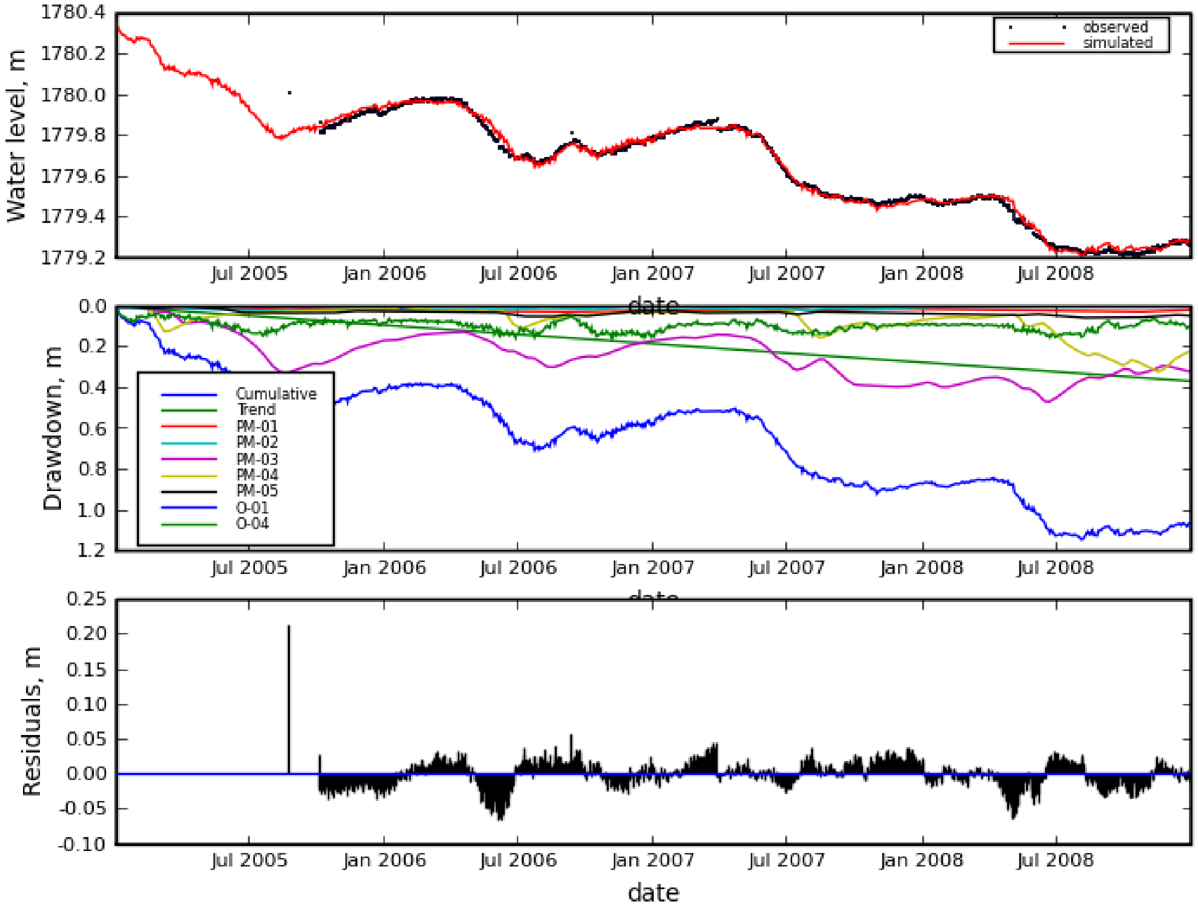
Notes: The top plot presents the observed (black) and simulated (red) water elevations. The second plot presents the potential drawdown at R-2 due to pumping at the nearby water-supply wells and a linear temporal trend of water-level decline. The cumulative drawdown, or the sum of drawdown contributions from pumping effects and considering a linear decline, is included for reference. The last plot presents the simulation residuals, or the difference between the simulated and observed water elevations at R-2.

