Los Alamos
NATIONAL LABORATORY
EST. 1943

Environmental Programs
P.O. Box 1663, MS M991
Los Alamos, New Mexico 87545
(505) 606-2337/FAX (505) 665-1812

National Nuclear Security Administration
Los Alamos Site Office, MS A316
Environmental Restoration Program
Los Alamos, New Mexico 87544
(505) 667-4255/FAX (505) 606-2132

Date: December 28, 2008
Refer To: EP2008-0648

James P. Bearzi, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

Subject: Submittal of the Well Completion Report for R-38

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the Well Completion Report for R-38.The Well Construction Diagram and Well Summary Data Sheets and included as figures in the report. This report includes all available data collected through well development. A revision to the report that includes information not yet available will be submitted to your office by February 27, 2009.

If you have any questions, please contact Mark Everett at (505) 667-5931 (meverett@lanl.gov) or Nancy Werdel at (505) 665-3619 (nwerdel@doeal.gov).

Sincerely,

B. G. Schappell for
Michael J. Graham, Associate Director
Environmental Programs
Los Alamos National Laboratory

Sincerely,

Nancy Werdel for
David R. Gregory, Project Director
Environmental Operations
Los Alamos Site Office

MG/DG/PH/ME:sm

Enclosures: 1) Two hard copies with electronic files - Well Completion Report for R-38 (LA-UR-08-7863)

Cy: (w/enc.)
Neil Weber, San Ildefonso Pueblo
Mark Everett, EP-LWSP, MS M992
RPF, MS M707 (with two CDs)
Public Reading Room, MS M992

Cy: (Letter and CD only)
Laurie King, EPA Region 6, Dallas, TX
Steve Yanicak, NMED-OB, White Rock, NM
Andy Crowder, TPMC, Los Alamos, NM
Nancy Werdel, DOE-LASO, MS A316
Ed Worth, DOE-LASO, MS A316
Kristine Smeltz, WES-DO, MS M992
EP-LWSP File, MS M992

Cy: (w/o enc.)
Tom Skibitski, NMED-OB, Santa Fe, NM
Keyana DeAguero, DOE-LASO (date-stamped letter emailed)
Michael J. Graham, ADEP, MS M991
Alison M. Dorries, WES-DO, MS M992
Paul Huber, EP-LWSP, MS M992
IRM-RMMSO, MS A150 (date-stamped letter emailed)

LA-UR-08-7863
December 2008
EP2008-0648

Completion Report for Regional Aquifer Well R-38

Los Alamos
NATIONAL LABORATORY
EST.1943

Prepared by the Environmental Programs Directorate

LA-UR-08-7863
EP2008-0648

Completion Report for Regional Aquifer Well R-38

December 2008

Responsible project leader:

Printed Name	Signature	Title	Organization	Date
Mark Everett	Mark Everett	Project Leader	Environmental Programs	12-18-08

Responsible LANS representative:

Printed Name	Signature	Title	Organization	Date
Michael J. Graham	Bruce G Schappell for MJG	Associate Director	Environmental Programs	12-19-08

Responsible DOE representative:

Printed Name	Signature	Title	Organization	Date
David R. Gregory	Nancy Werdel for	Project Director	DOE-LASO	12/19/08

EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, and aquifer testing of Los Alamos National Laboratory (Laboratory) regional aquifer well R-38, which is located in the north fork of Cañada del Buey within Technical Area 54 (TA-54) in Los Alamos County, New Mexico. The well was installed at the direction of the New Mexico Environment Department (NMED), and this report was written in accordance with NMED requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent. Well R-38 was drilled as a single-screen well in the regional aquifer to monitor groundwater quality in support of remedy selection for Material Disposal Area (MDA) L. Well R-38 also assesses the conceptual model for contaminant fate and transport from TA-54 and serves as a downgradient monitoring well for MDA L.

The R-38 borehole was drilled using dual-rotary and open-hole drilling. Fluid additives used during the drilling included potable water and foam. Foam-assisted drilling was used only in the vadose zone; no drilling-fluid additives other than small amounts of potable water added to the air were used within the regional aquifer. Additive-free drilling provides minimal impacts to the groundwater and aquifer materials. The R-38 borehole was successfully completed to total depth using casing-advance and open-hole drilling methods. A retractable 16-in. casing was advanced through the Bandelier Tuff and the Guaje Pumice Bed to the top of the Cerros del Rio basalt. A 15-in. open borehole was advanced with fluid-assisted air-rotary methods and downhole hammer into the Cerros del Rio basalt to a depth of 515 ft below ground surface (bgs). Then 12-in. casing was advanced with a 12.75-in. underreaming hammer bit to a depth of 758.5 ft bgs. Fluid-assisted air-rotary methods were utilized to complete the R-38 borehole to total depth of 914.7 ft bgs in an open hole. Well R-38 was completed with a screen near the top of the regional aquifer in the lower Puye Formation.

The well was completed in accordance with an NMED-approved well design. The well was thoroughly developed and all target water-quality parameters were achieved. A dedicated submersible pump sampling system will be installed in the R-38 well, and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

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Acronyms and Abbreviations

µS/cm	microsiemen per centimeter
bgs	below ground surface
DO	dissolved oxygen
EP	Environmental Programs
ID	identification
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MDA	material disposal area
mV	millivolt
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxygen-reduction potential
Qal	Quaternary alluvium
Qbo	Quaternary Otowi Member of the Bandelier Tuff
Qbog	Quaternary Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member
Qct	Cerro Toledo interval
RPF	Records Processing Facility
SOP	standard operating procedure
TA	technical area
Tb 4	Tertiary Cerros del Rio basalt
TBD	to be determined

TD	total depth
TOC	total organic carbon
Tpf	Tertiary Puye Formation

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, and well construction for well R-38. An addendum to this report will be submitted following the completion of aquifer testing, dedicated sampling system installation, surface completion installation, and geodetic surveying. The report and addendum are written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent (the Consent Order). Well R-38 was drilled and the well was constructed from October 23, 2008, to December 8, 2008, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate Water Stewardship Project.

The R-38 project site is in the north fork of Cañada del Buey within Technical Area 54 (TA-54) in Los Alamos County, New Mexico (Figure 1.0-1). The purposes of the R-38 monitoring well are to monitor potential releases of contaminants from Material Disposal Area L to groundwater, assess the conceptual model for contaminant fate and transport from TA-54, monitor water levels within the regional aquifer, and measure pumping effects from municipal production wells in the vicinity.

The primary objective of the drilling activities was to drill and install a single-screened regional aquifer monitoring well in the upper portion of the regional aquifer. Secondary objectives were to collect drill-cutting samples, conduct borehole geophysical logging, and investigate potential perched groundwater zones.

The R-38 borehole was successfully drilled to a total depth (TD) of 914.7 ft below ground surface (bgs). A monitoring well was installed with a screened interval between 821.2 and 831.2 ft bgs. The depth to water in the open borehole was 810.2 ft bgs. Depth to water in the well following well development was 810.77 ft bgs on December 10, 2008. Cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. Ongoing activities include aquifer testing, dedicated sampling system installation, geodetic surveying, waste management, and site restoration.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, will be on file at the Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendixes completed to date associated with the R-38 project.

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.

2.1 Administrative Preparation

The following documents were prepared to guide the implementation of the scope of work for well R-38: “Drilling Plan for Regional Aquifer Well R-38” (TerranearPMC 2008, 103941); “Integrated Work Document for Regional and Intermediate Aquifer Well Drilling” (LANL 2007, 100972); “Storm Water Pollution Prevention Plan Addendum” (LANL 2006, 092600); and “Waste Characterization Strategy Form for the R-38, R-41, R-44, R-45, and R-46 Regional Groundwater Well Installation and Corehole Drilling” (LANL 2008, 103916).

2.2 Site Preparation

Site preparation was performed between October 21 and October 22, 2008, and included mobilizing the drill rig, air compressors, trailers, and support vehicles to the drill site and staging alternative drilling tools and construction materials at the Pajarito Road lay down yard.

Office supply trailers, generators, and general field equipment were moved on-site after mobilization of drilling equipment. Potable water was obtained from the Puye Road fire hydrant and a fire hydrant near the Los Alamos County landfill on East Jemez Road. 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 provides a chronological summary of field activities conducted at monitoring well R-38.

3.1 Drilling Approach

The selection of drilling equipment and drill-casing sizes for R-38 was designed to ensure successful completion of the borehole. This strategy retained the ability to case off perched groundwater and reach TD with sufficiently sized casing to meet the required 2-in. minimum annular thickness of the filter pack. Further, it was anticipated that if perched groundwater was encountered at R-38, the perched zone would be isolated and sealed off either with casing or by cementing to avoid commingling perched groundwater with the regional aquifer.

