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Completion Report for Intermediate Aquifer Well R-27i

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EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, and development of intermediate perched groundwater monitoring well R-27i, located in Water Canyon, within Los Alamos National Laboratory Technical Area 36 (TA-36), in Los Alamos County, New Mexico. This report was written in accordance with the requirements in Section IV.A.3.e.iv of the Compliance Order on Consent. The well was installed at the direction of the New Mexico Environment Department to establish a monitoring location that would benefit corrective measures decisions for both TA-16 and Material Disposal Area AB.

The R-27i monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was used only above the anticipated perched water zone; no drilling-fluid additives other than small amounts of potable water were used below 507 ft below ground surface (bgs), roughly 100 ft above the targeted zone. Additive-free drilling provides minimal impacts to the groundwater and aquifer materials. The R-27i borehole was successfully completed to total depth using dual-rotary casing-advance drilling methods.

During drilling, a retractable 16-in. casing was advanced through alluvium, the upper part of the Bandelier Tuff, and the Cerro Toledo interval, to a depth of 351.6 ft bgs. A retractable 12-in. casing was then advanced through the lower part of the Bandelier Tuff and into the Puye Formation, to a total depth of 633.0 ft bgs. The R-27i monitoring well was completed with a single screen to evaluate water quality and measure water levels in a perched aquifer within the Puye Formation stratigraphically above the Cerros del Rio basalt. The 10-ft-long screened interval has the top of the screen set at 619.0 ft bgs.

The well was completed in accordance with a New Mexico Environment Department-approved well design. Well development activities indicate that the perched water-bearing zone at monitoring well R-27i is poorly productive, but the well will likely perform effectively to meet the planned objectives. A water-level transducer and sampling system have been installed in the R-27i well and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

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Acronyms and Abbreviations

AK	acceptable knowledge
amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
EES	Earth and Environmental Sciences
Eh	oxidation-reduction potential
ENV	environmental
EP	Environmental Programs
gpm	gallons per minute
HE	high explosives
IC	ion chromatography
ICPMS	inductively coupled (argon) plasma mass spectrometry
ICPOES	inductively coupled (argon) plasma optical emission spectroscopy
ID	identification
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MDA	material disposal area

µS/cm	microsiemens per centimeter
mV	millivolt
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
pH	potential of hydrogen
PVC	polyvinyl chloride
Qal	Quaternary Alluvium
Qbo	Quaternary Otowi Member of the Bandelier Tuff
Qbog	Quaternary Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
Qbt 1g	Quaternary Unit 1g of Tshirege Member of the Bandelier Tuff
Qct	Quaternary Cerro Toledo interval
RCRA	Resource Conservation and Recovery Act
RPF	Records Processing Facility
SOP	standard operating procedure
TA	technical area
TD	total depth
TOC	total organic carbon
Tpf	Tertiary Puye Formation
TU	tritium unit
VOA	volatile organic analysis
VOC	volatile organic compound
WCSF	waste characterization strategy form
wt%	weight percent

1.0 INTRODUCTION

This completion report summarizes site preparation, borehole drilling, well construction, well development, and dedicated sampling system installation for intermediate perched groundwater monitoring well R-27i. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the Compliance Order on Consent (the Consent Order). The R-27i monitoring well borehole was drilled from September 10 to 24, 2009 and completed from September 28, 2009 to October 17, 2009, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

The R-27i project site is located in Water Canyon on the existing regional aquifer monitoring well R-27 drill pad, within the Laboratory's Technical Area 36 (TA-36) in Los Alamos County, New Mexico (Figure 1.0-1). The purpose of the R-27i well is to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the Groundwater Protection Program for the Laboratory, the Consent Order, and the New Mexico Environment Department (NMED) approved work plan. This new well is intended to establish a monitoring location that would benefit corrective measures decisions for both TA-16 and Material Disposal Area (MDA) AB, providing near-field monitoring for potential contaminant transport from MDA AB, and midfield to distal monitoring for potential migration from known, contaminated perched-intermediate groundwater beneath TA-16.

The primary objective of the drilling activities at R-27i was to drill and install a single-screen, intermediate-depth perched aquifer monitoring well. Secondary objectives were to collect drill-cutting samples and sample the targeted perched groundwater zone.

The R-27i borehole was drilled to a total depth (TD) of 633.0 ft below ground surface (bgs). A monitoring well was then installed with one 10-ft screen between 619.0 and 629.0 ft bgs. The depth to water after well installation was 616.4 ft bgs on October 17, 2009. During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD.

Post-installation activities included well development, surface completion, geodetic surveying, and dedicated sampling system installation. Future activities will include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendices completed to date associated with the R-27i project. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the NMED in accordance with U.S. Department of Energy policy.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities included preparing administrative planning documents and preparing the drill site and drill pad. All preparatory activities were completed in accordance with Laboratory policies and procedures and regulatory requirements.

2.1 Administrative Preparation

The following documents helped guide the implementation of the scope of work for well R-27i:

- "Drilling Work Plan for Perched-Intermediate Aquifer Well R-27i" (LANL 2009, 106684)
- "Drilling Plan for Intermediate Well R-27i" (TerranearPMC 2009, 106982)
- "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (Mobilization, Site Preparation and Setup Stages)" (LANL 2007, 100972)
- "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan" (LANL 2006, 092600)
- "Waste Characterization Strategy Form for South Canyon Wells CdV-37-1i and R-27i Intermediate Aquifer Well Installation and Corehole Drilling" (LANL 2009, 106895)

2.2 Site Preparation

Minor site preparation was performed by Laboratory personnel to the existing R-27 drill site prior to rig mobilization. On September 2, 2009, activities included moving the dual rotary drill rig, air compressors, trailers, and support vehicles to the drill site and staging alternative drilling tools and construction materials at the Pajarito Road laydown yard.

Potable water was transported by Laboratory personnel and stored in a frac tank on the R-27i drill pad. Safety barriers and signs were installed around the borehole-cuttings containment pit and along the perimeter of the work area.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and approach and provides a chronological summary of field activities conducted at monitoring well R-27i.

3.1 Drilling Approach

The drilling methodology and selection of equipment and drill-casing sizes for the R-27i monitoring well were designed to retain the ability to investigate and case off perched groundwater above the target perched water zone. Further, the drilling approach ensured that a sufficiently sized drill casing was used to meet the required 2-in. minimum annular thickness of the filter pack around a 5.56-in. outside-diameter (O.D.) well.

Dual-rotary air-drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-27i borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. The Foremost DR-24HD drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, a deck-mounted 900 ft^3/min air compressor, and general drilling equipment. Auxiliary equipment included two Sullair 1150 ft^3/min trailer-mounted air compressors. Two sizes of A53 grade B flush-welded mild carbon-steel casing (16-in. and 12-in. inside-diameter [I.D.]) were used for the R-27i project.

The dual-rotary technique at R-27i used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all 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 foaming agents was

terminated at 507.0 ft bgs, roughly 100 ft above the expected perched groundwater horizon. No additives other than municipal water were used for drilling below this depth (507.0 ft bgs). Total amounts of drilling fluids introduced into the borehole and those recovered are recorded and presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-27i Well

Mobilization of drilling equipment and supplies to the R-27i drill site occurred from September 2 to September 4, 2009. Decontamination of the equipment and tooling was performed before mobilization to the site. On September 10, 2009, following on-site equipment inspections, the monitoring well borehole was initiated at 0116 h using dual-rotary methods with 16-in. drill casing and a 15-in. (14.88-in.) air-hammer bit.

Drilling and advancing 16-in. casing proceeded rapidly through canyon-bottom alluvium, the Tshirege Member of the Bandelier Tuff, and the Cerro Toledo interval. Drilling continued to 351.6 ft bgs where the 16-in. drill casing was landed on September 14, 2009. No indications of groundwater were observed while advancing the 16-in. casing.

On September 15, 2009, the 16-in. casing's drive shoe was cut off at 344.3 ft bgs. A string of 12-in. drill casing was started into the borehole that day. Drilling, using dual-rotary methods with the 12-in. casing string and a 12-in. (11.62-in.) tricone bit, started on September 18, 2009, at 351.6 ft bgs. Drilling progressed into the Otowi Member ash flows, Guaje Pumice Bed, and the Puye Formation to a depth of 585 ft bgs on September 21, 2009.

On September 22, 2009, water flow of 1 gallon per minute (gpm) or less was noted at 622.0 ft bgs. A water sample was collected, the casing was lifted 1 ft, and the borehole was left open to better allow water to enter the borehole. The next day (September 23), a small amount of water was observed at TD and a water level of 616.7 ft bgs was measured. Open-hole drilling resumed with an 11.75-in. air-hammer bit; drilling was suspended at 626.0 ft bgs due to borehole instability.

On September 24, 2009, the 12-in. casing was advanced to 633.0 ft bgs (TD). The next day, September 25, depth to water was measured at 630.4 ft bgs, and the 12-in. casing retracted 23.0 ft (to 610.0 ft bgs) in preparation for video logging. The camera (Laboratory equipment) was run from 610.0 to 630.0 ft bgs. During the same shift, approximately 90 gal. of water was bailed from the borehole, and a water sample was collected. After bailing, preparations were started for well design and construction.

During drilling, field crews worked a single 12-h shift each night, 7 nights/wk. All associated nightly activities proceeded normally without incident or delay.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-27i. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-27i monitoring well borehole at 5-ft intervals from ground surface to the TD of 633.0 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected by the site geologist from the drilling cyclone discharge, placed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected from ground surface to TD and placed in chip trays along with unsieved (whole rock) cuttings. Recovery of cuttings samples was 100% for the R-27i borehole. Radiation control technicians screened cuttings before removal from

the site. All screening measurements were within the range of background values. The core boxes and chip trays were delivered to the Laboratory's archive at the conclusion of drilling activities.

The borehole lithologic log for R-27i stratigraphy is summarized in section 5.1 and detailed in Appendix A.

4.2 Water Sampling

A groundwater-screening sample was collected from the drilling discharge hose on September 22, 2009, at 622.0 ft bgs to evaluate the targeted perched groundwater zone. A second groundwater screening sample was collected on September 26, 2009, at 632.0 ft bgs, using a bailer. The screening sample collected at 622.0 ft bgs was analyzed in the Laboratory's Earth and Environmental Services Group 14 (EES-14) for cations, anions, perchlorate and metals. The sample collected just above the TD of the borehole, at 632.0 ft bgs, was analyzed at an offsite laboratory for volatile organic compounds, low-level tritium, and high explosives. Table 4.2-1 shows a summary of screening samples collected during drilling at the R-27i monitoring well.

Seven groundwater screening samples were collected during well development from the development pump's discharge line. Development screening samples were analyzed by EES-14 for cations, anions, perchlorate, metals, and total organic carbon (TOC). Table 4.2-1 shows a summary of screening samples collected during development at the R-27i monitoring well. Groundwater chemistry and field water quality parameters are discussed in Appendix B.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for the full suite of constituents including radioactive elements; anions/cations; general inorganic chemicals; volatile and semi-volatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sample frequency at R-27i will be evaluated and presented in the annual "Interim Facility-Wide Groundwater Monitoring Plan."

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-27i is presented below. The Laboratory's geology task leader and site geologists examined cuttings to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, and water-level measurements were used to characterize groundwater occurrences encountered at R-27i.

5.1 Stratigraphy

The stratigraphy observed in the R-27i borehole is described below in order of youngest to oldest geologic units. Unit descriptions and geologic contacts are based on drill cuttings collected from the discharge hose. Figure 5.1-1 illustrates the stratigraphy at R-27i. A detailed lithologic log based on microscopic examination and analysis of drill cuttings is presented in Appendix A.

Alluvium (0–25 ft bgs)

Alluvial sediments were encountered at R-27i from ground surface to 25 ft bgs. These tuffaceous, detrital sediments are made up of poorly sorted, unconsolidated silt, fine to coarse sand, and fine to coarse gravel derived from local tuff and other volcanic rocks. No evidence of alluvial groundwater was observed.