Figure C-3.0-2 Water-level transients and decomposition of drawdown influences at R-2



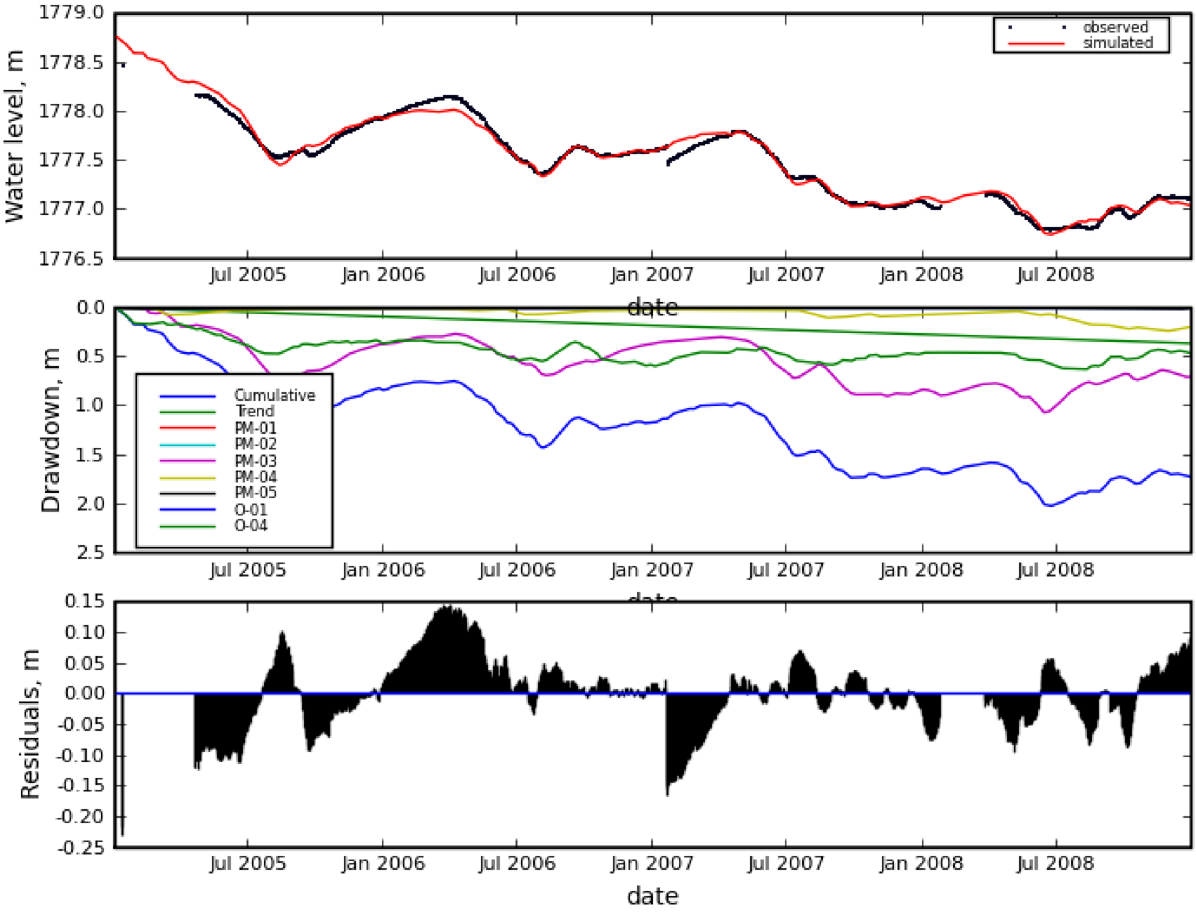
Notes: The top plot presents the observed (black) and simulated (red) water elevations. The second plot presents the potential drawdown at R-7 due to pumping at the nearby water-supply wells and a linear temporal trend of water-level decline. The cumulative drawdown or the sum of drawdown contributions is included for reference. The last plot presents the simulation residuals, or the difference between the simulated and observed water elevations at R-7.

Figure C-3.0-3 Water-level transients and decomposition of drawdown influences at R-7