Dual-rotary air-drilling techniques and a Foremost DR-24HD drill rig were employed to drill the R-38 borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. The Foremost DR-24HD drill rig was equipped with conventional direct circulation drilling rods, tricone bits, downhole hammer bits, one deck-mounted 900 ft^3/min air compressor, and general drilling equipment. On-site equipment included two Wagner/Sullair 1150 ft^3/min trailer-mounted air compressors. Two sizes of flush-welded mild carbon-steel casing (16-in. and 12-in.) were used for the R-38 project. The 16-in. casing was used for drilling from ground surface to the top of the Cerros del Rio basalt. The 12-in. casing was utilized when unstable conditions were encountered within the basalt. When stable conditions resumed, open-hole drilling methods were utilized and continued to TD in the lower Puye Formation.

Drilling fluids, other than air, used in the vadose zone included municipal water and a mixture of municipal water with Baroid AQF-2 foaming agent. The fluids cool the bit and help lift cuttings from the borehole. A cumulative total of drilling fluids introduced into the borehole and those recovered are recorded and presented in Table 3.1-1. No additives other than municipal water were used for drilling within the regional aquifer.

3.2 Chronological Drilling Activities

Drilling equipment and supplies were mobilized to the site from October 21 to 22, 2008. On October 23, 2008, the R-38 borehole was initiated with dual-rotary methods using 16-in. casing and a 15-in. conventional hammer bit. On October 25, 2008, the 16-in. casing was advanced through the alluvium, the Tshirege Member of the Bandelier Tuff (unit 1g), the Cerro Toledo interval, the Otowi Member of the Bandelier Tuff, and upper Puye Formation; the casing was landed at 259.1 ft bgs, approximately 2 ft into the top of the Cerros del Rio basalt. Drilling resumed below the top of the Cerros del Rio basalt using open-hole drilling methods with the 15-in. hammer bit.

During October 25–26, 2008, drilling proceeded in the upper part of the Cerros del Rio basalt to a depth of 493 ft bgs. Because of binding and poor circulation, the decision was made to seal the basalt with Portland cement. On October 27, 2008, 17 yd^3 of Portland cement and sand was installed in the borehole. The top of cured cement was measured at 243 ft bgs. Early on the morning of October 28, 2008, open-hole drilling with a 15-in. hammer bit resumed. Cuttings from the cemented interval were redirected into on-site rolloff bins, rather than into the cuttings pit. After reaching 515 ft bgs on October 29, 2008, the borehole again became unstable. A Laboratory video log revealed cement chunks caked to the borehole wall. That day, the cemented open-hole section was reamed with the 15-in. hammer bit.

To address the unstable basalts, drilling was changed to casing advance with a 12-in. casing. Before hanging and welding the 12-in. casing string in the hole, the 16-in. casing drive shoe was cut off at 258.0 ft bgs on October 30, 2008. On October 31, 2008, drilling resumed with 12-in. casing advance utilizing a 12.75-in. underreaming hammer bit. Drilling with this method progressed slowly through variable zones of dense competent basalt and unstable basaltic cinders and sediment intervals to a casing depth of 758.5 ft bgs that was reached on November 4, 2008. Several possible minor water-bearing zones were investigated and sampled. After circulating the borehole dry, the water did not reappear. Therefore, the water was likely introduced and not groundwater.

On November 5, 2008, open-hole drilling began again with a 12-in. hammer bit when more stable conditions were encountered, still within the Cerros del Rio basalt. Multiple water samples were collected during the next 24 h until the borehole reached a final TD of 914.7 ft bgs. The Cerros del Rio basalts transitioned into Puye sediments from 820 to 834 ft bgs. The borehole reached TD in saturated, unstable, lower Puye Formation gravels on November 6, 2008. The 12-in. casing drive shoe was cut off at 738.0 ft bgs on November 7, 2008.

On the night of November 7, 2008, a Schlumberger logging unit was mobilized for geophysical logging, which concluded in the morning of the next day. TD of 893.4 ft was measured on November 8, 2008, indicating some sloughing and loss of open borehole. The drill rig was removed from the well site on November 8, 2008.

Over the course of drilling, the R-38 borehole field crews worked two 12-h shifts per day, 7 d/wk. Operations sustained no weather delays throughout the duration of drilling and only minor mechanical delays affected progress.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities at well R-38. All sampling activities were conducted in accordance with all applicable Laboratory procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-38 borehole at 5-ft intervals from ground surface to the TD of 914.7 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected from the discharge hose, sealed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were processed from the bulk sample and placed in chip trays along with unsieved (whole rock) cuttings. Radiation control technicians screened all cuttings before they were removed from the site.

Drilling and sample collection methods used at R-38 did not retain a majority of the fine fraction (silt and clay) of the drill cuttings, and much of the fine material throughout the borehole stratigraphy was lost. This effect was particularly evident with increasing depth and in the unconsolidated sedimentary units below the Cerros del Rio basalt. The foaming agent helped to retain the fines and acquire more representative samples in the intervals where it was used. The high volume of compressed air required for circulation made catching samples difficult because samples were manually collected with a wire mesh basket directly from the discharge hose, and discharge velocities forced the fine fraction of sample through the mesh. Recovery of the coarser fraction of the cuttings samples was excellent in nearly 100% of the borehole. The borehole log for R-38 is presented in Appendix A.

4.2 Water Sampling

Groundwater-screening samples were collected from the drilling discharge hose in the R-38 borehole. The driller stopped water circulation (if injecting water) and circulated air to clean out the borehole. As the discharge cleared, a water sample was collected directly from the discharge hose. Screening samples were analyzed for dissolved cations/metals and anions by the Laboratory's Earth and Environmental Sciences Division chemistry laboratory. Table 4.2-1 presents a summary of the groundwater-screening samples collected from the borehole.

Ten to 60 d following well development, groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. The samples will be analyzed for the full suite of constituents, including radioactive elements, metals/cations, general inorganic chemicals, volatile and semivolatile organic compounds, and stable isotopes of hydrogen, nitrogen, and oxygen. These groundwater analytical results will be report in the annual update to the "Interim Facility-Wide Groundwater Monitoring Plan."

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-38 is presented below. The Laboratory's geology task leader and site geologists examined cuttings and geophysical logs to determine geologic contacts and hydrogeologic conditions. Drilling observations, drill cuttings, video logging, water-level measurements, and geophysical logs were used to characterize groundwater occurrences encountered at R-38.

5.1 Stratigraphy

The stratigraphy for the R-38 borehole is presented below in order of youngest to oldest geologic units. Lithologic descriptions are based on cuttings samples collected from the discharge hose. Cuttings and borehole geophysical logs were used to identify geologic contacts. Figure 5.1-1 illustrates the stratigraphy at R-38. A detailed lithologic log is presented in Appendix A.

Quaternary Alluvium, Qal (0–52 ft bgs)

Quaternary alluvium consisting of unconsolidated tuffaceous silty sand to sandy silt with volcanic pebbles and gravels was encountered from 0 to 52 ft bgs. No evidence of alluvial groundwater was observed.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt (52–136 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff occurs from 52 to 135 ft bgs. Unit 1g is a poorly welded ash-flow tuff that is pumiceous, lithic-poor, locally crystal-rich, and generally has abundant ash matrix. Characteristic of unit 1g are white, fibrous, glassy pumice lapilli, locally minor volcanic lithic inclusions (predominantly dacites, up to 15 mm in diameter), and abundant quartz and sanidine crystals.

Cerro Toledo Interval, Qct (136–156 ft bgs)

The Cerro Toledo interval, a thin layer of poorly consolidated volcaniclastic sediments that occurs stratigraphically between the Tshirege and Otowi Members of the Bandelier Tuff, is present from 136 to 156 ft bgs. Locally, this unit consists of silty to clayey sands and gravels made up of detrital dacites and minor rhyolite (clasts up to 15 mm in diameter), white vitric pumice fragments, abundant quartz and sanidine crystal grains, and volcanic ash.

Otowi Member of the Bandelier Tuff, Qbo (156–230 ft bgs)

The Otowi Member of the Bandelier Tuff is present from 156 to 230 ft bgs. The Otowi Member is a poorly welded, pumiceous, locally lithic-rich, ash-flow tuff. Abundant pumice lapilli are white to pale orange, glassy, and quartz- and sanidine-phyric. Locally abundant volcanic lithic fragments or xenoliths (up to 13 mm in diameter) are commonly subangular to subrounded and of intermediate volcanic composition, including hornblende- and biotite-dacites and rhyodacites.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (230–240 ft bgs)

The Guaje Pumice Bed occurs from 230 to 240 ft bgs. The pumice bed contains abundant (98%–100% by volume) pristine-appearing vitric, phenocryst-poor pumice fragments, and lapilli with minor amounts of volcanic lithics, quartz and sanidine phenocrysts, and fine ash.

Upper Puye Formation, Tpf (240–250 ft bgs)

A thin layer of Puye Formation fanglomeratic sediments is recognized from 240 to 250 ft bgs. Detrital constituents consist of abundant white vitric pumices, pebbles and grains of diverse volcanic lithologies (andesite, dacite, rhyodacite), plus quartz and sanidine crystals. Lost circulation during drilling resulted in poor sample capture in this interval.