Unit 1g of the Tshirege Member of the Bandelier Tuff (25–100 ft bgs)

The Quaternary Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g) was encountered from 25 ft to 100 ft bgs as interpreted from microscopic and descriptive analysis. Unit 1g is recognized by the appearance of vitric pumices as a primary tuff component. The Qbt 1g section in R-27i represents ash flow tuff that is generally poorly to non-welded, strongly pumiceous, crystal-rich and lithic-bearing with a matrix of weathered to vitric ash. Unit 1g cuttings commonly exhibit pale orange to white glassy, quartz- and sanidine-phyric pumice lapilli, subangular, granular to pebble, volcanic lithic fragments (predominantly dacitic), free quartz and sanidine crystals and locally abundant light pink ash. Indurated fragments of intact Qbt 1g tuff are generally not observed in cuttings.

Cerro Toledo Interval (100–355 ft bgs)

The Quaternary Cerro Toledo interval (Qct), intersected from 100 ft to 355 ft bgs, is estimated to be 255 ft thick at R-27i as interpreted from microscopic and descriptive analysis. This unit, consisting of poorly consolidated sediments derived from western tuffaceous and volcanic sources, stratigraphically separates the Tshirege and Otowi Members of the Bandelier Tuff. Unit Qct locally consists of weakly consolidated silt, fine to coarse sand and pebble detritus, made up of tuffaceous and volcanic materials (predominantly light gray porphyritic and other varieties of dacite), weathered to glassy pumice fragments, and abundant quartz and sanidine crystal grains.

It is important to note that the top of the Cerro Toledo in adjacent well R-27 is 80 ft bgs, as inferred from a sharp decrease in the gamma log at this depth. In addition, an increase in the gamma log in R-27 at 332 ft bgs was interpreted to mark the bottom of the Cerro Toledo. Because R-27i is very close to R-27 (100 ft west) and at approximately the same surface elevation, these large stratigraphic discrepancies for the upper and lower Cerro Toledo contacts (20 ft and 23 ft, respectively) are unexpected. Typically, gamma logs provide one of the best lines of evidence for defining the stratigraphic extent of Qct, but the absence of a gamma log at R-27i rules out direct comparison. Observation of clay and manganese oxide spots on lapilli at approximately 340 ft bgs in R-27i could be interpreted as paleosol developed on the Otowi upper surface at a depth more compatible with the Qct/Quaternary Otowi Member of the Bandelier Tuff (Qbo) contact identified at R-27. Further study of data from both boreholes would be warranted to better define the Qct at this location.

Otowi Member of the Bandelier Tuff (355–525 ft bgs)

The Quaternary Otowi Member of the Bandelier Tuff (Qbo), encountered in R-27i from 355 ft to 525 ft bgs, is 170 ft thick as interpreted from microscopic and descriptive analysis. The Otowi Member is a poorly welded, pumiceous, locally lithic-rich, crystal-bearing ash-flow tuff. Unit Qbo locally contains abundant white to pale orange, glassy pumice lapilli (fibrous-textured and quartz- and sanidine-phyric), volcanic lithic fragments and moderately abundant quartz and sanidine crystals enclosed in a matrix of vitric ash. Locally abundant subangular, lithic fragments are predominantly of intermediate volcanic compositions that include gray to pinkish gray hornblende- and/or biotite-phyric dacites. Preserved fragments of intact Qbo tuff are seldom present in drill cuttings.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (525–533 ft bgs)

The Quaternary Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog) occurs in R-27i from 525 ft to 533 ft bgs on the basis of microscopic and descriptive analysis and is estimated to be 8 ft thick. This tuff unit is commonly characterized by a predominance of white vitric, phenocryst-poor pumice lapilli. Cuttings suggest that the Guaje Pumice Bed is locally non-welded, pumiceous, lithic and

crystal-bearing. Abundant angular to subangular dacitic lithics, quartz and sanidine crystals, and fine ash are present.

Puye Formation (533–633 ft bgs)

A 100-ft-thick section of the Tertiary Puye Formation (Tpf) volcaniclastic sediments was encountered in R-27i stratigraphically underlying the Bandelier Tuff, from 533 ft to 633 ft bgs. The Puye Formation is locally comprised of texturally diverse gray, reddish gray and purple, poorly sorted, fine sand to pebble conglomerates, and silty sandstones. Intervals of silt-rich sediments were observed only in the uppermost part of the Puye drill cuttings. The remainder of the Puye Formation is compositionally uniform throughout the section. Detrital constituents making up these sediments are generally subangular and predominantly of light gray to medium gray porphyritic hornblende-phyric dacites with lesser aphanitic medium to dark gray dacites. Minor reddish brown scoria and red rhyolite fragments are present in drill cuttings.

5.2 Groundwater

Drilling proceeded without any groundwater indications until 622.0 ft bgs, in the Puye Formation. The borehole was then advanced to a TD of 633.0 ft bgs, where the groundwater flow rate was estimated at 5 gpm. The 12-in. casing was retracted to 610.0 ft bgs, to allow water flow into the borehole. Measured water levels indicated a stabilized depth to water of 616.8 ft bgs on September 26, 2009, prior to well installation.

6.0 BOREHOLE LOGGING

A single video log was collected during the R-27i drilling project using Laboratory-owned equipment. A summary of the video logging run is presented in Table 6.0-1.

6.1 Video Logging

A video run was made in the R-27i monitoring well at the final TD of 633.0 ft bgs, with the 12-in. drill casing retracted to 610.0 ft bgs. The video verified a water level at 617.0 ft bgs. The video log is presented on DVD as Appendix C included with this document.

Table 6.0-1 details the video logging run.

6.2 Geophysical Logging

There were no geophysical surveys run in the R-27i monitoring well because geophysical logging was previously conducted at adjacent well R-27.

7.0 WELL INSTALLATION R-27i MONITORING WELL

The R-27i well was installed between September 28 and October 17, 2009.

7.1 Well Design

The R-27i well was designed in accordance with the Consent Order. NMED approved the well design before installation. The well was designed with a single screened interval between 619.0 ft and 629.0 ft bgs to monitor perched groundwater quality and water levels in the upper part of the Puye Formation.

7.2 Well Construction

The R-27i monitoring well was constructed of 5.0-in. I.D./5.56-in. O.D., type A304 passivated stainless-steel threaded casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The screened section utilized one 10-ft length of 5.0-in.-I.D. rod-based, 0.020-in.-slot, wire-wrapped well screen. Compatible external stainless-steel couplings (also type A304 stainless steel fabricated to ASTM A312 standards) were used to join all individual casing and screen sections. The coupled unions between threaded sections were approximately 0.7 ft long. All casing, couplings, and screen were steam and pressure washed on-site before installation. A 2-in. I.D. threaded/coupled steel tremie pipe (decontaminated prior to use) was utilized for delivery of backfill and annular fill materials down-hole during well construction. The placement of annular and backfill materials was accomplished by a two-part procedure where the backfill and annular fill material were first installed through the tremie pipe, followed by the retraction of the drill casing coupled with raising the tremie pipe. The well casing was hung on a wireline while the drill casing was supported by a ring and slips. During this part of the process, the cut pieces of drill casing were picked up by an additional wireline, laid down and staged away from the drill rig.

Due to the close proximity of the top of the Cerros del Rio basalt and the bottom of the borehole, a decision was made to attempt to extract the entire 12-in. casing string without cutting off the drive shoe in order to avoid leaving any carbon steel drill casing near the well screen. Another principal concern was advancing the borehole too far and/or too near the basalt with a risk of penetrating the perching horizon for the groundwater encountered. The DR-24HD drill rig was used for the initial phase of well construction and the entire string of 12-in. casing was extracted from the borehole using this rig. A short length of 16-in. (7.3-ft casing/shoe) drill casing remains in the borehole at a depth of 344.3 to 351.6 ft bgs, well above the screen, and was entombed in cement and bentonite. The DR-24HD drill rig was used to construct the well from 442.5 to 631.3 ft bgs. A Semco work-over rig was used for all well construction activities after the DR-24HD drill rig was demobilized from the drill pad on October 7, 2009.

One screened interval was chosen for the R-27i well design. The nominal 10-ft-long screened interval was set from 619.0 ft to 629.0 ft bgs. A 1.2-ft stainless-steel sump was placed below the bottom of the well screen. Stainless-steel centralizers (two sets of four) were welded to the well casing approximately 1.0 ft above and below the screen. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Decontamination of the stainless-steel well casing and screen took place from September 26 to September 28, 2009, along with mobilization of initial well construction materials to the site.

On September 28, at 2304 h, installation of the stainless-steel 5-in. well casing was started into the wellbore. After landing the well casing at 630.2 ft bgs, the process of installation of annular materials began on September 30, 2009. A 10/20 silica sand filter pack was installed from 614.0 to 631.3 ft bgs and surged to promote compaction (total 10/20 sand: 15.6 ft^3). Note that the actual volume of 10/20 silica sand used over that interval exceeded the calculated volume (12.4 ft^3) by 26%, which is likely due to the borehole being slightly washed out across the water-bearing interval. A short 20/40 silica sand transition collar on top of the filter pack was placed from 612.0 to 614.0 ft bgs (total 20/40 sand: 1.6 ft^3).

The installation of the lower bentonite seal (1/4-in. pellets, 3/8-in. chips) began on October 1 and continued through October 3, 2009, from 559.2 to 612.0 ft bgs using a total of 30.5 ft^3 of bentonite. The lower surface seal, a mix of 98 weight percent (wt%) Portland cement with 2 wt% Baroid IDP-381 additive was placed above the lower bentonite seal from 348.2 to 559.2 ft bgs using a total of 170.4 ft^3 of cement grout. Baroid IDP-381 enhances the flow properties and bonding characteristics of Portland cement, which will serve to improve the function of the surface seal.

The well's upper bentonite seal (3/8-in. and 3/4-in. chips) was installed on October 12 through October 14, 2009, from 250.1 to 348.2 ft bgs using a total of 112.6 ft^3 of bentonite. The upper surface seal, a mix of 98 wt% Portland cement with 2 wt% Baroid IDP-381 additive was placed above the upper bentonite seal from 3.0 to 250.1 ft bgs using a total of 408.2 ft^3 of cement grout. This marked formal NMED well construction completion on October 17, 2009 (at 0425 h). Table 7.2-1 itemizes volumes of all materials used during well construction.

Operationally, well construction proceeded smoothly, 12 h/night, 7 nights/wk, from September 28 (well casing install) to October 17, 2009.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation at R-27i, the well was developed. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system has been installed. Site restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees.

8.1 Well Development

Well development was conducted between October 17 and 26, 2009. A total of 2608 gal. was removed during development. Initially, the screened interval was bailed to remove formation fines in the filter pack and sump. Bailing continued until water clarity visibly improved. Final development was accomplished using a submersible pump.

The bailing tool employed was a 4.0-in.-O.D. by 21.0-ft-long carbon steel bailer with a total capacity of 12 gal. The tool was lowered by wireline and repeatedly filled, withdrawn from hole and dumped into cuttings pit. After bailing, a 1.5-hp, 4-in.-Grundfos submersible pump was installed in the well for the final stage of well development. The small pump was necessary due to the zone's low rate of recharge to avoid pumping the well dry. Even with the pump at its lowest operational limit of 0.5 gpm, the well would draw down and dewater after 10 to 11 h of sustained pumping (approximately one full shift). Approximately 2608 gal. of groundwater was purged at R-27i during the eight days of well development activities.

During the pumping stage of well development, turbidity, temperature, potential of hydrogen (pH), dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance parameters were measured. In addition, water samples were collected for TOC analysis. The required values for TOC and turbidity to determine adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTUs), respectively.

8.1.1 Well Development Field Parameters

Field parameters were measured at well R-27i by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. These conditions resulted in a variation of field parameters during well development and during the pumping test, most notably, temperature, pH, ORP, and DO.