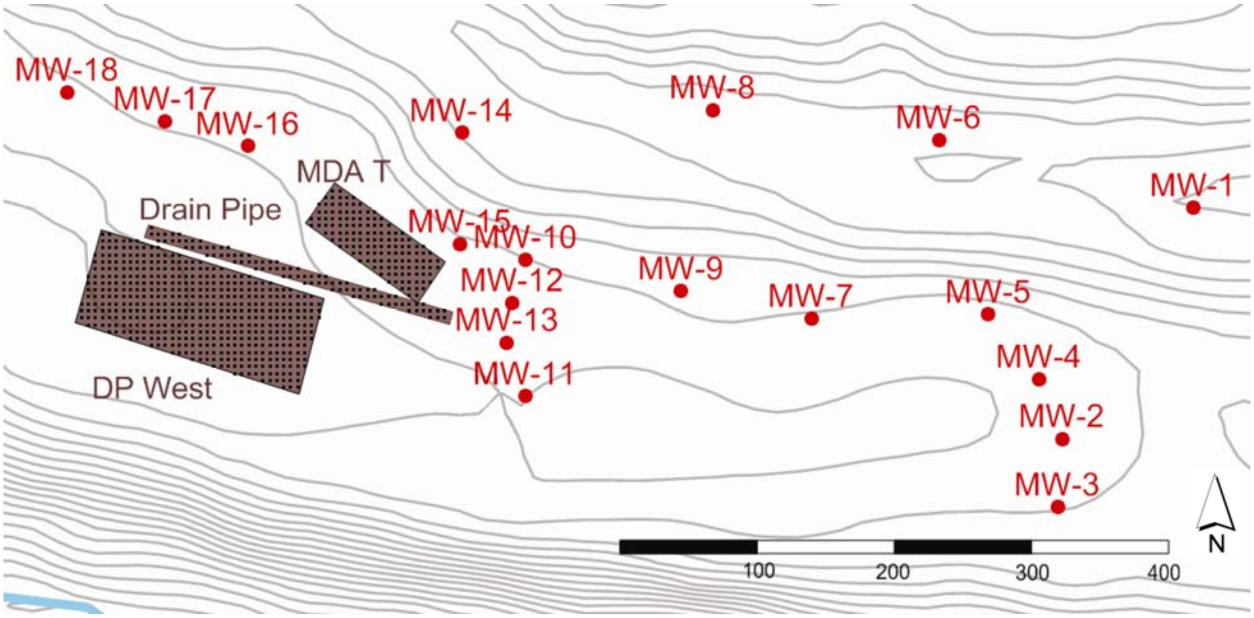
Notes: The top plot presents the observed (black) and simulated (red) water elevations. The second plot presents the potential drawdown at R-6 due to pumping at the nearby water-supply wells and a linear temporal trend of water-level decline. The cumulative drawdown or the sum of drawdown contributions is included for reference. The last plot presents the simulation residuals, or the difference between the simulated and observed water elevations at R-6. PM-3, PM-4, and O-4 pumping appear to influence water levels.

Figure C-3.0-4 Water-level transients and decomposition of drawdown influences at R-6



Notes: The top plot presents the observed (black) and simulated (red) water elevations. The second plot presents the potential drawdown at R-4 due to pumping at the nearby water-supply wells and a linear temporal trend of water-level decline. The cumulative drawdown or the sum of drawdown contributions is included for reference. The last plot presents the simulation residuals, or the difference between the simulated and observed water elevations at R-4. PM-3, PM-4, and O-4 pumping appear to influence water levels.

Figure C-3.0-5 Water-level transients and decomposition of drawdown influences at R-4



Note: Each window is represented by a series of point-source locations (black dots within polygons) distributed at 5-m spacing within the polygons. Scale bar units are in meters.

Figure C-3.0-6 Proposed new monitoring wells and potential breakthrough locations (MDA T, DP West, and the drainlines) of contaminant arrival at the top of the regional aquifer beneath TA-21 considered in the network evaluation

Table C-3.0-1
Model Parameters Evaluating the Monitoring Network of Regional Aquifer Wells

Parameter	Range	
	Minimum	Maximum
Porosity (m^3/m^3)	0.05	0.15
Flow azimuth (degrees)	30	90
Hydraulic gradient (m/m)	0.01	0.022
Hydraulic conductivity (m/d)	0.3	20
Dispersivity transverse (m)	0.5	5
Dispersivity longitudinal (m)	5	50

Note: Each parameter has a range of values used in the model runs.

Table C-3.0-2
Locations of Potential New Regional Aquifer Monitoring Wells Near TA-21

Well	X Coordinate	Y Coordinate
MW-1	498249.7	540894.7
MW-2	498155.8	540728.9
MW-3	498152.6	540679.8
MW-4	498139.5	540771.7
MW-5	498103.0	540818.3
MW-6	498067.5	540943.6
MW-7	497976.0	540815.3
MW-8	497905.6	540965.2
MW-9	497882.7	540835.0
MW-10	497771.4	540857.4
MW-11	497770.9	540759.5
MW-12	497761.7	540826.6
MW-13	497757.9	540798.2
MW-14	497725.6	540948.6
MW-15	497724.2	540868.9
MW-16	497572.2	540939.1
MW-17	497513.1	540956.9
MW-18	497442.6	540977.9

Note: NM state coordinate system in meters.