Basalt Lava/Volcaniclastic Sediments (250–255 ft bgs)

At approximately 250 ft bgs, the upper Puye Formation transitions from brown volcaniclastic sediments with pumice, intermediate volcanics, and quartz and sanidine crystals to a predominance of basalt fragments. The basalt fragments appear to be derived from the underlying Cerros del Rio basalt lava.

Cerros del Rio Basalt, Tb 4 (255–834 ft bgs)

The Cerros del Rio basalt, encountered from 255 to 834 ft bgs, is locally a complex package of volcanic and intercalated sedimentary layers that includes discrete lava flows; basaltic cinder deposits; basaltic sandstone/tuffs; and both coarse- and fine-grained clastic sediments with basaltic, mixed volcanic and Precambrian quartzo-feldspathic constituents. An upper succession of flows and interlayered cinder deposits from 255 to 470 ft bgs includes olivine- and clinopyroxene-basalt lavas. The section from 470 to 760 ft bgs is represented by a complex sequence of thin basalt flows, hydromagmatic basaltic tuffs containing quartzo-feldspathic detritus, basaltic scoria and cinder deposits, and locally siliceous clay-rich beds of possible lacustrine origin. The lowermost basalt flow and 5-ft-thick basal breccia occurs from 760 to 815 ft bgs. A basalt-rich mixed transitional zone occurs from approximately 820 to 834 ft bgs.

Lower Puye Formation, Tpf (834–915 ft bgs)

The lower section of Puye Formation sediments encountered from 834 to 915 ft bgs consists of poorly sorted basalt-rich gravels and siltstones and volcaniclastic sediments with predominantly dacitic detritus and quartz-bearing (i.e., well-rounded Precambrian quartzite and granitic constituents) volcaniclastic gravels that likely represent axial river deposits. These sediments are made up of gray, grayish brown, and pinkish tan coarse- to fine-gravels and sandstones with little apparent silt or clay.

5.2 Groundwater

Groundwater was first encountered at R-38 during drilling at approximately 758.5 ft bgs in the lower Cerros del Rio basalt on November 5, 2008. Groundwater was not encountered in the basalt at later dates; this water may have been introduced during the drilling activities. After the well was drilled to final depth of 914.7 ft bgs, the static water level was measured at approximately 810.1 ft bgs in the open hole. Following well development, depth to regional groundwater in R-38 was 810.77 ft bgs in the lower Puye Formation on December 10, 2008.

Groundwater-screening samples were collected during drilling as discussed in section 4.2. Groundwater chemistry will be discussed in the report addendum as Appendix B.

6.0 BOREHOLE LOGGING

Several video logs and a limited suite of geophysical logs were collected during the R-38 drilling project using Laboratory-owned equipment. A summary of video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

Video logging of the R-38 borehole occurred on multiple occasions and aided both drilling and well construction activities (Table 6.0-1). On October 29, 2008, the Laboratory video tool was run to inspect borehole condition after cementing the Cerros del Rio basalt. It revealed remnants of cement caking on the borehole wall, and the hole was reamed.

During well construction, the Laboratory video camera was run on November 17, 2008, to locate the top and condition of a section of 2-in. tremie pipe that was separated and lost from the bottom of the tremie pipe string. Unfortunately, because of tight annular space, the tool could not get past 430 ft bgs and was unsuccessful. As part of the ensuing fishing operations, Jet West Geophysical ran a video camera on three separate occasions (November 19, 21, and 22, 2008) for the same purpose. The last run was inside a 3-in. conductor pipe and guided an overshot tool to retrieve the lost tremie pipe.

6.2 Geophysical Logging

A suite of Schlumberger geophysical logs was run in both the open-hole and cased section of the R-38 borehole on November 8, 2008. At the time of logging, the terminations of the two casing strings in the borehole were located at the following depths: 16-in. casing at 259.1 ft bgs and the 12-in. casing at 758.5 ft bgs. The geophysical suite included Array Induction Imager, Natural Gamma Ray Spectroscopy, Accelerator Porosity, Formation MicroImager, magnetic resonance, and combined gamma ray and caliper tools (Table 6.0-1). Interpretation and details of the logging in the geophysical logging report will be presented in the report addendum as Appendix C.

7.0 WELL INSTALLATION

R-38 well casing and annular fill were installed between November 15, 2008, and December 7, 2008.

7.1 Well Design

The R-38 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 to monitor groundwater quality in the lower Puye Formation sediments within the uppermost productive zone of the regional aquifer.

7.2 Well Construction R-38

The R-38 monitoring well was constructed of 5.0-in.-inside diameter (I.D.)/5.56-in.-outside diameter (O.D.), type A304 stainless-steel unthreaded casing fabricated to American Society for Testing and Materials A312 standards. Welding with compatible stainless-steel welding rods was used to join all individual casing and screen sections. The screen section utilized had a 10-ft length of 5.0-in.-I.D. rod-based 0.020-in. wire-wrapped well screen. Both casing and screen were steam- and pressure-cleaned on-site before installation. Both 2-in. and 3-in.-I.D. steel threaded/coupled tremie pipe strings were used to deliver backfill and annular fill materials during well construction.

A single screened interval was chosen for the R-38 well design. The resulting nominal 10-ft long screened interval had the top of the screen set at 821.2 ft bgs, and a 21.2-ft stainless-steel sump was placed below the well screen. Four stainless-steel centralizers were welded to the well casing approximately 1.7 ft above and below the screen. A Semco work-over rig was used for well construction and development activities—a Smeal rig was also used additionally for fishing purposes. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

The well casing was welded as it was installed in the borehole, with particular care taken to avoid welding slag falling into the borehole. After landing the casing, the process of installing annular backfill materials started. The filter pack, fine sand collar, and associated bentonite seals were placed via tremie pipe. When the annular fill reached the bottom of the 12-in. casing at 758.4 ft bgs, the backfilling activity had two components—installing materials and retracting the drill casing—in addition to raising the tremie pipe. As each section of drill casing was cut off the string, it was picked up and laid down. During this part of the process, the well casing was hung on a wireline in the borehole and the drill casing was supported by a ring and slips. Short lengths of 12-in. (20.5-ft casing and shoe) and 16-in. (1.1-ft casing and shoe) drill casing remain in the borehole. The 12-in. casing was buried in bentonite, and the 16-in. casing was set in cement to avoid unwanted impacts in the future.

Formation slough backfill occurred from 914.7 to 889.6 ft bgs. Backfill, in the form of 10/20 sand, was placed above the slough from 889.6 to 846.4 ft bgs. The volume of sand used for the sand backfill (164.9 ft^3) was five times greater than calculated because of apparent borehole washouts, as noted by the Schlumberger caliper log. The bentonite seal was placed from 835.2 to 846.4 ft bgs. The filter pack of 10/20 silica sand was then placed across the screened interval from 816.6 to 835.2 ft bgs. After installation of the filter pack, the work-over rig was used to surge the screened interval with a surge block to promote settling and compaction of the filter pack. A fine-grained transition sand collar of 20/40 silica sand was placed above the filter pack from 812.5 to 816.6 ft bgs. The well's upper bentonite seal then capped the transition sand collar and was installed from 321 to 812.5 ft bgs. A surface seal composed of a mix of 97% Portland cement and 3% bentonite was installed from 3 to 321 ft bgs. Figure 7.2-1 depicts depths and volumes used in each interval. Table 7.2-1 details volumes of materials used during well construction.

Overall, well construction proceeded relatively smoothly from November 11, 2008, to December 7, 2008, and was briefly interrupted when the lower four sections of the tremie pipe parted and dropped in the borehole on November 17, 2008. The tremie was recovered several days later on November 23, 2008, when video wireline equipment was used to guide a 2-in. grapel run inside a 3-in. conductor pipe. Well construction progressed to completion on December 7, 2008, without incident.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation, well development began on December 8, 2008, and was finished on December 10, 2008. An aquifer test consisting of several short-duration pumping tests, a 24-h constant rate pumping test, and two 24-h background data collection periods will be performed. A dedicated submersible pump will be installed and the wellhead and surface pad will be constructed. A geodetic survey of the wellhead will be performed. Site restoration activities will commence once the final disposition of contained drill cuttings and groundwater is determined in accordance with the NMED-approved waste-decision trees.

8.1 Well Development

Well development was conducted between December 8, 2008, and December 10, 2008. Initially, the screened interval was swabbed and bailed to remove suspended solids in the well and formation fines in the filter pack. Bailing and swabbing methods were used until returned water was clear, and then a submersible pump was utilized to complete development. The swabbing tool was a 4.75-in.-O.D. 1-in.-thick nylon disk attached to a steel rod. The swabbing tool was lowered by wireline and drawn repeatedly across the screened interval. After bailing and swabbing, a 5-hp, 4-in.-Berkeley submersible pump was lowered into the well for the final stage of well development.