Measurements of pH varied from 6.55 to 8.86 and temperature varied from 14.83°C to 23.99°C. DO varied from 2.21 to 6.4 mg/L and specific conductance ranged from 99 to 234 microsiemens per centimeter (µS/cm). ORP measurements varied from -101.7 to 165.7 millivolts (mV) and corrected

oxidation-reduction potential (Eh) values varied from 107.2 to 369.6 mV. Turbidity ranged from 0.6 to 60.6 NTUs for the nonfiltered groundwater samples.

The final development parameters at R-27i were pH of 7.15, temperature of 16.11°C, specific conductance of 151 µS/cm, and turbidity of 18.7 NTUs. The final TOC concentration was 0.39 milligrams of carbon per liter. Note that 150 gal. of water had been removed prior to the final turbidity reading. The poorly productive well was not recharging very quickly, which accounts for the elevated final turbidity reading. However, as Table B-1.2-1 in Appendix B shows, the majority of turbidity readings during development at R-27i were below 5 NTUs when lower volumes were purged. Table B-1.2-1 presents all of the field parameters and volumes discharged during development.

8.2 Aquifer Testing

Due to the low recharge rates observed from the intermediate perched zone during well development, no aquifer testing was conducted at R-27i.

8.3 Dedicated Sampling System Installation

A dedicated sampling system composed of a pneumatic Bennett pump was installed in R-27i. The Bennett pump is a model 1800-7 and is hung in the well on a tube bundle that includes a Teflon water-discharge line. The pump intake is set near the bottom of the screen interval at a depth of 628.0 ft bgs. To measure water levels in the well, one 1-in.-I.D. schedule 40 polyvinyl chloride (PVC) pipe was installed with and banded to the Bennett pump tube bundle to set a dedicated transducer below the measured static water level. The PVC transducer tube is equipped with a 6-in. section of 0.010-in. slot screen with a threaded end cap at the bottom of the tube. An In-Situ Level Troll 500 transducer was installed inside the PVC tube. The transducer is readily removable for manual water level measurements.

The sampling system components for R-27i monitoring well are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-27i wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 10-in.-I.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. A total of four bollards, painted yellow for visibility, were set at the outside edges of the pad to protect the well from traffic. All of the four bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on February 22, 2010 (Table 8.5-1). The survey data collected conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in ft above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground-surface elevation near the concrete pad, the top of the brass pin in the concrete pad, the top of the well casing, and the top of the protective casing for the R-27i monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-27i project includes drilling fluids, purged groundwater, drill cuttings, decontamination water, and contact waste. A summary of the waste characterization samples collected during drilling, construction and development of the R-27i well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with "Waste Characterization Strategy Form for South Canyon Wells CdV-37-1i and R-27i Intermediate Aquifer Well Installation and Corehole Drilling" (LANL 2009, 106895).

Fluids produced during drilling and well development are expected to be land-applied after a review of associated analytical results per the waste characterization strategy form (WCSF) and the EP-Directorate Standard Operating Procedure (SOP) 010.0, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criteria for land application, the drilling fluids will be evaluated for treatment and disposal at one of the Laboratory's six wastewater treatment facilities. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA SOP-011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criterion for land application, they will be disposed of at an authorized facility. Decontamination fluid used for cleaning the drill rig and equipment is currently containerized. The fluid waste was sampled and will be disposed of at an authorized facility. Characterization of contact waste will be based upon acceptable knowledge, pending analyses of the waste samples collected from the drill cuttings, purge water, and decontamination fluid.

Site restoration activities will include removing drilling fluids and cuttings from the pit and managing the fluids and cuttings in accordance with applicable SOPs, removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area, as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-27i were performed as specified in "Drilling Plan for Intermediate Well R-27i" (TerranearPMC 2009, 106982).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-27i monitoring well.

Pat Longmire wrote Appendix B, Groundwater Analytical Results.

Laboratory personnel ran downhole video equipment.

Terranear PMC provided oversight on all preparatory and field-related activities.

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

The following list includes all documents cited in this report. 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 EP Directorate's 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), March 2006. "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan," Los Alamos National Laboratory document LA-UR-06-1840, Los Alamos, New Mexico. (LANL 2006, 092600)

LANL (Los Alamos National Laboratory), October 4, 2007. "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (Mobilization, Site Preparation and Setup Stages)," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2007, 100972)

LANL (Los Alamos National Laboratory), July 2009. "Drilling Work Plan for Perched-Intermediate Aquifer Well R-27i," Los Alamos National Laboratory document LA-UR-09-4727, Los Alamos, New Mexico. (LANL 2009, 106684)

LANL (Los Alamos National Laboratory), September 9, 2009. "Waste Characterization Strategy Form for South Canyon Wells CdV-37-1i and R-27i Intermediate Aquifer Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2009, 106895)

TerranearPMC, August 2009. "Drilling Plan for Intermediate Well R-27i," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2009, 106982)

11.2 Map Data Sources

Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2008-0109; 28 February 2008.

Hypsography, 100 and 20 Ft Contour Interval; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1991.

Surface Drainages, 1991; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program, ER2002-0591; 1:24,000 Scale Data; Unknown publication date.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning and Project Initiation Group, Infrastructure Planning Division; 19 September 2007.

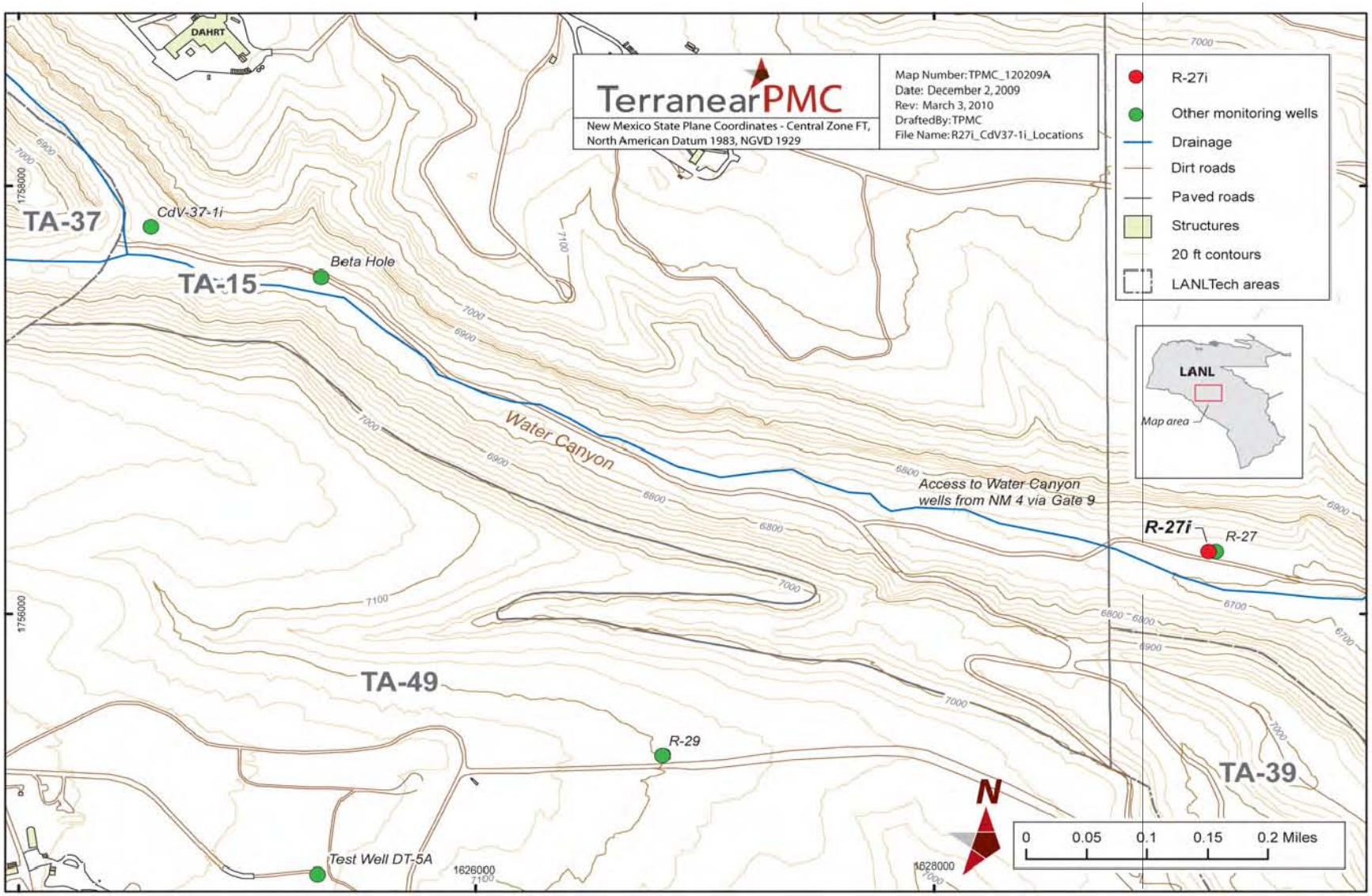

Figure 1.0-1 Location of monitoring well R-27i with respect to regional well R-27