Table C-5.0-1
Detection Efficiency of the Newly Proposed Monitoring Wells for Plumes Originating from the Potential Breakthrough Locations

Well	MDA T (%)	DP West (%)	Drainlines (%)
MW-1	36	38	38
MW-2	12	17	15
MW-3	6	12	9
MW-4	18	23	20
MW-5	28	33	31
MW-6	62	58	61
MW-7	34	39	38
MW-8	88	77	82
MW-9	54	54	56
MW-10	87	77	81
MW-11	27	40	37
MW-12	75	70	73
MW-13	55	60	61
MW-14	96	90	90
MW-15	96	87	90
MW-16	37	71	56
MW-17	10	42	29
MW-18	1	13	6
MW-12:MW-14	100	96	98
MW-12:MW-15	97	87	90
MW-13:MW-14	98	96	98
MW-13:MW-15	96	87	90
MW-8:MW-12	89	80	84
MW-8:MW-13	89	79	83
MW-8:MW-14	100	95	97
MW-8:MW-15	97	87	90
MW-6:MW-12	80	71	76
MW-6:MW-13	71	65	70
MW-6:MW-14	100	96	98
MW-6:MW-15	97	87	90
MW-7:MW-12	75	70	73
MW-7:MW-13	57	60	62
MW-7:MW-14	99	96	96
MW-7:MW-15	97	87	90
MW-11:MW-10	87	77	81
MW-11:MW-12	75	70	73

Table C-5.0-1 (continued)

Well	MDA T (%)	DP West (%)	Drainlines (%)
MW-11:MW-13	55	60	61
MW-11:MW-14	96	96	94
MW-11:MW-15	96	87	90
MW-10:MW-8	91	80	85
MW-10:MW-9	87	77	81
MW-10:MW-12	87	77	81
MW-10:MW-13	87	77	81
MW-10:MW-14	100	96	98

Table C-5.0-2
Average Peak Travel Times from the Potential Breakthrough Locations to the Newly Proposed Monitoring Wells

Well	MDA T (yr)	DP West (yr)	Drainlines (yr)
MW-1	15.9	18.1	16.8
MW-2	18.7	20.1	19.2
MW-3	20.1	21.4	20.6
MW-4	16.8	18.4	17.4
MW-5	14.1	16.1	14.9
MW-6	9.3	12.0	10.5
MW-7	10.4	12.5	11.3
MW-8	4.8	7.6	6.1
MW-9	7.0	9.1	7.9
MW-10	3.0	5.3	4.0
MW-11	6.8	8.3	7.4
MW-12	3.8	5.8	4.6
MW-13	4.9	6.6	5.5
MW-14	2.2	4.2	3.4
MW-15	1.5	3.9	2.7
MW-16	4.7	4.1	4.3
MW-17	7.0	6.0	6.5
MW-18	9.8	8.6	9.2

Table C-5.0-3
Average Pore Velocities from the Potential Breakthrough Locations to the Newly Proposed Monitoring Wells

Well	MDA T (m/yr)	DP West (m/yr)	Drainlines (m/yr)
MW-1	212.1	216.3	216.0
MW-2	160.0	175.9	168.0
MW-3	147.3	163.8	155.7
MW-4	172.5	188.7	180.5
MW-5	188.6	205.0	197.9
MW-6	239.2	247.0	243.4
MW-7	179.8	208.2	194.7
MW-8	258.6	261.9	258.0
MW-9	180.9	216.3	203.2
MW-10	167.5	234.3	204.7
MW-11	122.7	167.3	137.3
MW-12	136.9	213.6	172.8
MW-13	124.8	190.6	147.9
MW-14	182.1	246.6	215.7
MW-15	136.9	238.5	191.8
MW-16	124.5	161.3	131.2
MW-17	136.6	131.2	122.3
MW-18	145.1	122.9	129.8

Appendix D

Observations of Perched-Intermediate Groundwater Near Technical Area 21

This section describes known occurrences of intermediate perched water beneath Los Alamos and Pueblo Canyons, the two large watersheds bounding Technical Area 21 (TA-21) on the south and north, respectively. Table D-1 lists 17 occurrences of perched-intermediate groundwater detected in boreholes in the area. The perched zones nearest TA-21 are schematically shown on the conceptual cross-sections, Figures 3.0-2 and 3.0-3, in the report.