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxygen-reduction potential (ORP), and specific conductance parameters were collected. In addition, water samples for total organic carbon (TOC) analysis were collected. The required values for TOC and turbidity by the end of well development are less than 2.0 parts per million and less than 5 nephelometric turbidity units (NTUs), respectively. The turbidity measurement at the end of well development was 0.4 NTU. TOC values for well development and aquifer testing will be reported in the report addendum.

Approximately 10,600 gal. of groundwater was purged during development activities. Table 8.1-1 presents the volume of water removed during well development and the corresponding water-quality parameters. Discussion of analytical results will be presented in the report addendum.

8.1.1 Field Parameters

Field parameters, including pH, temperature, DO, ORP, specific conductance, and turbidity, were measured at regular time intervals; results are provided in Table 8.1-1. Field parameters were measured at well R-38 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. This condition probably resulted in a slight variation of field parameters during well development and during the pumping test, most notably, temperature, pH, and DO. Measurements of pH and temperature varied from 7.75 to 8.15 and from 17.71°C to 19.59°C, respectively, at well R-38. Concentrations of DO varied from 6.96 to 7.18 mg/L in the well. ORP varied from 151.2 to 184.1 millivolts (mV). Regional aquifer groundwater is relatively oxidizing at well R-38, based on DO and ORP measurements. Specific conductance ranged from 141 to

181 microsiemens per centimeter (μS/cm). Turbidity was measured for the majority of sampling, and values ranged from 0.1 to 53.4 NTUs for the nonfiltered groundwater samples collected.

Discussion of field parameters collected during aquifer testing will be presented in the report addendum.

8.2 Aquifer Testing

Aquifer pump testing and the associated analysis will be presented in the report addendum as Appendix D.

8.3 Dedicated Sampling System Installation

A dedicated environmentally retrofitted submersible pump will be installed in R-38. Postinstallation construction and sampling system component installation details will be presented in the report addendum.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, will be installed at the R-38 well head. The pad will provide long-term structural integrity for the well. A brass survey monument imprinted with well identification information will be placed in the northwest corner of the pad. A 10-in.-I.D. steel protective casing with a locking lid will be installed around the stainless-steel well riser. A weep-hole will be installed to prevent water build-up inside the protective casing. The concrete pad will be slightly elevated above the ground surface with an overall height, including 3-ft, 6-in. riser cap to promote runoff. A total of four bollards, painted yellow for visibility, will be set at the outside corners of the pad to protect the well from traffic. One of the four bollards will be designed for easy removal to allow access to the well. Details of the proposed wellhead completion are presented in Figure 8.4-1a. As-built technical notes for R-38 are presented in Figure 8.4-1b.

8.5 Geodetic Survey

A geodetic survey will be conducted by a New Mexico licensed professional land surveyor and will 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 will be expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation will be expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929. Survey points will 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.

8.6 Waste Management and Site Restoration

Waste generated from the R-38 project include contact waste, decontamination fluids, petroleum contaminated soil, drill cuttings, discharged drilling water, cement slurry, and purged groundwater. Waste characterization samples of drill cuttings, purge water, and cement slurry will be collected. A summary of the waste samples collected for the R-38 well to date is presented as Table 8.6-1.

Fluids, cuttings, cement slurry, and contact waste produced during drilling and development were containerized and sampled in accordance with "Waste Characterization Strategy Form for the R-38, R-41, R-44, R-45, and R-46 Regional Groundwater Well Installation and Corehole Drilling" (LANL 2008, 103916).

Fluids produced during drilling and well development are expected to be land-applied after a review of associated analytical results per the WCSF and the EP-Directorate SOP 010.0, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criterion for land application, the water 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 waste 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 Standard Operating Procedure (SOP) 011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criterion for land application, they will be removed from the pit and disposed of at an authorized facility. The cement slurry waste stream will be managed as industrial nonhazardous waste pending analytical review. Disposal of this concrete slurry will take place at an authorized disposal 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 cement slurry.

Site restoration activities will include removing water from the cuttings containment pit and land-applying it on-site (if applicable), removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area. Cuttings will be managed in accordance with SOP-011.0, referenced above. The site will be reseeded with a native seed mix consisting of Indian rice grass, mountain broam, blue stem, sand drop, and slender wheat grass seed. The Laboratory-approved seed mix will be applied at the required rate of 20 lb/acre; Biosol fertilizer will be applied at a rate of 80 lb/acre.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-38 were performed as specified in the "Final Drilling Plan for Regional Aquifer Well R-38" (TerranearPMC 2008, 103941).

9.1 NMED-Approved Modifications to the Work Plan

Drilling, sampling, and well construction at R-38 were performed as specified in the "Drilling Work Plan for Regional and Intermediate Wells at Technical Area 54" (LANL 2007, 099662).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled the R-38 borehole and installed the well.

Jet West Geophysical ran downhole video equipment in support of fishing the lost tremie pipe.

Right Bit Services and Equipment Repair welded the stainless well screen and casing.

TerranearPMC provided oversight on all preparatory and field-related activities.

11.0 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 number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs 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; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; 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), November 2007. “Drilling Work Plan for Regional and Intermediate Wells at Technical Area 54,” Los Alamos National Laboratory document LA-UR-07-7578, Los Alamos, New Mexico. (LANL 2007, 099662)

LANL (Los Alamos National Laboratory), October 2008. “Waste Characterization Strategy Form for the R-38, R-41, R-44, R-45, and R-46 Regional Groundwater Well Installation and Corehole Drilling,” Los Alamos, New Mexico. (LANL 2008, 103916)

TerranearPMC, October 2008. “Final Drilling Plan for Regional Aquifer Well R-38,” plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2008, 103941)