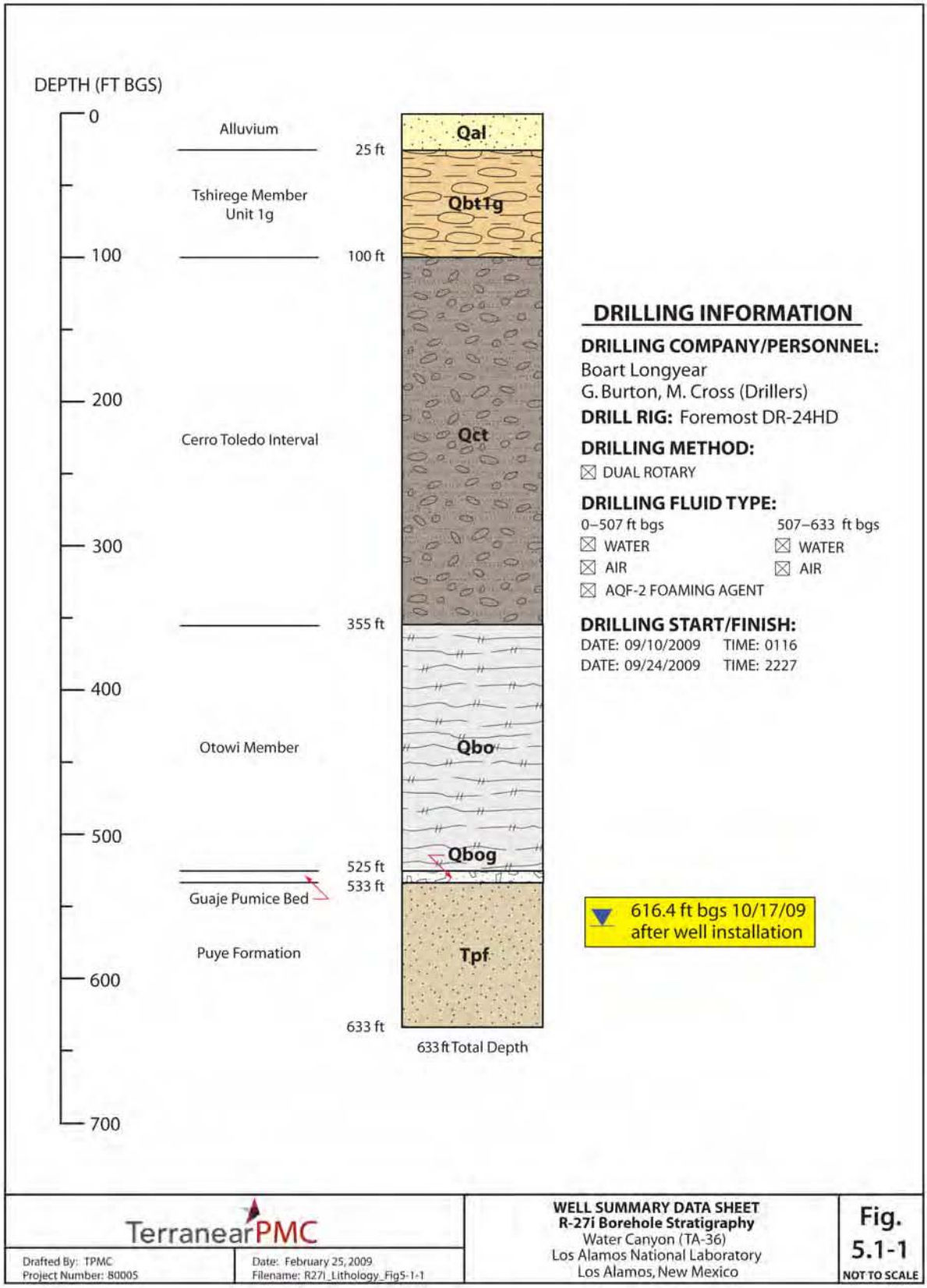

Figure 5.1-1 Monitoring well R-27i borehole stratigraphy

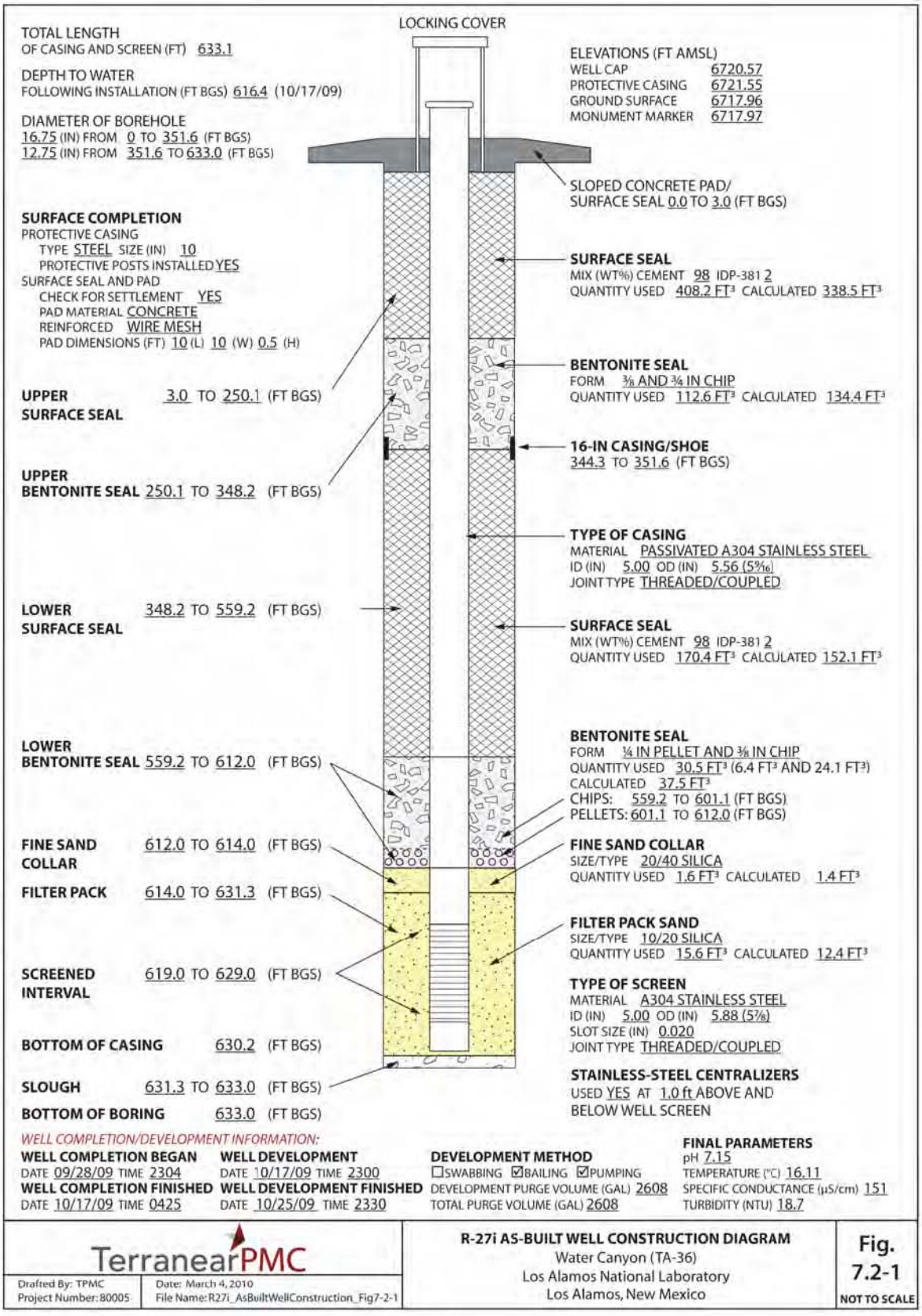

Figure 7.2-1 Monitoring well R-27i as-built well construction diagram

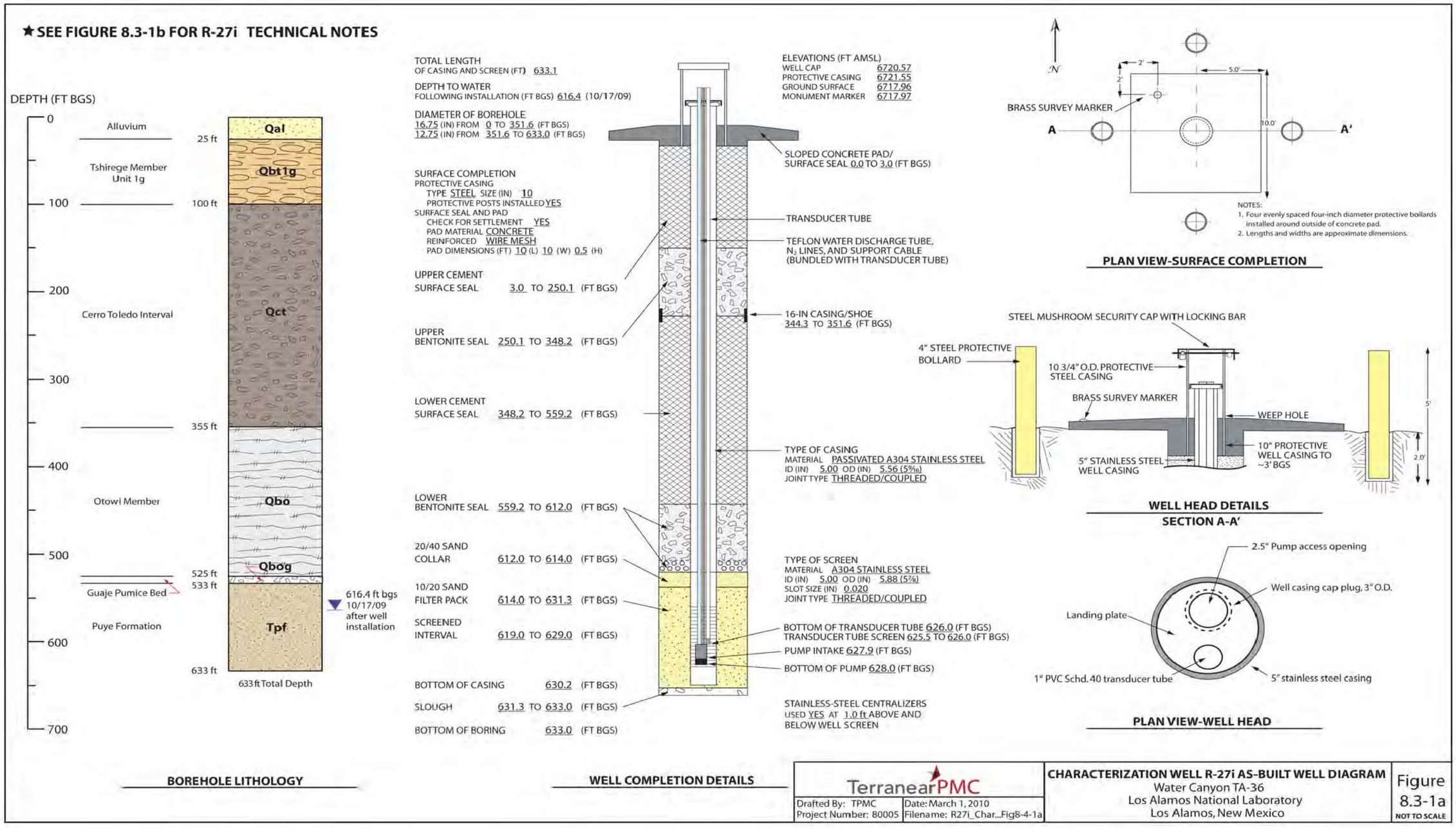

Figure 8.3-1a As-built schematic for intermediate water monitoring well R-27i

R-27i TECHNICAL NOTES:

SURVEY INFORMATION*
Brass Marker
Northing: 1756302.42 ft
Easting: 1629129.03 ft
Elevation: 6717.97 ft AMSL

Well Casing (top of stainless steel)
Northing: 1756297.48 ft
Easting: 1629132.22 ft
Elevation: 6720.57 ft AMSL

BOREHOLE GEOPHYSICAL LOGS
LANL: Video

DRILLING INFORMATION
Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual Rotary
Fluid-assisted air rotary, Foam-assisted air rotary

Drilling Fluids
Air, potable water, AQF-2 Foam

MILESTONE DATES
Drilling
Start: 09/10/2009
Finished: 09/24/2009

Well Completion
Start: 09/28/2009
Finished: 10/17/2009

Well Development
Start: 10/17/2009
Finished: 10/25/2009

WELL DEVELOPMENT
Development Methods
Performed bailing and pumping
Total Volume Purged: 2608 gallons

Parameter Measurments (Final)
pH: 7.15
Temperature: 16.11 °C
Specific Conductance: 151 µS/cm
Turbidity: 18.7 NTU

AQUIFER TESTING
Not tested

DEDICATED SAMPLING SYSTEM
Pump
Type: Bennett Sample Pump
Model: 1800-7
Motor: Pneumatic Piston

Pump Column
0.5-in. Teflon tubing

Transducer Tubes
1-in. flush threaded schd. 40 PVC tubing
0.01-in. slot screen at 625.5–626.0 ft bgs

Transducer
Make: In-Situ, Inc.
Model: Level TROLL 500
0–30 psig range (vented)
S/N: 156555

NOTES:
* Coordinates based on New Mexico State Plane Grid Coordinates, Central Zone (NAD83)
Elevation expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

TerranearPMC	R-27i TECHNICAL NOTES	Figure 8.3-1b
Drafted By: TPMC Project Number: 80005 Date: March 4, 2010 Filename: R27i_TechnicalNotes_Fig8-3-1b	Water Canyon (TA-36) Los Alamos National Laboratory Los Alamos, New Mexico	NOT TO SCALE

Figure 8.3-1b As-built technical notes for monitoring well R-27

Table 3.1-1
Fluid Quantities Used during R-27i Drilling and Well Construction

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit Fluids (gal.)
Drilling					
09/10/09	100	100	0	0	<50
09/11/09	900	1000	2	2	<250
09/12/09	1100	2100	6	8	<500
09/13/09	700	2800	5	13	<500
09/14/09	900	3700	3	16	<1000
09/15/09	300	4000	0	16	<1000
09/19/09	550	4550	8	24	<1500
09/20/09	2400	6950	10	34	<1500
09/21/09	3500	10,450	0	34	<2000
09/22/09	2000	12,450	0	34	<2000
09/24/09	600	13,050	0	34	<2000
09/25/09	100	13,150	0	34	<2000
Well Construction					
09/30/09	1700	1700	n/a*	n/a	n/a
10/01/09	1000	2700	n/a	n/a	n/a
10/02/09	1700	4400	n/a	n/a	n/a
10/03/09	3300	7700	n/a	n/a	n/a
10/04/09	260	7960	n/a	n/a	n/a
10/06/09	400	8360	n/a	n/a	n/a
10/09/09	144	8504	n/a	n/a	n/a
10/12/09	160	8664	n/a	n/a	n/a
10/13/09	457	9121	n/a	n/a	n/a
10/14/09	382	9503	n/a	n/a	n/a
10/15/09	892	10,395	n/a	n/a	n/a
10/16/09	1000	11,395	n/a	n/a	n/a
10/17/09	416	11,811	n/a	n/a	n/a
10/18/09	26	11,837	n/a	n/a	n/a
Total Water Volume (gal.)					
R-27i	24,987				

* n/a = Not applicable. Foam use terminated at 507.0 ft bgs during drilling; none used during well construction.