Perched groundwater beneath Los Alamos and Pueblo Canyons results from infiltration of surface water and alluvial groundwater derived from snowmelt and seasonal rainfall in large watersheds with headwaters high in the Jemez Mountains. Surface water in Pueblo Canyon was previously augmented by effluent released from the Pueblo Canyon wastewater treatment plant (WWTP) from 1951 to 1991 and the Central WWTP from 1947 to 1961. Perched water in lower Pueblo Canyon includes contributions of canyon-floor effluent infiltration from the Bayo WWTP that operated from 1963 to 2007 and the Los Alamos WWTP that began operations in 2007.

The most significant perched-intermediate groundwater in the vicinity of TA-21 occurs within the Guaje Pumice Bed and the underlying Puye Formation beneath Los Alamos Canyon. Near TA-21, saturated thicknesses for these occurrences range from about 9 ft at LADP-3 to more than 31 ft at LAOI-3.2a. These perched groundwater occurrences are probably part of a larger integrated system that extends over 3.5 mi along the axis of Los Alamos Canyon from H-19 to LAOI-3.2 and LAOI-3.2a. Based on these relationships, it appears that an important control of intermediate-zone groundwater flow in the vicinity of TA-21 is the contact between the Guaje Pumice Bed and the underlying Puye Formation. Structure contours indicate that the downdip direction for the base of the Guaje Pumice Bed is towards the south, southeast, and southwest in the vicinity of TA-21 (Figure D-1). The control exerted on groundwater flow by the Guaje Pumice Bed suggests that perched water beneath Los Alamos Canyon should move generally southward away from TA-21. This conclusion is supported by observations that deep boreholes at Material Disposal Area (MDA) V (21-02523 and 21-24524) and MDA T (21-25262 and 21-607955) did not encounter perched groundwater in the Guaje Pumice Bed or the underlying Puye Formation. In contrast, well TA-53i, located on Mesita de Los Alamos to the south, encountered perched water that is geochemically similar to groundwater in wells LAOI-3.2 and LAOI-3.2a, supporting the conclusion that the perched groundwater beneath Los Alamos Canyon has a southern component of flow (LANL 2009, 107453). In the vicinity of LADP-3, LAOI-3.2, and LAOI-3.2a, the Guaje Pumice Bed dips toward the southwest, and well TA-53i appears to be downgradient of these wells.

Units of the Bandelier Tuff, including the Guaje Pumice Bed, pinch out eastward beneath the floor of Los Alamos Canyon, and the perched zones to the east are found in stratigraphically lower geologic units such as the Cerros del Rio basalt and underlying sedimentary units. These eastern perched zone occurrences tend to become thicker and occur at multiple depths. For example, at well R-9 located in lower Los Alamos Canyon, three perched systems were encountered: (1) in the central part of a thick sequence of Cerros del Rio basalts, (2) in the basal part of the Cerros del Rio basalts, and (3) in clay-rich, pumiceous deposits in volcanogenic sediments above Miocene basalt. Saturated thicknesses for the top and bottom zones at R-9 range from about 45 to 103 ft, and the middle zone was about 7 ft thick. The top and middle perched zones at R-9 are also present within similar lavas at well LAWS-1, located 1300 ft to the east. At well LAOI-7, saturated intervals are dispersed in a zone up to 138 ft thick in fractures of the Cerros del Rio basalt. The occurrence of thicker perched zones in the eastern part of Los Alamos Canyon may be due to enhanced infiltration where the canyon floor is underlain by Cerros del Rio basalts rather than by Bandelier Tuff. Because the Cerros del Rio basalt does not extend as far west as the developed portion of TA-21, it is unlikely that the eastern perched zones of Los Alamos Canyon extend beneath the TA-21 area.

In Pueblo Canyon, perched-intermediate water occurs within Pliocene and Miocene volcanogenic sediments and has a saturated thickness of >23 ft at well TW-2A and TW-2Ar and a saturated thickness of about 49 ft at R-5. Depth to water is 110 ft at TW-2A and about 338 ft at R-5. These perched zones probably represent relatively small, unrelated water bodies because of their distance from one another (2.5 mi), the lateral heterogeneity of volcanogenic sediments, and their varying depths beneath the canyon floor. These groundwater bodies are generally small and are unlikely to extend southward into the TA-21 area.