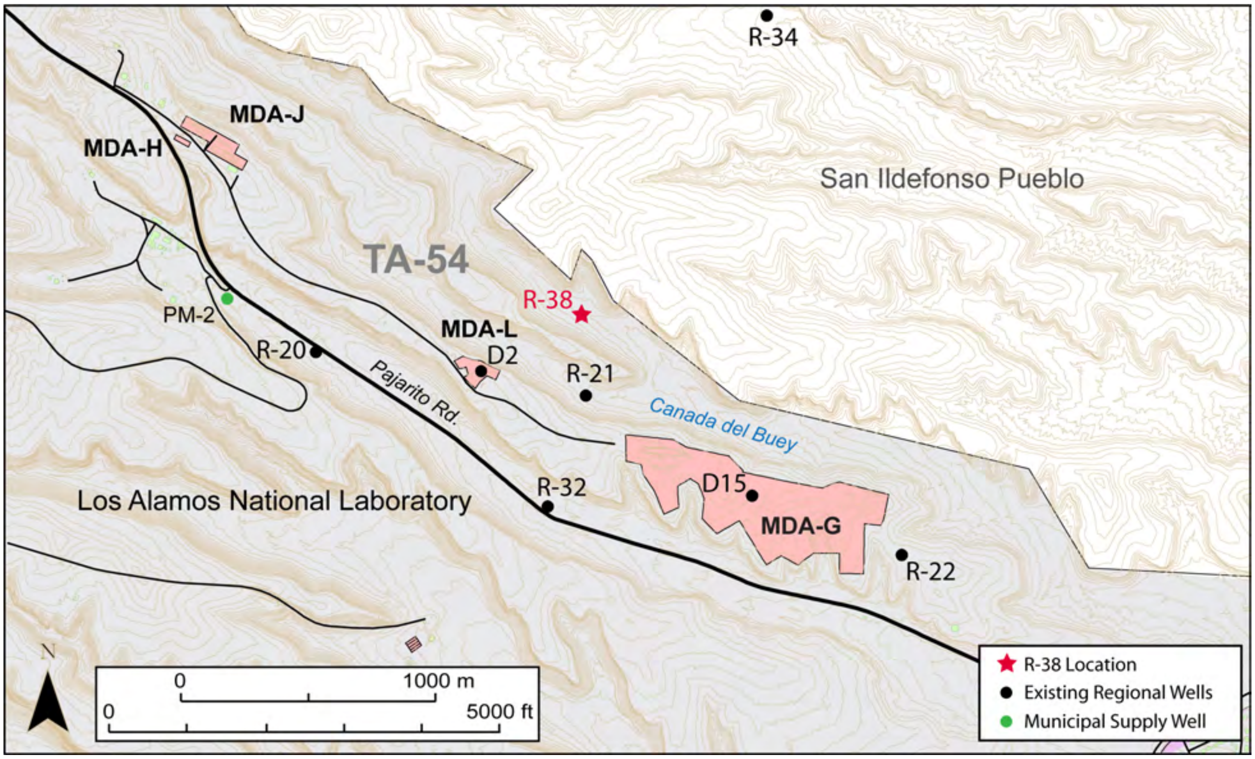

Figure 1.0-1 Regional aquifer well R-38

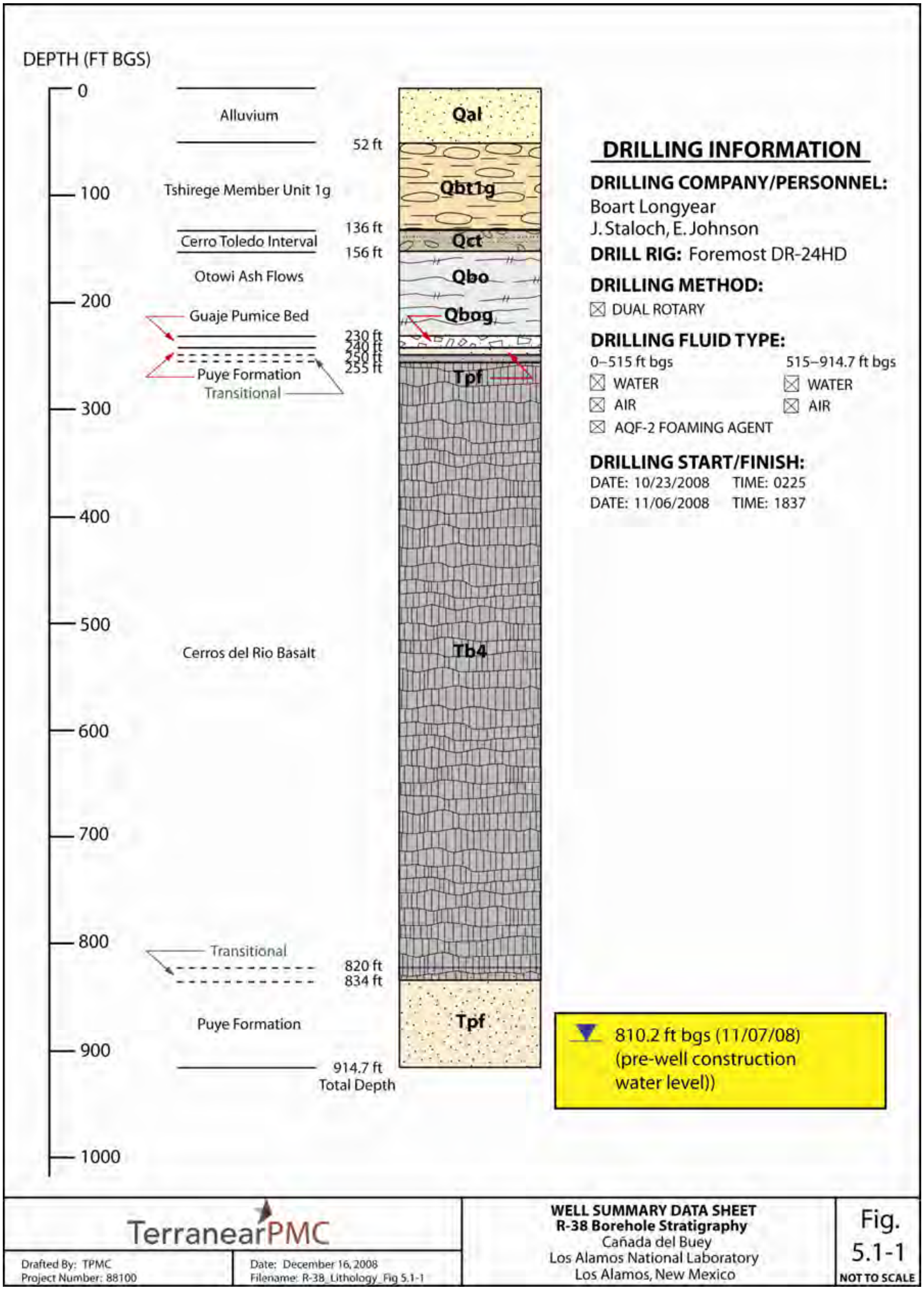

Figure 5.1-1 R-38 borehole stratigraphy

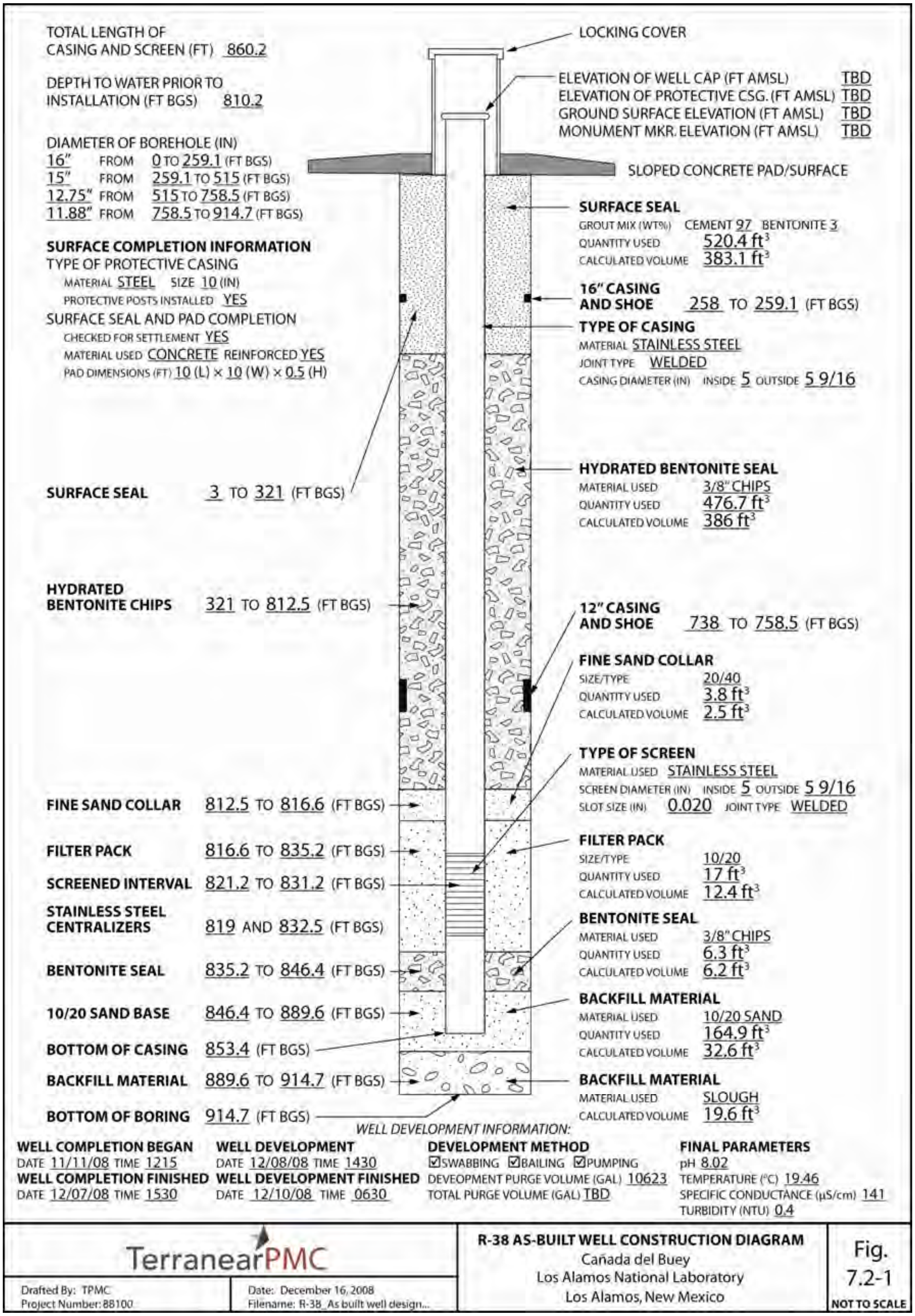

Figure 7.2-1 R-38 as-built well construction diagram

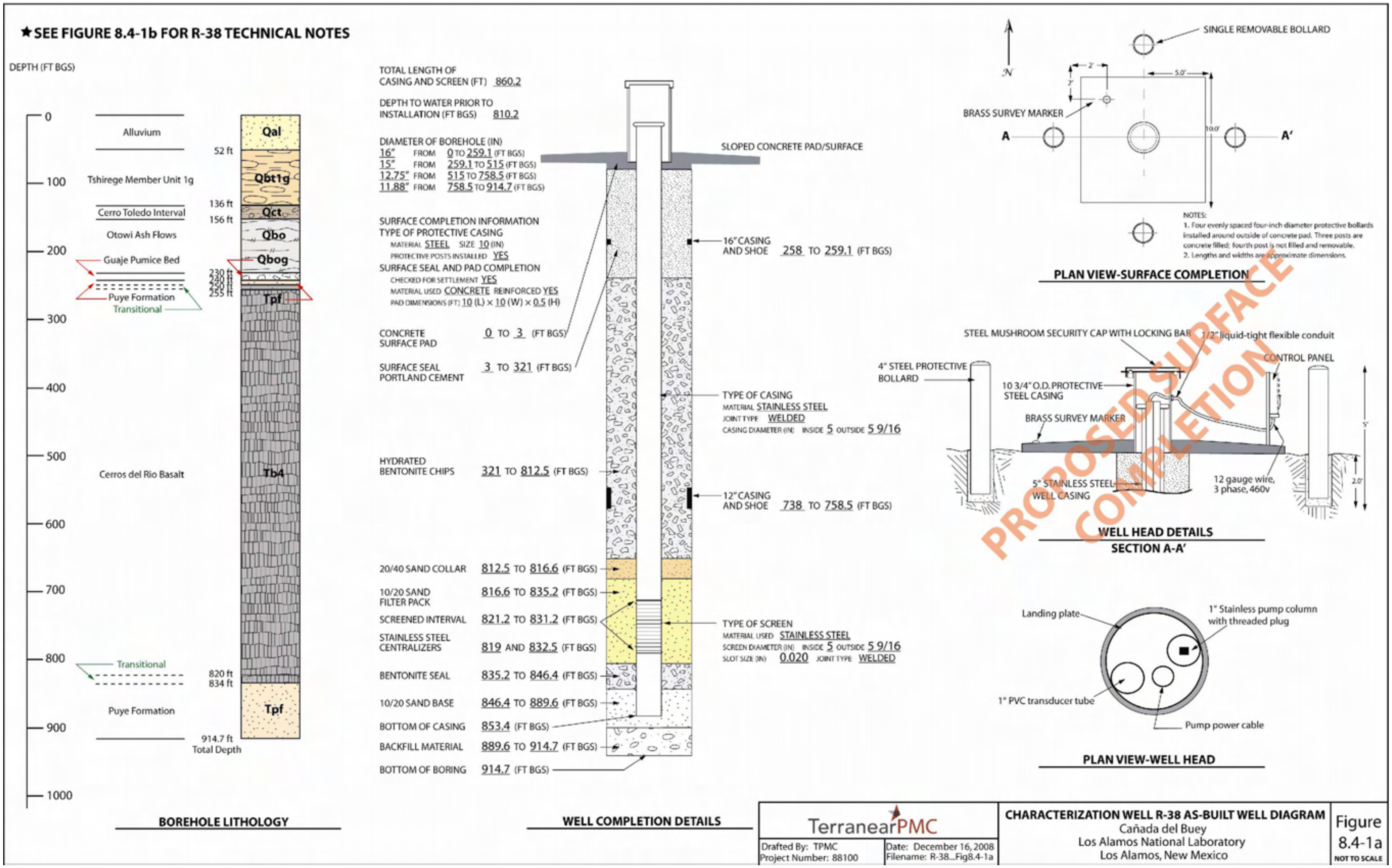

Figure 8.4-1a As-built schematic for regional well R-38

R-38 TECHNICAL NOTES: [1]

SURVEY INFORMATION[2]

Brass Marker
Northing: TBD
Easting: TBD
Elevation: TBD

Well Casing (top of stainless steel)
Northing: TBD
Easting: TBD
Elevation: TBD

BOREHOLE GEOPHYSICAL LOGS

Schlumberger

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: 10/23/2008
Finished: 11/08/2008

Well Completion
Start: 11/11/2008
Finished: 12/07/2008

Well Development
Start: 12/08/2008
Finished: 12/10/2008

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 10623 gallons

Parameter Measurments (Final)
pH: 8.02
Temperature: 19.46 ˚C
Specific Conductance: 141 μS/cm
Turbidity: 0.4 NTU

AQUIFER TESTING

Constant Rate Pumping Test
Water Produced: TBD gallons
Average Flow Rate: TBD gpm
Performed on: TBD

DEDICATED SAMPLING SYSTEM

Pump
Make: TBD, Type: TBD
Model: TBD
Capacity: TBD U.S. gpm, intake at TBD ft bgs
Environmental Retrofit

Motor
Make: TBD, model: TBD

Pump Column
TBD

Transducer Tube
TBD

Transducer
In-Situ, Make: TBD, Model: TBD

NOTES:
1) Additional information available in "Final Completion Report, Characterization Well R-38, Los Alamos National Laboratory, Los Alamos, New Mexico, date TBD.
2) 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-38 TECHNICAL NOTES Cañada del Buey Los Alamos National Laboratory Los Alamos, New Mexico	Figure 8.4-1b NOT TO SCALE
Drafted By: TPMC Project Number: 88100	Date: December 16, 2008 Filename: R-38_TechnicalNotes_Fig 8.4-1b		

Figure 8.4-1b As-built technical notes for R-38

Table 3.1-1
Fluid Quantities Used during 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					
10/23/08	175	175	0	0	na[a]
10/24/08	1600	1775	18	18	na
10/25/08	3200	4975	28	46	na
10/26/08	5500	10,475	41	87	na
10/27/08	850	11,325	2	89	na
10/28/08	4300	15,625	60	149	na
10/31/08	1650	17,275	n/a[b]	n/a	na
11/01/08	5500	22,775	n/a	n/a	na
11/02/08	400	23,176	n/a	n/a	na
11/03/08	4500	27,675	n/a	n/a	na
11/04/08	4000	31,675	n/a	n/a	na
11/05/08	1300	32,975	n/a	n/a	na
11/06/08	2000	34,975	n/a	n/a	na
Well Construction					
11/14/08	100	35,075	n/a	n/a	na
11/15/08	3350	38,425	n/a	n/a	na
11/16/08	1650	40,075	n/a	n/a	na
11/24/08	5800	45,875	n/a	n/a	na
11/25/08	1700	47,575	n/a	n/a	na
12/02/08	3000	50,575	n/a	n/a	na
12/03/08	3200	53,775	n/a	n/a	na
12/04/08	3000	56,775	n/a	n/a	na
Total Volume (gal.)					
R-38	56,775				30,500

[a] na = Not available.