Table 4.2-1
Summary of Groundwater Screening Samples
Collected during Drilling and Well Development of Well R-27i

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-27i	GW27(i)-09-13148	09/22/09	622	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13167	09/26/09	632	Groundwater	VOA[a], LH3[b], HEXP[c]
Well Development					
R-27i	GW27(i)-09-13149	10/21/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13150	10/21/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13151	10/22/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13152	10/23/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13153	10/24/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13154	10/25/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC
R-27i	GW27(i)-09-13155	10/25/09	619.0–629.0	Groundwater	Cations, anions, perchlorate, metals, TOC

[a] VOA = Volatile organic analysis.

[b] LH3 = Low-level tritium.

[c] HEXP = High explosives.

Table 6.0-1
R-27i Video Logging Run

Date	Depth (ft bgs)	Description
09/25/09	610.0–630.0	Laboratory personnel ran a video log inside 12-in. casing after the 12-in. casing was retracted to 610.0 ft bgs to observe standing water column.

Table 7.2-1
R-27i Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: cement slurry	408.2 ft^3
Upper bentonite seal: bentonite chips	112.6 ft^3
Lower surface seal: cement slurry	170.4 ft^3
Lower bentonite seal: bentonite pellets/chips	30.5 ft^3
Fine sand collar: 20/40 silica sand	1.6 ft^3
Filter pack: 10/20 silica sand	15.6 ft^3

Table 8.5-1
R-27i Survey Coordinates

Identification	Northing	Easting	Elevation
R-27i brass cap embedded in pad	1756302.42	1629129.03	6717.97
R-27i ground surface near pad	1756301.80	1629128.09	6717.96
R-27i top of 10-in. protective casing	1756297.41	1629131.89	6721.55
R-27i top of stainless-steel well casing	1756297.48	1629132.22	6720.57

Note: All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in ft amsl using the National Geodetic Vertical Datum of 1929.

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-27i

Location ID	Sample ID	Date Collected	Description	Sample Type
R-27i	n/a[a]	n/a	Contact waste, use AK[b] from drill cuttings	Solid
R-27i	WST27(i)-10-81	10/04/2009	Decon fluid	Liquid
R-27i	WST27(i)-10-75	10/04/2009	Decon fluid	Liquid
R-27i	WST27(i)-10-90	10/04/2009	Decon fluid	Liquid
R-27i	WST27(i)-10-85	10/04/2009	Decon fluid	Liquid
R-27i	WST27(i)-10-98	10/4/2009	Drilling fluid	Liquid
R-27i	WST27(i)-10-97	10/04/2009	Drilling fluid	Liquid
R-27i	WST27(i)-10-96	10/04/2009	Drilling fluid	Liquid
R-27i	WST27(i)-10-99	10/4/2009	Drilling fluid	Liquid
R-27i	WST27(i)-10-95	10/4/2009	Drill cuttings	Solid
R-27i	WST27(i)-10-94	10/4/2009	Drill cuttings	Solid
R-27i	WST27(i)-10-1885	10/28/2009	Development water	Liquid
R-27i	WST27(i)-10-1884	10/28/2009	Development water	Liquid
R-27i	WST27(i)-10-1886	10/28/2009	Development water	Liquid
R-27i	WST27(i)-10-1887	10/28/2009	Field trip blank	Liquid

[a] n/a = Not applicable.
[b] AK = Acceptable knowledge.

Appendix A

Borehole R-27i Lithologic Log

R-27i Completion Report
Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-27I	**TECHNICAL AREA (TA):** 36	**PAGE:** 1 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
0–20	**ALLUVIUM:** Construction fill—Brown (7.5YR 5/2), unconsolidated pebble gravel with very fine to coarse sand, detritus of mixed volcanic and quartzite and granite (indicating drill pad base-coarse gravel). 0'–20' WR: very fine to coarse sand, some organic material (root segments and bark). +10F: subangular to subrounded granitic, quartzite, dacite and indurated AFT detritus. +35F: abundant quartz and sanidine crystals.	Qal	Note: Drill cuttings for microscopic and descriptive analysis were collected at 5-ft intervals from 0 ft to borehole TD at 633 ft bgs. Alluvial sediments, encountered from 0 ft to 25 ft, are approximately 25 ft thick.
20–25	Tuffaceous sediments—Pink (7.5 YR 7/3), unconsolidated, silty pebble gravel with fine to coarse sand. 20'–25' +10F/35F: detrital clasts subangular to subrounded predominantly of gray porphyritic dacite, minor pale red rhyolite, abundant sand grains of quartz and sanidine crystals and dacite and red rhyolite.	Qal	The Qal–Qbt 1g contact, estimated to be at 25 ft bgs, based on microscopic and descriptive analysis.
25–30	**UNIT 1g OF THE TSCHIREGE MEMBER OF THE BANDELIERTUFF:** Tuff—Light gray (5YR 7/1), poorly to nonwelded, lithic-bearing, pumiceous and crystal-rich. 25'–30' WR: abundant light pink volcanic ash. +10F: 85%–90% pale orange, glassy pumice fragments with secondary manganese oxide. 10%–15% light purple to medium gray, subangular, dacite granular to pebbles. +35F: 45% fragments of glassy pumice, 45% quartz and sanidine crystals and 10% dacite and rhyolite grains.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 25 ft to 100 ft bgs, is estimated to be 75 ft thick

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 2 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
30–80	Tuff—White (7.5YR 8/1), poorly to nonwelded, lithic-bearing, pumiceous and crystal-rich. 30'–80' +10F: 70-80% pumice fragments, 10%–15% quartz crystals, and 10%–15% dacite lithics. +35F: 65%–75% quartz crystals, 20%–-25% glassy pumice fragments and 5%–10% lithics.	Qbt 1g	None.
80–85	Tuff—White (7.5YR 8/1), poorly welded, lithic-bearing, pumiceous and crystal-rich. 80'–85' +10F: abundant flow banded rhyolite clasts.	Qbt 1g	None.
85–100	Tuff—White (7.5YR 8/1), poorly welded, lithic-bearing, pumiceous and crystal-rich. 30'–80' +10F: 70%–80% pumice fragments, 10%–15% quartz crystals, 10%–15% dacitic and rhyolitic lithics. +35F: 65%–75% quartz crystals, 20%–25% glassy pumice fragments and 5%–10% dacitic and rhyolitic lithics.	Qbt 1g	The Qbt 1g–Qct contact, estimated to be at 100 ft bgs, is based on based on microscopic and descriptive analysis.
100–110	**CERRO TOLEDO INTERVAL:** Tuffaceous sediments—Very pale brown (10YR 8/2), unconsolidated, silty pebble conglomerate with medium to coarse sand. Detritus primarily subangular to subrounded dacitic clasts and quarts grains. 100'–110' +10F: 80% quartz grains, 20% lithics and pumice fragments. +35: primarily purple gray dacite clasts and light gray porphyritic dacite. Minor quartz crystals and vitric pumice fragments.	Qct	The Cerro Toledo Interval (Qct), encountered from 100 ft to 355 ft bgs, is estimated to be 255 ft thick.
110–115	Tuffaceous sediments—Pink (7.5YR 7/3), unconsolidated, silty pebble conglomerate with medium to coarse sand. Detritus primarily subangular to subrounded dacitic clasts and quartz grains. 110'–115' +10F pale orange, subrounded pumice fragments.	Qct	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 3 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
115–125	Tuffaceous sediments—Variable color light gray (7.5YR 7/1) to dark reddish gray (2.5YR 3/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains. 115'–125' +10F: 20%–25% pale orange, devitrified pumice fragments. +35F: 50% quartz and sanidine grains, 50% sub angular to subrounded dacitic lithics and pumice fragments.	Qct	None.
125–130	Tuffaceous sediments— Variable color light gray (7.5YR 7/1) to dark reddish gray (2.5YR 3/1), unconsolidated, silty pebble conglomerate with medium to coarse sand. Detritus primarily subangular to subrounded dacitic clasts and quartz grains. 125'–130' WR: abundant clay and silt.	Qct	None.
130–155	Tuffaceous sediments— Variable color light gray (7.5YR 7/1) to dark reddish gray (2.5YR 3/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains. 115'–125' +10F: 20%–25% pale orange, devitrified pumice fragments. +35F: 50% quartz and sanidine grains, 50% sub angular to subrounded dacitic lithics and pumice grains.	Qct	None.
155–165	Tuffaceous sediments— Variable color light gray (7.5YR 7/1) to dark reddish gray (2.5YR 3/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains. 155'–165' WR/+10F: abundant subrounded, pale orange pumice grains.	Qct	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 4 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
165–175	Tuffaceous sediments— Variable color light gray (7.5YR 7/1) to dark reddish gray (2.5YR 3/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains. 165'–175' WR/10+: granular to pebble, sub angular to subrounded medium gray dacite and light gray porphyritic dacite clasts. Minor pumice grains. +35F: 50% quartz and sanidine grains, 50% lithics including minor pale orange, devitrified pumice grains.	Qct	None.
175–190	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 175'–190' +35F: 25% subangular to subrounded, pale orange pumice grains.	Qct	None.
190–195	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 190'–195' +10F/+35F: 5% subangular to subrounded, pale orange pumice grains.	Qct	None.
195–235	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subangular to subrounded dacitic clasts and quartz grains. 195'–235' WR: subangular, medium gray to purple, aphanitic dacite. +10F: 2.5%–5% pumice grains. +35F: 50% quartz and sanidine grains, 50% lithics including minor pumice grains.	Qct	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 5 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
235–240	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, silty pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains. 235'–240' WR: abundant clay and silt.	Qct	None.
240–245	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains.	Qct	None.
245–265	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts and quartz grains. 245'–265' WR/+10F: abundant subrounded to subangular, light gray to light brown ,pumice grains	Qct	None.
265–270	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 265'–270' WR/+10F: minor pumice grains.	Qct	None.
270–290	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), weakly consolidated, silty pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 270'–290' WR: abundant clay and silt.	Qct	None.
290–295	Pumiceous sediment— Variable color light gray (7.5YR 7/1), unconsolidated, medium to coarse sand. Primarily subrounded to rounded buff to pale orange pumice grains, and quartz grains.	Qct	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 6 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
295–305	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), weakly consolidated, silty pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 300'–305' WR: abundant clay and silt. +10F: Primarily granular to pebble, medium gray to purple dacite clasts. +35F: 50% quartz and sanidine grains, 50% lithics.	Qct	None.
305–310	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 305'–310' +10F 20%–25% light gray to buff pumice grains.	Qct	None.
310–315	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 305'–310' +10F 30%–35% light gray to buff pumice grains.	Qct	None.
315–340	Tuffaceous sediments— Variable color light gray (7.5YR 7/1), unconsolidated, pebble conglomerate with medium to coarse sand. Detritus primarily subrounded dacitic clasts, pumice and quartz grains. 315'–320' +10F: minor flow banded rhyolite.	Qct	None.
340–350	Pumiceous sediment—10YR 6/4 light yellowish brown, unconsolidated, pebble conglomerate with medium to coarse sand. Primarily subrounded to rounded buff to pale orange pumice grains, and dacite clasts. 340'–350' WR/+10F 50% subangular to subrounded, pale orange pumice clasts.	Qct	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 7 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
350–355	Pumiceous sediment—10YR 6/4 light yellowish brown, unconsolidated, medium to coarse sand. Primarily subrounded to rounded pale orange pumice grains, dacite clasts and quartz grains. 350'–355' WR: Well sorted, subangular to subrounded, pale orange pumice clasts. +10F: 50% pumice grains, 50% lithics (primarily dacite). +35F: 50% lithics, 50% quartz/sanidine grains.	Qct	The Qbct–Qbo contact, estimated to be at 355 ft bgs, is based on based on microscopic and descriptive analysis.
355–360	**OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—variable color, yellow (10YR 7/6) to light gray (5YR 7/1), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 355'–360' WR: No ash preserved.	Qbo	The Otowi Member of the Bandelier Tuff (Qbo) is intersected from 355 ft to 525 ft bgs, is estimated to be 170 ft thick.
360–365	Tuff—pink (5YR 7/3), poorly welded, strongly pumiceous, crystal- and lithic-poor. No indurated tuff fragments present.	Qbo	None.
365–370	Tuff—pink (5YR 7/3), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 355'–360' WR: No ash preserved.	Qbo	None.
370–375	Tuff—pink (5YR 7/3), poorly welded, strongly pumiceous, crystal- and lithic-poor. No indurated tuff fragments present.	Qbo	None.
375–380	Tuff—pink (5YR 7/3), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 375'–380' WR: No ash preserved.	Qbo	None.
380–390	Tuff—white (5YR 8/1), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 380'–390' +35F:10% reddish brown rhyolite lithics present.	Qbo	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 8 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
390–420	Tuff—white (5YR 8/1) to light gray (5YR 7/1), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 390'–420' WR/+10F/+35F:50% pumice fragments and 50% lithics.	Qbo	None.
420–430	Tuff—light gray (5YR 7/1), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 420'–430' WR/+10F/+35F:>50% pumice fragments.	Qbo	None.
430–490	Tuff—light gray (5YR 7/1), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 430'–490' WR/+10F/+35F:Variable amount of pumice fragments content from ~50% to > 50%.	Qbo	None.
490–505	Tuff—light gray (5YR 7/1), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 490'–505' WR/+10F: 90%subrounded, white pumice fragments, 10% lithics.+35F: 50% pumice fragments, 30% quartz crystals, 20% lithics (rhyolite and dacite).	Qbo	None.
505–525	Tuff—light gray (5YR 7/1), poor to moderately well welded, lithic-rich, pumiceous, crystal-bearing. Some indurated tuff fragments present with iron staining of fractureplanes. 505'–525' WR/+10F/+35F: 50% pumice fragments, 50% lithics. Lithics are subangular and include fine-grained dark gray dacite, purple gray, porphyritic, hornblende rich dacite and fragments of a chloritized material.	Qbo	The estimated Qbo-Qbog contact, estimated to be at 525 ft bgs, is based on based on microscopic and descriptive analysis.
525–533	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—white (5YR 8/1), non- welded, pumiceous, lithic- and crystal-bearing. 525'–533' +10F: 10mm diameter vitric pumice lapilli. 20% subangular to angular dacitic lithic fragments.	Qbog	The Guaje Pumice Bed (Qbog), intersected from 525 ft to 533 ft bgs, is estimated to be 8 ft thick.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 9 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
533–540	**PUYE FORMATION:** Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), locally silty pebbly gravel with medium to coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 533'–540' WR: locally silty matrix. +10F: subangular to subrounded clasts of light to medium gray and purple porphyritic dacite.	Tpf	Puye volcaniclastic sediments (Tpf), intersected from 533 ft to the bottom of the R-27i borehole at 633 ft bgs, are estimated to be 100 ft thick.
540–545	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 540'–545' WR/10F+: Broken chips and subrounded to subangular coarse sand and granular, fairly well sorted, light to medium gray dacite . +35F: 90% dacite and red rhyolite, 10% subangular to subrounded quartz grains, minor red cinders.	Tpf	None.
545–575	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 545'–575' WR/+10F: Broken chips, up to 25mm. Subrounded, dacitic coarse sand to pebbles. +35F: 1% subangular to subrounded quartz grains.	Tpf	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 10 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
575–580	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), pumice rich granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 575'–580' +10F: white, subrounded to subangular, clay rich, crystal bearing pumice fragments, up to 15mm in diameter.	Tpf	None.
580–595	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 580'–595' WR/+10F: Broken chips, up to 25mm. Subrounded, dacitic coarse sand to pebbles. Also, subrounded to rounded immature sandstone clasts up to 10mm in diameter +35F: 1% subangular to subrounded quartz grains. 10% white pumice clasts.	Tpf	None.
595–605	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 595'–605' WR/+10F: Broken chips, up to 25mm. Subrounded, dacitic coarse sand to pebbles. Also, subrounded to rounded red scoria casts up to 5mm in diameter. +35F: 1% subangular to subrounded quartz grains.	Tpf	None.
605–610	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 605'–610' WR/+10F/+35F: minor rounded red/brown cinders present.	Tpf	None.