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Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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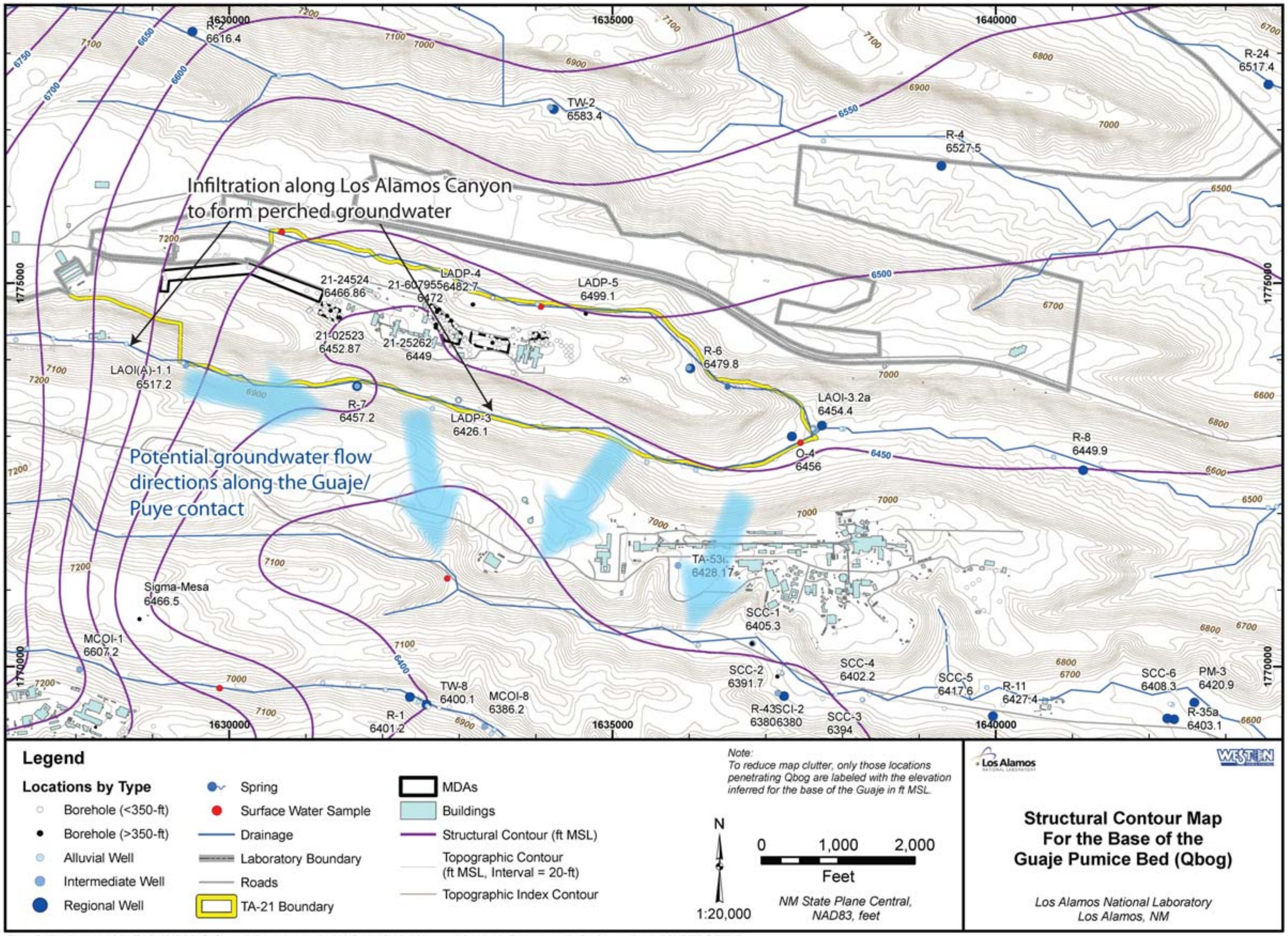

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Note: Arrows show potential directions of flow for perched-intermediate groundwater recharged by infiltration of surface water and alluvial groundwater beneath Los Alamos Canyon.