[b] n/a = Not applicable. Foam use and pit use discontinued after drilling activities; therefore, no additional fluids were produced.

Table 4.2-1
Summary of Groundwater Screening Samples
Collected during Drilling, Well Development, and Aquifer Testing of Well R-38

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type
Drilling				
R-38	GW38-09-934	11/04/08	635	Groundwater
R-38	GW38-09-935	11/04/08	720	Groundwater
R-38	GW38-09-936	11/06/08	764	Groundwater
R-38	GW38-09-937	11/06/08	784	Groundwater
R-38	GW38-09-938	11/06/08	804	Groundwater
R-38	GW38-09-939	11/06/08	824	Groundwater
R-38	GW38-09-940	11/06/08	844	Groundwater
R-38	GW38-09-941	11/06/08	864	Groundwater
R-38	GW38-09-942	11/06/08	884	Groundwater
R-38	GW38-09-943	11-06-08	904	Groundwater
Well Development				
R-38	GW38-09-915	11/09/08	829.89	Groundwater
R-38	GW38-09-916	11/09/08	822.89	Groundwater
R-38	GW38-09-917	11/09/08	822.89	Groundwater
R-38	GW38-09-918	11/09/08	822.89	Groundwater
Aquifer Pump Test				
To be determined				
Postaquifer Pump Test Purging				
To be determined				

Table 6.0-1
R-38 Video and Geophysical Logging Runs

Date	Depth (ft bgs)	Description
10/29/08	Surface–515	Ran LANL video tool to inspect borehole condition after cementing off Cerros del Rio basalt. The run revealed "chunks of cement sticking to borehole wall"; a reamer was run as a result.
11/08/08	Surface–893.4	Ran Schlumberger Array Induction Imager, Natural Gamma Ray Spectroscopy, Accelerator Porosity, Formation MicroImager, magnetic resonance, and combined gamma ray and caliper tools—the 14-h logging job went smoothly.
11/17/08	Surface–430	Ran LANL video tool to determine location and condition of top of four lost stick of 2-in. tremie pipe at ≥785 ft bgs. Tool run in 12-in. × 5.5-in. annular space; could not get past 430 ft bgs—run unsuccessful.
11/19/08	Surface–808	Ran Jet West Geophysical video tool inside 3-in. fishing pipe to determine location and condition of top of four lost sticks of 2-in. tremie pipe at ≥785 ft bgs. The top collar of lost tremie was found at 806 ft bgs (water at 808 ft bgs), wedged between 5-in. well casing and the borehole wall.
11/21/08	Surface–818	Ran Jet West Geophysical video tool both in 5.5-in. well casing (to inspect screen) and in 12-in. × 5.5-in. annular space (inspect lost 2-in. tremie pipe location and condition). In-well casing run showed screen OK. Two annular runs not able to get below 361.7 ft bgs. Decide to pull 3-in. fishing pipe.
11/22/08	Surface–853	Ran Jet West Geophysical video tool in both 12-in. × 5.5-in. annulus and newly rerun 3-in. fishing pipe. Showed top of lost 2-in. tremie pipe at 824.5 ft bgs and guided fishing pipe over top of lost 2-in. tremie successfully. Lost tremie pipe recovered shortly thereafter.