Borehole Lithologic Log (continued)

Borehole ID: R-27i	**TA:** 36	**Page:** 11 of 11
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/10/09:0116	**END DATE/TIME:**9/24/09: 2227
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6717.96 ft AMSL		**TOTAL DEPTH:** 633 ft
DRILLERS:G. Burton, M. Cross	**SITE GEOLOGISTS:** R. McGuill, C.Pigman, J. R. Lawrence,E. Huggins, S. Muggleton	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
610–620	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 610'–620' WR/+10F: minor, subrounded to rounded immature sandstone clasts up to 10mm in diameter.	Tpf	None.
620–625	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 620'–625' +10F: subrounded basalt clasts up to 20mm in diameter.	Tpf	None.
625–630	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present.	Tpf	None.
630–633	Volcaniclastic sediments – light gray (5YR 7/1) to dark reddish gray (2.5YR 3/1), granular pebbles with coarse sand. Detrital clasts predominantly light to medium gray porphyritic dacite. Purple porphyritic and aphanitic medium to dark gray dacite present. 630'–633' +10F: minor rounded red/brown cinders present.	Tpf	None.

Borehole Lithologic Log (continued)

ABBREVIATIONS

5YR 8/4 = Munsell rock color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g., 4) are expressed. Hue indicates soil color's relation to red, yellow, green, blue, and purple. Value indicates soil color's lightness. Chroma indicates soil color's strength.
% = estimated per cent by volume of a given sample constituent
AMSL = above mean sea level
bgs = below ground surface
ft = feet
GM = groundmass

Qal = Quaternary Alluvium
Qbo = Otowi Member of Bandelier Tuff
Qbog = Guaje Pumice Bed
Qbt = Tshirege Member of the Bandelier Tuff
Qct = Cerro Toledo Interval
Tpf = Puye Formation
N/S = no assigned symbol for geologic unit

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in.

1 in. = 25.4 mm

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-27i

A total of nine groundwater-screening samples were collected during drilling and development at well R-27i. Two groundwater-screening samples were collected at borehole R-27i during drilling within perched intermediate saturation within the Puye Formation, one at 622.0 ft below ground surface (bgs) and one at 632.0 ft bgs. Aliquots of the borehole sample collected at 632.0 ft bgs were submitted to external analytical laboratories for analyses of volatile organic compounds (VOCs), high explosives (HE) compounds, and low-level tritium. Seven groundwater-screening samples were collected from well R-27i during development. These groundwater-screening samples were collected between the screened interval from 619.0 to 629.0 ft bgs. Groundwater-screening samples collected from R-27i during development were filtered and analyzed for cations, anions, perchlorate, metals, and total organic carbon (TOC). A total of 2608 gal. of groundwater was pumped from well R-27i during development.

B-1.1 Field Preparation and Analytical Techniques

Chemical analyses of groundwater-screening samples were performed at Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences (EES) 14. Groundwater samples were filtered (0.45-µm membranes) before preservation and chemical analyses. Samples were acidified at the EES-14 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (IC) (EPA Method 300, rev. 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limit for perchlorate was 0.002 ppm (EPA Method 314.0, rev. 1). Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) (EPA Method 200.7, rev. 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, total chromium, iron, lithium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS) (EPA Method 200.8, rev. 5.4). The precision limits (analytical error) for major ions and trace elements were generally less than ±7% using ICPOES and ICPMS. Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques. No groundwater samples were collected for TOC analyses at borehole R-27i before development due to sample matrix and potential presence of drilling fluids. Analyses of TOC were performed on groundwater-screening samples collected during development following EPA Method 415.1. Charge balance errors for total cations and anions were less than ±8% for complete analyses of the above inorganic chemicals. The negative cation-anion charge balance values indicate excess anions for the filtered samples.

B-1.2 FIELD PARAMETERS

B-1.2.1 Well Development

Water samples were drawn from the pump discharge line into sealed containers, and field parameters were measured using a YSI multimeter. Results of field parameters, consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during well development at R-27i, are provided in Table B-1.2-1. Forty-eight measurements of pH and temperature varied from 6.55 to 8.76 and from 14.83°C to 23.99°C, respectively, in groundwater

pumped from well R-27i during development. Concentrations of DO ranged from 2.21 to 6.40 mg/L. Corrected decreasing oxidation-reduction potential (Eh) values determined from field ORP measurements varied from 107.2 to 369.6 millivolts (mV) during development of well R-27i (Table B-1.2-1). Temperature-dependent correction factors for calculating Eh values from field ORP measurements were based on an Ag/AgCl, KCl-saturated filling solution contained in the ORP electrode. The correction factors are 208.9, 203.9, and 198.5 mV at 15.0°C, 20.0°C, and 25.0°C, respectively. Several negative and uncorrected ORP readings were recorded during development at well R-27i most likely resulting from instrument drift. Corrected Eh values associated with well R-27i are considered to be reliable and representative of the known relatively oxidizing conditions characteristic of perched intermediate zones beneath the Pajarito Plateau, in addition to measurable DO concentrations recorded at well R-27i. Specific conductance varied from 99 to 234 microsiemens per centimeter (μS/cm), and turbidity ranged from 0.6 to 60.6 nephelometric turbidity units (NTUs) during development of well R-27i (Table B-1.2-1). Eleven turbidity values exceeding 10 NTUs were recorded during development. The majority of turbidity readings recorded during development at well R-27i were less than 7 NTUs.

B-1.3 Analytical Results for Groundwater-Screening Samples

Analytical results from the offsite laboratories and from LANL EES-14 analyses are presented below. Where available, analytical results are screened against background concentrations developed for the Laboratory as a whole (LANL 2007, 095817). It should be noted that, due to localized variations in geochemistry, background concentrations for the area upgradient of R-27i may vary.

B-1.3.1 Volatile Organic Compounds, High Explosive Compounds, and Low-Level Tritium

VOCs, HE, and tritium were not detected in the borehole water sample [GW27(i)-09-13167] collected at R-27i. The activity of tritium was less than 0.15 pCi/L in the borehole sample (Table B-1.3-1).

B-1.3.2 Cations, Anions, Perchlorate, and Metals

Analytical results for one of the borehole samples collected at well R-27i during drilling and for all samples collected during well development are provided in Table B-1.3-2. The filtered borehole sample [GW27(i)-09-1348] consists of disaggregated colloidal aquifer material, drilling material, water used during drilling, and native groundwater. Analytical results for the borehole water sample show elevated concentrations of molybdenum (0.054 ppm) that is potentially from the lubricant used during drilling. Perchlorate was not detected in the borehole sample.