Figure D-1 **Structure contour map for the base of the Guaje Pumice Bed in the vicinity of TA-21**

Table D-1
Perched-Intermediate Groundwater in Pueblo and Los Alamos Canyons

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Pueblo Canyon	TW-2A 133 6646 and TW-2Ar 157 6646	95–100	<23	Puye Formation fanglomerate	Siltstone and gravels with silt-rich matrix	Tritium and nitrate	For TW-2A, a single-screen well was installed in this zone (Griggs and Hem 1964, 092516; Purtymun 1995, 045344). Replacement well TW-2Ar was installed at the same site in 2010.
Pueblo Canyon	R-5 902 6473	338	~49	Miocene/Pliocene dacitic sands and gravels mixed with 5%–15% rounded quartzite and granite river gravels	Within Pliocene/Miocene sediments; perching lithology not known	Nitrate, fluoride, chloride, uranium, and sulfate	A canyon-floor well was installed with four isolated screens (LANL 2003, 080925). Screen 1 is dry. Screen 2 is completed in this perched zone. The vertical extent of this zone is poorly known. Screens 3 and 4 are in regional groundwater.
Los Alamos Canyon	H-19 2000 7172	450	22	Porous, stratified, and well-sorted fall deposits of the Guaje Pumice Bed	Tschicoma Formation lava flow top	Not sampled	Saturation in this zone was noted while drilling to reach the regional aquifer (Griggs and Hem 1964, 092516). The perched zone was not screened, and the regional well was later abandoned.
Los Alamos Canyon	LAOI(A)1.1 323 6833	289	27	Porous, stratified, and well-sorted fall deposits of the Guaje Pumice Bed	Top of Puye Formation; possible clay-rich soil horizon. See description for well LADP-3.	None	A single-screen well was installed in this zone.

Table D-1 (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	R-7 1097 6779	373	9	Puye Formation silty, clayey, and sandy gravels	Clay-rich gravels from 382- to 397-ft depth in the Puye Formation	None	A canyon-floor well was installed with three isolated screens (Stone et al. 2002, 072717). Screen 1 in well R-7 is completed in this perched zone.
Los Alamos Canyon	R-7 1097 6779	744	~23	Pliocene/Miocene. sandy gravel with abundant pumice clasts	Possible perching layer from 767 to 772 ft in silty pebble gravel or from 772 to 777 ft in clayey pumiceous sands	None	Screen 2 in well R-7 is completed in this zone. Geophysical logs and borehole videos suggest additional perched groundwater zones were encountered when the R-7 borehole was drilled.
Los Alamos Canyon	LADP-3 349 6756	320	9	Porous, stratified, and well-sorted fall deposits of the Guaje Pumice Bed	Smectite- and kaolinite-rich soil a few inches thick at top of Puye Formation	Tritium	Soil development occurs at top of the Puye Formation in outcrops and in boreholes elsewhere. A single-screen well was installed in this zone (Broxton et al. 1995, 050119).
Mesita de Los Alamos at TA-53; mesa top between Los Alamos and Sandia Canyons	TA-53i 636.5 6987.2	600	10-15 ft	Puye Formation fine to medium gravels	Gravels with silt-rich matrix and fine sands	Nitrate, perchlorate?, and tritium	Perched groundwater occurs beneath the mesa in clean gravels overlying silt-rich gravels in Puye deposits above Cerros del Rio basalt (LANL 2009, 107661). The water chemistry of this zone is similar to wells LAOI-3.2 and LAOI-3.2a and supports the conclusion that this groundwater is derived from Los Alamos Canyon (LANL 2009, 107453).

Table D-1 (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	R-6i 660 6997	592	23	Puye Formation gravels	Poorly sorted fanglomerate with a silty matrix	Nitrate and perchlorate	This zone occurs at the same elevation and may be related to the perched zone identified by borehole video in nearby supply well O-4 during drilling. A single-screen well was installed in this zone.
Los Alamos Canyon	O-4 2806 6639	~253	Not known	Puye Formation gravels	Within Puye Formation fanglomerate; perching lithology not known	Not sampled	Saturation in this zone was noted while drilling to install a municipal supply well in the regional aquifer (Stoker et al. 1992, 058718). The geologic log notes, “Some perched water was visible in a video log of the 48-in. hole at about 253 ft where water cascaded in from a large gravel.” This perched zone is not accessed by a well screen in O-4.
Los Alamos Canyon	LAOI-3.2 165.5 6623	134	>31	Basal ash-flow tuffs of the Otowi Member and porous, stratified, and well-sorted fall deposits of the Guaje Pumice Bed	The perched zone was not fully penetrated during drilling; perching lithology not known	Nitrate, perchlorate, and chloride	Perched groundwater was detected while coring through the lowermost part of the Bandelier Tuff. The bottom of saturation was not penetrated by the borehole. A single-screen well was installed in this zone.