Table 7.2-1
R-38 Annular Fill Materials

Material	Volume
Surface seal: cement slurry	262.5 ft^3
Bentonite seal: bentonite chips	476.7 ft^3
Fine sand collar: 20/40 silica sand	3.8 ft^3
Primary filter: 10/20 silica sand	17.0 ft^3
Bentonite lower seal: bentonite chips	6.3 ft^3
Backfill material: 10/20 sand	164.9 ft^3
Backfill material: slough	19.6 ft^3
Potable water used in the intermediate aquifer (drilling and well construction)	56,775 gal.

Table 8.1-1
Well Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-38

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
12/08/08	Bailing; parameters not collected						na*	155
	Bailing; parameters not collected						15.3	170.3
12/09/08	7.75	18.94	7.06	184.1	181	8.7	49	219
	8.13	19.19	7.01	155.3	149	13.6	720	769
	8.15	19.13	6.96	151.2	146	9.9	375	1470
	8.12	17.71	7.02	153.8	148	5.1	304	1774
	8.12	18.83	7.10	151.9	146	2.0	388	2162
	8.11	19.32	7.18	146.9	145	2.9	294	2456
	8.09	19.28	7.09	156.3	145	2.7	352	2808
	8.08	19.24	7.06	159.5	144	1.7	342	3150
	8.06	19.44	7.00	160.6	145	2.2	303	3453
	8.06	19.30	7.00	163.7	145	3.2	315	3768
	8.04	19.56	7.06	166.3	146	53.4	259	4027
	8.04	18.87	7.06	166.5	145	1.2	312	4339
	8.04	19.56	7.00	167.5	144	1.5	284	4623
	8.02	19.51	7.02	169.0	144	0.1	298	4921
	8.02	19.59	7.02	171.6	143	1.9	312	5233
	8.03	19.26	7.05	173.2	143	0.1	281	5514
	8.02	19.34	7.01	174.6	143	na	301	5815
	8.03	19.31	7.03	175.7	143	na	317	6132
	8.02	19.31	7.03	176.5	142	na	276	6408
	8.02	19.08	7.00	177.7	143	1.0	300	6708
	8.02	19.40	7.05	176.8	143	0.7	202	6910
	8.01	19.49	7.09	176.1	142	na	199	7109
	8.02	19.31	7.01	178.4	142	na	204	7313
	8.03	19.24	7.05	179.3	142	na	204	7517
	8.00	19.34	7.01	177.9	143	na	187	7704
	7.99	19.36	7.10	169.1	142	na	181	7885
	8.03	19.31	7.01	178.1	142	0.2	200	8085
	8.02	19.45	7.14	175.7	142	na	85	8170
	8.02	19.49	7.08	176.7	142	na	90	8260
	8.01	19.47	7.00	177.2	142	0.7	101	8361
	8.00	19.46	7.04	176.9	142	0.8	92	8453

Table 8.1-1 (continued)

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
12/09/08	8.01	19.15	7.02	175.2	142	na	93	8546
	8.02	19.08	7.07	175.3	142	na	51	8597
	8.02	19.29	7.04	171.6	142	0.7	46	8643
	8.02	19.07	7.09	170.3	142	na	49	8692
	8.02	19.46	7.03	168.7	141	na	47	8739
Aquifer Pump Test Volumes								
To be determined								
Post Pump Test Purging								
To be determined								

Note: Cumulative purge volumes calculated using average pump discharge rate of 9.8 gal./min.

*na = Not available.

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-38

Location ID	Sample ID	Date Collected	Description	Sample Type
WST-600902	GW38-09-966	11/03/2008	Diesel contaminated soil	New Mexico special waste soil
WST-600902	GW38-09-968	11/03/2008	Diesel contaminated soil	New Mexico special waste soil
R-38 well	RC38-09-1515	12/04/2008	Decontamination water	Water
R-38 well	RC38-09-1516	12/04/2008	Decontamination water	Water
R-38 well	RC38-09-1517	12/04/2008	Decontamination water	Water
R-38 well	RC38-09-1518	12/04/2008	Decontamination water	Water