Calcium and sodium were the dominant cations in groundwater collected from well R-27i during development. Dissolved concentrations of calcium and sodium ranged from 10.90 to 15.53 ppm or mg/L and from 10.74 to 12.73 ppm, respectively, during development (Table B-1.3-2). Dissolved concentrations of chloride and fluoride ranged from 2.36 to 2.85 ppm and from 0.17 to 0.21 ppm, respectively, during development. The median background concentrations for dissolved chloride and fluoride in perched intermediate groundwater are 1.37 and 0.12 mg/L, respectively (LANL 2007, 095817). Dissolved concentrations of bromide were generally less than analytical detection (0.01 ppm) during development at well R-27i. Dissolved concentrations of nitrate(N) and sulfate ranged from 0.07 to 0.21 ppm and from 3.86 to 8.26 ppm, respectively, during this phase. Median background concentrations for dissolved nitrate plus nitrite(N) and sulfate in perched intermediate groundwater are 0.29 mg/L and 4.08 mg/L, respectively (LANL 2007, 095817). Dissolved concentrations of chloride, fluoride and sulfate slightly exceeded Laboratory median background for perched intermediate groundwater (LANL 2007, 095817). Concentrations of TOC ranged from 0.28 to 2.16 mgC/L, with six out of seven values less than 0.5 mgC/L, in groundwater-screening samples collected during development conducted at well R-27i

(Table B-1.3-2). The median background concentration of TOC is 0.45 mgC/L for perched intermediate groundwater (LANL 2007, 095817). Concentrations of perchlorate were less than analytical detection (<0.002 ppm) in the groundwater-screening samples collected from well R-27i during development.

During well development conducted at R-27i, dissolved concentrations of iron varied from 0.40 to 2.25 ppm using ICPOES (Table B-1.3-2), which exceeded the maximum background value of 480 μg/L (0.480 ppm, 0.480 mg/L, or 480 ppb) for perched intermediate groundwater (LANL 2007, 095817). A corroded carbon-steel discharge pipe was used during development at well R-27i and most likely contributed colloidal iron in the form of ferric hydroxide or rust to the filtered groundwater-screening samples. Dissolved concentrations of manganese ranged from 0.037 to 0.052 ppm or from 37 to 52 ppb (Table B-1.3-2), which exceeded the maximum background value of 3.63 μg/L (3.63 ppb or 0.00363 ppm) for perched intermediate groundwater (LANL 2007, 095817). Dissolved concentrations of boron ranged from 0.013 to 0.057 ppm or 14 to 57 ppb (Table B-1.3-2) at well R-27i, which is above the median background value of 8.25 μg/L or ppb (0.00825 ppm) for perched intermediate groundwater (LANL 2007, 095817). Dissolved concentrations of barium generally decreased from 0.016 to 0.011 ppm or from 16 to 11 ppb (Table B-1.3-2) at well R-27i during development, which is near the median background value of 15.50 μg/L or ppb (0.01550 ppm) for perched intermediate groundwater (LANL 2007, 095817). Dissolved concentrations of nickel ranged from 0.002 to 0.010 ppm (2 to 10 ppb) (Table B-1.3-2) in the seven groundwater-screening samples collected during development conducted at well R-27i. The background median concentration of nickel in filtered samples is 0.50 μg/L or ppb (0.0005 ppm) for perched intermediate groundwater (LANL 2007, 095817). Dissolved concentrations of zinc ranged from 0.041 to 0.150 ppm or 41 to 150 ppb in groundwater-screening samples collected at well R-27i during development (Table B-1.3-2). Measured concentrations of dissolved zinc most likely result from using a carbon-steel discharge pipe at the well. The background median concentration of zinc in filtered samples is 0.75 μg/L or ppb (0.00075 ppm) for perched intermediate groundwater (LANL 2007, 095817). Total dissolved concentrations of chromium ranged from 0.001 to 0.004 ppm (1 to 4 ppb or 1 to 4 μg/L) at well R-27i during development (Table B-1.3-2). Background mean, median, and maximum concentrations of total dissolved chromium are 0.86 μg/L or ppb (0.00086 ppm), 0.50 μg/L or ppb (0.0005 ppm), and 2.40 μg/L or ppb (0.00240 ppm), respectively, for perched intermediate groundwater (LANL 2007, 095817).

In summary, dissolved concentrations of boron, chloride, fluoride, sulfate and TOC (in one sample) slightly exceeded median background concentrations of these solutes within perched intermediate groundwater present at well R-27i. Additionally, dissolved concentrations of iron, manganese, nickel, zinc and chromium also exceeded their respective median background concentrations. Elevated iron and zinc concentrations are likely attributable to a corroded metal discharge pipe used in development. Groundwater at well R-27i is relatively oxidizing, based on corrected Eh values and measurable concentrations of DO, nitrate(N), and sulfate. Residual drilling fluid effects from foam used higher in the borehole at R-27i are not present in the water-bearing zone based on measurable concentrations of dissolved nitrate(N) and sulfate coupled with measurable concentrations of DO characteristic of relatively oxidizing groundwater.

B-2.0 REFERENCE

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)

Table B-1.2-1
Well Development Volumes and Associated Field Water-Quality Parameters for R-27i

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP and Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development									
10/18/09	0520	n/r[b], bailing						335	335
10/19/09	0145	n/r, bailing						255	590
10/19/09	2340	8.75	22.60	4.98	133.2, 331.7	145	6.5	n/r	590
	0000	8.18	20.44	4.84	130.2, 334.1	141	4.2	n/r	590
10/20/09	0130	8.59	20.58	6.22	123.5, 327.4	141	5.3	150	740
	0145	8.06	23.99	5.34	117.8, 316.3	138	6.9	2.5	742.5
	0215	8.35	23.5	5.31	110.6, 309.1	138	1.0	15	757.5
	0245	8.07	21.89	5.33	108.5, 309.1	137	6.2	15	772.5
	0315	8.04	21.5	5.49	97.3, 301.2	135	4.2	15	787.5
	0345	7.94	21.8	5.43	93.1, 297.0	133	4.0	15	802.5
	0415	8.03	21.53	5.19	86.0, 289.9	134	6.9	15	817.5
	0445	7.92	21.43	4.97	66.4. 270.3	132	3.6	15	832.5
	0516	7.90	21.84	4.88	47.7, 251.6	132	2.4	15.5	848
10/21/09	0055	7.09	20.28	3.65	165.7, 369.6	148	0.6	155	1003
	0155	7.3	19.74	4.51	131.7, 335.6	134	1.7	30	1033
	0225	7.58	20.88	4.19	81.0, 284.9	135	1.1	15	1048
	0255	7.63	21.38	4.14	47.4, 251.3	134	1.7	15	1063
	0325	7.6	20.96	3.95	-2.4, 201.5	133	2.0	15	1078
	0355	7.55	20.73	4.03	-11.6, 192.3	132	0.6	15	1093
	0425	7.59	20.62	4.00	-25.5, 178.4	132	0.6	15	1108
	0455	7.59	19.81	3.97	-20.2, 183.7	128	2.9	15	1123
	0515	7.6	19.37	4.0	-27.6, 176.3	127	3.1	10	1133
10/22/09	0510	8.31	17.85	6.4	73.5, 277.4	145	60.6	157	1390
	2010	8.76	21.48	4.48	135.2, 339.1	234	49.9	24.5	1414.5
	2045	8.66	16.33	3.77	63.9, 272.8	127	39.4	38.5	1453
	2130	8.43	16.24	3.79	93.5, 302.4	122	15.1	33.7	1486.75
	2230	8.12	16.88	4.48	89.7, 298.6	122	22.5	45	1531.75

Table B-1.2-1 continued

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP and Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
10/23/09	0055	7.95	17.9	4.40	3.4, 207.3	122	0.7	3.7	1535.5
	0200	8.86	16.61	4.07	51.2, 260.1	126	3.6	7.5	1543
	0300	8.31	17.30	4.51	47.6, 251.5	122	3.0	30	1573
	0400	8.07	16.81	3.53	21.1, 230.0	120	3.7	30	1603
	0500	8.09	17.11	3.51	30.5, 239.4	120	6.4	30	1633
	2000	8.43	19.80	4.57	112.3, 316.2	224	31.6	30	1663
	2100	8.30	16.35	3.03	52.8, 261.7	119	30.1	30	1693
	2200	8.42	19.40	2.78	75.5, 279.4	114	31.7	30	1723
	2300	8.35	14.83	2.89	76.6, 285.5	116	15.7	30	1753
10/24/09	0000	8.13	16.52	3.15	68.2, 277.1	117	2.1	30	1783
	0100	7.97	16.17	3.64	-6.0, 202.9	118	0.8	30	1813
	0200	7.87	16.72	2.85	-34.5, 174.4	118	1.5	30	1843
	0300	7.84	16.78	3.02	-25.3, 183.6	117	1.1	30	1873
	0400	7.78	16.80	2.68	-66.1, 142.8	117	1.5	30	1903
	1240	n/r	n/r	n/r	n/r	n/r	n/r	200	2103
	1800	n/r	n/r	n/r	n/r	n/r	n/r	85	2188
	1930	6.55	17.37	2.89	71.4, 280.3	181	11.1	45	2233
	2030	7.68	17.38	2.40	-73.4, 135.5	118	5.8	30	2263
	2130	7.72	16.77	3.67	-57.4, 151.5	114	3.0	30	2293
	2230	7.70	17.24	3.26	-61.7, 147.2	115	2.2	30	2323
	2330	7.67	16.89	3.49	-77.5, 131.4	114	2.3	30	2353
10/25/09	0030	7.81	16.29	3.72	-18.7, 190.2	99	2.5	0	2353
	0230	7.71	16.62	2.5	-101.7, 107.2	114	7.6	60	2413
	0330	7.73	16.47	2.51	-96.3, 112.6	114	5.7	30	2443
	0400	n/r	n/r	n/r	n/r	n/r	n/r	15	2458
	2330	7.15	16.11	2.21	25.0, 233.9	151	18.7	150	2608

[a] Eh (mV) is calculated from an Ag/AgCl-saturated KCl electrode filling solution at 15.0°C, 20.0°C, and 25.0°C by adding temperature-sensitive correction factors of 208.9, 203.9, and 198.5 mV, respectively.

[b] n/r = Not recorded.

Table B-1.3-1
Off-site Analytical Results for Borehole Sample Collected at R-27i

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Validation Qualifier Code	Result Unit
GW27(i)-09-13167	H3[a]	Generic:Low_Level_Tritium	Tritium	0.15	U[b]	TU[c]
GW27(i)-09-13167	H3	Generic:Low_Level_Tritium	Tritium	0.12	U	TU
GW27(i)-09-13167	VOC	SW-846:8260B	Ethylbenzene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Styrene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Propylbenzene[1-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Butylbenzene[n-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chlorotoluene[4-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Acrolein	5	UJ[d]	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Propionitrile	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Acrylonitrile	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Vinyl acetate	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Bromobenzene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Toluene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chlorobenzene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chlorodibromomethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Methacrylonitrile	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Tetrachloroethene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Butylbenzene[sec-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Methyl tert-Butyl Ether	1	U	µg/L

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Validation Qualifier Code	Result Unit
GW27(i)-09-13167	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Carbon Tetrachloride	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Hexanone[2-]	5	UJ	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Diethyl Ether	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Acetone	10	UJ	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chloroform	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Butanol[1-]	50	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Benzene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Bromomethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chloromethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Iodomethane	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dibromomethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Bromochloromethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chloroethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Vinyl Chloride	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Acetonitrile	25	R	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Methylene Chloride	10	UJ	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Carbon Disulfide	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Bromoform	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Bromodichloromethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichlorofluoromethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichlorodifluoromethane	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	UJ	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Isobutyl alcohol	50	R	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Butanone[2-]	5	UJ	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	U	µg/L

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Validation Qualifier Code	Result Unit
GW27(i)-09-13167	VOC	SW-846:8260B	Trichloroethene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Methyl Methacrylate	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Hexachlorobutadiene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Naphthalene	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Xylene[1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Chlorotoluene[2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Dibromo-3-Chloropropane[1,2-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Ethyl Methacrylate	5	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Butylbenzene[tert-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2	U	µg/L
GW27(i)-09-13167	VOC	SW-846:8260B	Isopropylbenzene	1	UJ	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	2,6-Diamino-4-nitrotoluene	13	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Dinitrotoluene[2,6-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	3,5-Dinitroaniline	13	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	2,4-Diamino-6-nitrotoluene	13	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Amino-2,6-dinitrotoluene[4-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	HMX[e]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	TATB[f]	13	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Amino-4,6-dinitrotoluene[2-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Tetryl	6.49	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Dinitrotoluene[2,4-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	RDX[g]	3.25	UJ	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Trinitrotoluene[2,4,6-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	PETN[h]	13	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Tris (o-cresyl) phosphate	13	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Nitrotoluene[2-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Nitrobenzene	3.25	U	µg/L

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Validation Qualifier Code	Result Unit
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Nitrotoluene[3-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Trinitrobenzene[1,3,5-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Dinitrobenzene[1,3-]	3.25	U	µg/L
GW27(i)-09-13167	HEXP	SW-846:8321A_MOD	Nitrotoluene[4-]	6.49	U	µg/L

[a] H3 = Tritium.