Table D-1 (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	LAOI-3.2a 266.9 6624	175	~20 ft	Puye Formation gravels	The perching horizon appears to be a stratified sequence of brown homogeneous silts and fine-grained sands with subordinate clay in the interval from 195 to 266.5 ft.	Nitrate, perchlorate, and chlorate	LAOI-3.2 and LAOI-3.2a are located about 50 ft apart with LAOI-3.2 screened in the Guaje Pumice Bed and LAOI-3.2a screened in the upper Puye Formation. The differences in depth to water in these two wells suggest two separate water-bearing zones occur at that location.
Los Alamos Canyon	LAOI-7 380 6458	26	See comments.	Basal ash-flow tuffs of the Otowi Member and porous, stratified, and well-sorted fall deposits of the Guaje Pumice Bed	The perching horizon is uncertain but may be silty sediments of the Puye Formation.	Nitrate and mercury	Perched groundwater was detected in the lower part of the Otowi Member during coring. The base of the perched water is uncertain because of incomplete core recovery, but most likely it extends to the top of dry silt-rich sediments in Puye deposits that overlie the Cerros del Rio basalt in this area.

Table D-1 (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	LAOI-7 380 6458	222	Groundwater dispersed in fractures over an interval of about 138 ft	Cerros del Rio basalt, in portions of lava flows cut by high-angle fractures and in interflow breccias separating basalt flows	Perching appears to occur above those sections of massive basalt flows where fractures are rare to absent. The lowermost perching horizon is not known with certainty but may be layered maar deposits between 360 and 363.4 ft at the base of the basalt sequence.	Mercury	This is a complex zone with saturation occurring at several horizons in the interval between 237.2 and 286.8 ft. The saturated horizons seem to be interconnected via high-angle fractures because the saturated zones yielded similar water levels. Water was first noted in the core barrel after drilling the 237.2- to 242.2-ft interval. Coring was halted and the water level stabilized at 221.6 ft. Fractures below 234.3 ft contain common clay; clay is much less abundant above this depth. Additional zones of saturation in core occurred between depths of 256.8 and 262.2 ft in a basalt rubble zone and between depths of 282.2 and 286.8 ft in a vesicular basalt.

Table D-1 (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	R-9i 322 6383 and LAWS-01 281.5 6305	137	45–99	Cerros del Rio basalt interflow breccia and highly fractured basalt	Massive basalt with few fractures	Tritium	Groundwater was first encountered at a depth of 180 ft, but the water level quickly rose to 137 ft, indicating possible confinement. At R-9i a canyon-floor well was installed with two isolated screens (Broxton et al. 2001, 071251). Screen 1 of R-9i is completed in this zone. In LAWS-01, this zone is sampled via a flexible liner with sampling ports (Stone and Newell 2002, 099125).
Los Alamos Canyon	R-9i 322 6383 and LAWS-01 281.5 6305	275	7	Cerros del Rio basalt brecciated flow base	Clay-rich, stratified, basaltic tephra (maar deposits) from 282 to 289.8 ft	Tritium	Water was first encountered at 275 ft. The water level stabilized at 264 ft and may be confined (Broxton et al. 2001, 071251). Screen 2 in well R-9i is completed in this zone. In LAWS-01, this zone is sampled via a flexible liner with sampling ports (Stone and Newell 2002, 099125).

Table D-1 (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	R-9 771 6383	524	48–103	Pliocene/Miocene volcanogenic sands and gravels	Clay-rich tuffaceous sands and gravels	Tritium	Three stringers of sands and gravels at 579–580.5 ft, 615 ft, and 624–626.8 ft produced perched groundwater (Broxton et al. 2001, 071250). These occurrences probably constitute a single saturated zone because, when isolated, each yielded the same depth to water of 524 ft. The water-bearing stringers are enclosed by clay-rich tuffaceous sands and gravels that may be confining units or may simply be unproductive. No well screens were installed in this saturated zone.