[b] U = The analyte was analyzed for but not detected.

[c] TU = Tritium unit.

[d] UJ = The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.

[e] HMX = High-melting explosive (also 1,3,5,7-tetranitro-1,3,5,7-tetrazocine).

[f] TATB = Triaminotrinitrobenzene.

[g] RDX = Research department explosive (also hexahydro-1,3,5-trinitro-1,3,5-triazine).

[h] PETN = Pentaerythritol tetranitrate.

Table B-1.3-2
Analytical Results for Groundwater Screening Samples Collected at R-27i

Sample ID	Date Received	ER/RRES-WQH	Sample Type	Depth (feet)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)	Br(-) ppm	Br(-) (U)	TOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)
GW27_(i)-09-13148	9/25/2009	09-3342	Borehole	622	0.001	U	0.169	0.002	0.0004	0.0001	0.026	0.000	0.015	0.000	0.001	U	0.02	AD	Not Applicable	6.28	0.03
GW27_(i)-09-13149	10/21/2009	10-212	Development	620	0.001	U	0.009	0.000	0.0003	0.0000	0.019	0.000	0.016	0.000	0.001	U	0.01	U	0.46	12.58	0.04
GW27_(i)-09-13150	10/21/2009	10-212	Development	624	0.001	U	0.007	0.000	0.0004	0.0001	0.014	0.000	0.014	0.000	0.001	U	0.01	U	0.32	11.96	0.04
GW27_(i)-09-13151	10/23/2009	10-234	Development	619-629	0.001	U	0.005	0.000	0.0003	0.0000	0.024	0.000	0.011	0.000	0.001	U	0.02	AD	2.16	15.53	0.15
GW27_(i)-09-13152	10/23/2009	10-234	Development	619-629	0.001	U	0.006	0.000	0.0002	0.0000	0.014	0.000	0.012	0.000	0.001	U	0.01	U	0.35	12.07	0.03
GW27_(i)-09-13153	10/26/2009	10-250	Development	619-629	0.001	U	0.007	0.000	0.0003	0.0000	0.013	0.000	0.013	0.000	0.001	U	0.01	U	0.28	11.82	0.01
GW27_(i)-09-13154	10/26/2009	10-250	Development	619-629	0.001	U	0.005	0.000	0.0002	U	0.057	0.001	0.012	0.000	0.001	U	0.01	U	0.35	10.93	0.03
GW27_(i)-09-13155	10/26/2009	10-250	Development	619-629	0.001	U	0.006	0.000	0.0002	0.0000	0.031	0.000	0.011	0.000	0.001	U	0.01	U	0.39	10.90	0.04

Note: U means not detected and AD means above analytical detection limit.

Table B-1.3-2
Analytical Results for Groundwater Screening Samples Collected at R-27i

Sample ID	Date Received	ER/RRES-WQH	Cd rslt (ppm)	stdev (Cd)	Cl(-) ppm	ClO4(-) ppm	ClO4(-) (U)	Co rslt (ppm)	stdev (Co)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F(-) ppm	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)
GW27_(i)-09-13148	9/25/2009	09-3342	0.001	U	5.25	0.002	U	0.001	U	0.8	U	0.003	0.000	0.001	U	0.002	0.000	0.68	0.214	0.001	79.09
GW27_(i)-09-13149	10/21/2009	10-212	0.001	U	2.75	0.002	U	0.001	U	0.8	U	0.001	0.000	0.001	U	0.001	U	0.20	1.125	0.009	77.07
GW27_(i)-09-13150	10/21/2009	10-212	0.001	U	2.83	0.002	U	0.001	U	0.8	U	0.002	0.001	0.001	U	0.001	0.000	0.21	1.736	0.008	74.94
GW27_(i)-09-13151	10/23/2009	10-234	0.001	U	2.85	0.002	U	0.001	U	0.8	U	0.004	0.000	0.001	U	0.002	0.000	0.20	0.399	0.000	88.04
GW27_(i)-09-13152	10/23/2009	10-234	0.001	U	2.78	0.002	U	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U	0.18	1.170	0.001	74.68
GW27_(i)-09-13153	10/26/2009	10-250	0.001	U	2.68	0.002	U	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	0.000	0.18	2.154	0.003	74.19
GW27_(i)-09-13154	10/26/2009	10-250	0.001	U	2.65	0.002	U	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	U	0.17	1.683	0.012	71.81
GW27_(i)-09-13155	10/26/2009	10-250	0.001	U	2.36	0.002	U	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	0.000	0.18	2.247	0.022	73.82

Note: U means not detected and AD means above analytical detectio

Table B-1.3-2
Analytical Results for Groundwater Screening Samples Collected at R-27i

Sample ID	Date Received	ER/RRES-WQH	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	M rslt (ppm)	stdev (Mo)	Na rslt (ppm)	stdev (Na)	Ni rslt (ppm)	stdev (Ni)	NO2 (ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm
GW27_(i)-09-13148	9/25/2009	09-3342	0.00013	0.00001	3.88	0.03	0.020	0.001	1.69	0.02	0.048	0.000	0.054	0.000	18.53	0.14	0.001	U	0.06	0.02	AD	0.61
GW27_(i)-09-13149	10/21/2009	10-212	0.00005	U	1.08	0.01	0.012	0.000	2.61	0.02	0.037	0.000	0.002	0.000	11.56	0.13	0.002	0.000	0.01	0.00	U	0.88
GW27_(i)-09-13150	10/21/2009	10-212	0.00005	U	0.98	0.00	0.011	0.000	2.49	0.01	0.037	0.000	0.002	0.000	10.74	0.07	0.003	0.001	0.01	0.00	U	0.94
GW27_(i)-09-13151	10/23/2009	10-234	0.00005	U	2.00	0.00	0.015	0.000	2.69	0.02	0.052	0.000	0.003	0.000	12.73	0.04	0.010	0.000	0.01	0.00	U	0.01
GW27_(i)-09-13152	10/23/2009	10-234	0.00005	U	1.07	0.00	0.012	0.000	2.55	0.01	0.041	0.000	0.002	0.000	11.00	0.05	0.006	0.001	0.01	0.00	U	0.69
GW27_(i)-09-13153	10/26/2009	10-250	0.00005	U	1.03	0.00	0.012	0.000	2.54	0.01	0.045	0.000	0.002	0.000	10.83	0.05	0.006	0.000	0.01	0.00	U	0.63
GW27_(i)-09-13154	10/26/2009	10-250	0.00005	U	1.10	0.01	0.013	0.000	2.60	0.01	0.052	0.000	0.002	0.000	11.06	0.05	0.004	0.001	0.01	0.00	U	0.58
GW27_(i)-09-13155	10/26/2009	10-250	0.00005	U	1.07	0.00	0.012	0.000	2.68	0.01	0.051	0.000	0.002	0.000	11.01	0.04	0.008	0.001	0.01	0.00	U	0.33

Note: U means not detected and AD means above analytical detectio

Table B-1.3-2
Analytical Results for Groundwater Screening Samples Collected at R-27i

Sample ID	Date Received	ER/RRES-WQH	NO3-N rslt	C2O4 rslt (ppm)	C2O4 (U)	Pb rslt (ppm)	stdev (Pb)	pH	PO4(-3) rslt (ppm)	PO4(-3) (U)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)	Si rslt (ppm)	stdev (Si)	SiO2 rslt (ppm)	stdev (SiO2)	Sn rslt (ppm)	stdev (Sn)	SO4(-2) rslt (ppm)
GW27_(i)-09-13148	9/25/2009	09-3342	0.1	0.01	U	0.0002	U	7.94	0.01	U	0.005	0.000	0.001	U	0.001	0.000	6.81	0.06	14.57	0.12	0.001	U	3.06
GW27_(i)-09-13149	10/21/2009	10-212	0.2	0.01	U	0.0002	U	7.57	0.01	U	0.002	0.000	0.001	U	0.001	U	31.11	0.37	66.57	0.79	0.001	U	5.26
GW27_(i)-09-13150	10/21/2009	10-212	0.2	0.01	U	0.0002	U	7.46	0.01	U	0.002	0.000	0.001	U	0.001	U	29.56	0.14	63.25	0.30	0.001	U	4.78
GW27_(i)-09-13151	10/23/2009	10-234	0.0	0.01	U	0.0007	0.0000	7.22	0.01	U	0.003	0.000	0.001	U	0.001	U	27.26	0.15	58.34	0.33	0.001	U	8.26
GW27_(i)-09-13152	10/23/2009	10-234	0.2	0.01	U	0.0005	0.0001	7.76	0.01	U	0.001	0.000	0.001	U	0.001	U	30.23	0.11	64.69	0.24	0.001	U	4.96
GW27_(i)-09-13153	10/26/2009	10-250	0.1	0.01	U	0.0005	0.0000	7.33	0.01	U	0.001	0.000	0.001	U	0.001	U	30.85	0.11	66.01	0.24	0.001	U	4.45
GW27_(i)-09-13154	10/26/2009	10-250	0.1	0.01	U	0.0004	0.0000	7.26	0.01	U	0.001	0.000	0.001	U	0.001	U	30.57	0.28	65.42	0.60	0.001	U	3.94
GW27_(i)-09-13155	10/26/2009	10-250	0.1	0.01	U	0.0006	0.0000	7.30	0.01	U	0.001	0.000	0.001	U	0.001	U	25.43	0.16	54.42	0.34	0.001	U	3.86

Note: U means not detected and AD means above analytical detectio

Table B-1.3-2
Analytical Results for Groundwater Screening Samples Collected at R-27i

Sample ID	Date Received	ER/RRES-WQH	S rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
GW27_(i)-09-13148	9/25/2009	09-3342	0.03	0.00	0.001	U	0.010	0.000	0.001	U	0.0003	0.0000	0.001	0.000	0.005	0.001	135	1.36	1.58	-0.07
GW27_(i)-09-13149	10/21/2009	10-212	0.06	0.00	0.001	U	0.002	U	0.001	U	0.0002	0.0000	0.002	0.000	0.051	0.000	183	1.38	1.50	-0.04
GW27_(i)-09-13150	10/21/2009	10-212	0.05	0.00	0.001	U	0.002	U	0.001	U	0.0003	0.0001	0.003	0.001	0.045	0.001	176	1.30	1.46	-0.06
GW27_(i)-09-13151	10/23/2009	10-234	0.08	0.00	0.001	U	0.002	U	0.001	U	0.0002	0.0000	0.001	0.000	0.150	0.001	192	1.61	1.73	-0.04
GW27_(i)-09-13152	10/23/2009	10-234	0.05	0.00	0.001	U	0.002	U	0.001	U	0.0002	U	0.001	0.000	0.043	0.002	177	1.32	1.45	-0.05
GW27_(i)-09-13153	10/26/2009	10-250	0.05	0.00	0.001	U	0.002	U	0.001	U	0.0002	U	0.002	0.000	0.041	0.003	178	1.30	1.43	-0.05
GW27_(i)-09-13154	10/26/2009	10-250	0.04	0.00	0.001	U	0.002	U	0.001	U	0.0002	U	0.001	0.000	0.041	0.001	173	1.27	1.38	-0.04
GW27_(i)-09-13155	10/26/2009	10-250	0.05	0.00	0.001	U	0.002	U	0.001	U	0.0002	U	0.001	U	0.046	0.002	164	1.28	1.40	-0.05

Note: U means not detected and AD means above analytical detectio

Appendix C

Borehole Video Logging
(on DVD included with this document)