Appendix A

Rotary Borehole R-38 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

COREHOLE IDENTIFICATION (ID): R-38	**TECHNICAL AREA (TA):** 54	**PAGE:** 1 of 15
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 8/12/08: 1420	**END DATE/TIME:** 9/10/08: 1410
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: TO BE DETERMINED **(**TBD)		**TOTAL DEPTH** (TD): 915 ft below ground surface (bgs)
DRILLERS: J. Staloch/J. Bowen	**SITE GEOLOGISTS:** R. McQuill, J. R. Lawrence, A. Miller	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
0–52	**ALLUVIUM:** Unconsolidated sediments—pinkish to reddish gray (5YR 5/2 to 5YR 7/2) silty fine to medium sand with minor pebble gravel; detrital grains/clasts of indurated tuff, quartz and sanidine crystals, pumice and volcanic lithics. 0–6 ft surficial construction fill. 35–52 ft light pinkish gray (5YR 8/3) clayey sand with gravel to clayey gravel.	Qal	Note: Drill cuttings for microscopic and descriptive analysis were collected at 5-ft intervals from 0 ft bgs to borehole TD at 915 ft bgs. Quaternary alluvial sediments, from 0 to 52 ft bgs are estimated to be 52 ft thick. Estimated Qal–unit 1g, Qbt contact at 52 ft bgs.
52–90	**UNIT 1g, TSHIREGE MEMBER OF THE BANDELIER TUFF:** Volcanic tuff—white (10YR 8/1), poorly to moderately welded, pumiceous, crystal-rich, lithic-poor, locally abundant ash matrix. 55–60 ft +10F: 95%–97% white, fibrous, vitric pumices, quartz- and sanidine-phyric, also abundant black Cpx and/or clots of Fe-oxide; 3%–5% dacite lithic fragments (up to 5 mm); +35F: abundant pumice fragments plus quartz and sanidine crystals, trace volcanic lithics. 60–65 ft similar to 55–60 ft. 65–75 ft WR: abundant pinkish white (5YR 8/2) volcanic ash matrix. 75–80 ft +10F: 85%–90% white glassy pumices, quartz- and sanidine-phyric and distinctive clots of black Fe-oxide; 10%–15% lithics (dacite and pinkish welded tuff). 85–90 ft +10F: 97% glassy pumices, 1%–3% fragments of welded tuff indicating locally increased degree of welding in unit 1g, Qbt.	Unit 1g, Qbt	Unit 1g of the Tshirege Member of the Bandelier Tuff, from 52 to 135 ft bgs, is estimated to be 83 ft thick.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA:** 54		**PAGE:** 2 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
90–95	Volcanic tuff—white (10YR 8/1), poorly welded, pumiceous, crystal-rich, lithic-bearing abundant ash matrix. +10F: 85%–90% white glassy fibrous quartz- and sanidine-phyric pumices with black clots of secondary Fe-oxides; 10%–15% volcanic lithic fragments (dacite, rhyolite) up to 15 mm.	Unit 1g, Qbt	
95–135	Volcanic tuff—white (10YR 8/1), poorly welded, pumiceous (vitric pumices), crystal-rich, lithic-poor, locally abundant ash matrix. 95–100 ft +10F: 97% white glassy quartz- and sanidine-phyric pumices with black clots of secondary Fe-oxides; 3% volcanic lithic fragments (i.e., xenoliths) composed of dacite, rhyodacite. +35F: abundant pumice fragments, quartz and sanidine crystals. 110–115 ft WR: abundant white (10YR 8/1) to pinkish white (5YR 8/2) volcanic ash matrix; +10F: 97% white glassy pumices, 1%–3% dacite lithics (up to 17 mm). 115–135 ft WR: abundant volcanic ash matrix.		Estimated unit 1g, Qbt–Qct contact at 135 ft bgs.
135–140	**CERRO TOLEDO INTERVAL:** Volcaniclastic sediments—light pinkish tan (5YR 7/3) silty to clayey sand and gravel, detrital volcanic clasts broken to subangular. WR: abundant volcanic ash. +10F: 90%–95% clasts (up to 15 mm), predominantly of pinkish and gray dacites and white rhyolite (?); 5%–10% white glassy pumices; +35F: 70% quartz and sanidine crystals, 20% pumice fragments, 10% dacite grains.	Qct	Section of Cerro Toledo interval sediments, from 135 to 140 ft bgs, is estimated to be 5 ft thick. Estimated Qct–Qbo contact at 140 ft bgs.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA:** 54		**PAGE:** 3 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
140–180	**OTOWI MEMBER OF THE BANDELIER TUFF:** Volcanic tuff—light pinkish tan (5YR 8/3) to orange tan (5YR 7/6), poorly welded, pumiceous (vitric pumices), crystal-rich, lithic-rich, locally abundant ash matrix. 140–150 ft: No sample is available for description. 150–155 ft +10F: 45%–50% white to pale orange, glassy, quartz- and sanidine-phyric pumices; 45%–55% volcanic lithic fragments (i.e., xenoliths) composed of dacite, rhyodacite, flow-banded rhyolite; +35F: 50%–60% quartz and sanidine crystals, 30%–40% volcanic lithic fragments, 5%–10% pumice fragments. 155–160 ft +10F: 80%–85% volcanic lithic fragments (up to 13 mm) including biotite-dacite, rhyodacite, flow-banded rhyolite; 10%–15% glassy pumices. 160–180 ft similar to 155–160 ft. 170–180 ft: No sample is available for description.	Qbo	
180–190	Volcanic tuff—pinkish white (5YR 8/2), poorly welded, pumiceous, lithic- and crystal-bearing, locally abundant ash matrix. 180–185 ft WR: abundant volcanic ash. +10F: 45%–50% vitric pumice fragments with local orange limonitic (Fe-oxide) staining; 40%–50% dacite lithic fragments (i.e., xenoliths) up to 5 mm; +35F: 50% quartz and sanidine crystals, 30% volcanic lithic fragments, 20% pumice fragments. 185–190 ft similar to 180–185 ft.		189–190 ft poor recovery, low-volume samples.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	TA: 54		PAGE: 4 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
190–220	Volcanic tuff—pinkish white (5YR 8/2), poorly welded, pumiceous, lithic-rich, crystal-bearing, locally abundant ash matrix. 190–195 ft WR: abundant lithics; little or no ash matrix; +10F: 40%–50% vitric pumice fragments (up to 15 mm); 40%–50% volcanic lithic fragments, predominantly hornblende- and biotite-dacites (up to 27 mm); +35F: 50%–60% quartz and sanidine crystals, 20%–25% volcanic lithic fragments, 15%–20% pumice fragments. 195–200 ft WR: abundant orange to white ash matrix; +10F: 40%–50% white vitric, quartz- and sanidine-vitric pumice fragments; 40%–50% volcanic lithic fragments, predominantly gray hornblende dacites (up to 10 mm); +35F: 60%–70% quartz and sanidine crystals, 15%–20% volcanic lithic fragments, 15%–20% pumice fragments. 200–205 ft +10F: glassy fibrous-textured pumices are locally orange colored, limonite-stained. 205–220 ft similar to 200–205 ft.	Qbo	Estimated Qbo–Qbog contact at 220 ft bgs.
220–234	**GUAJE PUMICE BED:** Volcanic tuff—white (5YR 8/1), poorly welded to nonwelded, strongly pumiceous, lithic-poor, no apparent volcanic ash matrix. 220–225 ft WR/+10F: 100% vitric pumices (up to 10 mm); phenocryst-poor to aphyric, having pristine, very fresh appearance; +35F: trace amounts quartz and sanidine crystals, volcanic lithic fragments, and pumice fragments. 225–230 ft +10F: 98% vitric pumices, 2% dacite lithics. 230–234 ft similar to 225–230 ft.	Qbog	Guaje Pumice Bed, from 220 to 234 ft bgs, is estimated to be 14 ft thick. Estimated Qbo–Qbog contact at 220 ft bgs.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38		**TA:** 54	**PAGE:** 5 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
234–250	**PUYE FORMATION:** Pumiceous volcaniclastic sediments–White (5YR 8/1), pebble gravel and fine to medium sand, subangular to subrounded detritus composed of mixed glassy pumices, diverse volcanic rocks and fragments of pumice-bearing fine-grained sandstone. 234–2400 ft +10F: 60%–70% white vitric pumices, 15%–20% sunangular clasts made up of volcanic lithologies (andesite, dacite, rhyodacite), 15%–20% fragments of indurated tuffaceous sandstone containing grains of white pumice, quartz and sanidine crystals, and volcanics. 240–250 ft: No sample is available for description.	Tpf	Estimated Qbog–Tpf contact at 234 ft bgs. This section of Puye Formation pumiceous-volcaniclastic sediments is estimated to be 16 ft thick. Estimated Tpf-Tb4 contact at 250 ft bgs.
250–255	**CERROS DEL RIO BASALT:** Basalt lava/volcaniclastic sediments–pinkish white (5YR 8/2) fragments and/or clasts of strongly vesicular olivine-basalt. 250–255 ft WR/+10F: predominantly angular fragments (up to 44 mm) of vesicular olivine-phyric basalt, vesicles infilled with very fine-grained sandstone; less than 5% fragments of volcaniclastic sandstone; +35F: mixed basalt fragments, pumices, quartz and sanidine crystals, and fragments of indurated sandstone. This interval marks the transition from volcaniclastic sediments with pumice to the top of the Tb4 basalt section.	Tb4	The entire Cerros del Rio basalt section, including lavas, basaltic cinder deposits, hydromagmatic tuffs and intercalated basaltic clastic sediments intersected from 250 to 820 ft bgs, is estimated to be 570 ft thick.
255–260	Basalt lava–pinkish white (5YR 8/2) mixed fragments of strongly vesicular olivine-basalt and those of fine-grained volcaniclastic sandstone. 255–260 ft WR: silty to clayey matrix. +10F: 90%–95% broken basalt chips strongly vesicular olivine basalt; 5%–10% fragments of indurated pinkish tan (5YR 7/3) very fine-grained sandstone.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	TA: 54		PAGE: 6 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
260–275	Basalt lava–dark gray (GLEY1 4/1) angular chips vesicular olivine-phyric basalt, porphyritic with aphanitic groundmass, locally abundant clay. 260–265 ft +10F: 100% broken basalt chips, phenocrysts (5%–7% by volume) of small (up to 1 mm) translucent green olivine, minor black opaque clinopyroxene, minor plagioclase and rare xenocrystic quartz. 265–275 ft similar to 260–265 ft.	Tb4	
275–300	Basalt lava–dark gray (GLEY1 4/1) angular chips, vesicular olivine-phyric basalt, porphyritic with aphanitic groundmass. 275–280 ft WR/+10F: 100% broken basalt chips, strongly vesicular, phenocrysts (5%–7% by volume) of small (up to 1 mm) green olivine, minor plagioclase; fragments coated and vesicles filled with locally abundant light pinkish tan clay. 280–295 ft similar to 275–280 ft. 295–300 ft: No sample is available for description.		
300–325	Basalt lava–dark gray (GLEY1 4/1) angular chips, vesicular olivine-phyric basalt, porphyritic with aphanitic groundmass, locally strong secondary Fe-oxide. 300–305 ft WR/+10F: 100% broken basalt chips, strongly to weakly vesicular, phenocrysts (5%–7% by volume) of small (up to 1 mm) green olivine (locally iddingsitized), locally abundant light reddish brown (i.e., Fe-oxide) and/or pale tan clay filling vesicles. 305–325 ft similar to 300–305 ft.		
325–355	Basalt lava–dark gray (GLEY1 4/1) to locally dark reddish brown (2.5YR 4/6), vesicular to scoriaceous olivine-phyric basalt, porphyritic with aphanitic groundmass, local clay and/or secondary Fe-oxide. 325–330 ft WR/+10F: 100% strongly vesicular to scoriaceous basalt chips, phenocrysts (5%–7% by volume) of small (up to 1 mm) green olivine and plagioclase (olivine and feldspar commonly intergrown); locally abundant white clay and/or reddish secondary hematite lining vesicles. 330–355 ft similar to 325–330 ft.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA:** 54		**PAGE:** 7 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
355–380	Basaltic cinder deposits–dark gray (GLEY1 4/1) to light reddish brown (2.5YR 6/6), strongly vesicular to scoriaceous olivine-phyric basalt, porphyritic with aphanitic groundmass, commonly limonite-stained with local minor white clay. 355–360 ft WR/+10F: 100% basalt chips, mostly scoriaceous, phenocrysts (3%–5% by volume) of olivine (frequently replaced by iddingsite) and plagioclase, moderate limonite and/or weak white clay lining vesicles. 360–380 ft similar to 355–360 ft.	63.0	
380–420	Basalt lava–dark gray (GLEY1 4/1) vesicular olivine-phyric basalt, porphyritic with aphanitic groundmass, local minor secondary Fe-oxide. 380–385 ft WR/+10F: 100% moderately vesicular basalt chips, phenocrysts (3%–5% by volume) of small (up to 2 mm) plagioclase and green olivine (up to 1 mm); locally weak reddish earthy hematite lining vesicles. Olivine-plagioclase intergrowths common. 385–400 ft similar to 380–385 ft. 400–405 ft +10F: olivine phenocrysts commonly replaced by iddingsite; locally strong secondary hematite lining vesicles. 405–410 ft +10F: euhedral olivines proportionately more prominent and larger (up to 3 mm), locally strong hematite staining. 410–420 ft similar to 380–385 ft.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA:** 54		**PAGE:** 8 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
420–450	<u>Basalt lava</u>–medium gray (GLEY1 6/1) to dark reddish brown (2.5YR 4/6) vesicular to scoriaceous olivine- and clinopyroxene-phyric basalt, porphyritic with aphanitic groundmass, local strong secondary Fe-oxide. 420–425 ft WR/+10F: 100% basalt chips, partly scoriaceous, phenocrysts (3%–5% by volume) of euhedral plagioclase (up to 3 mm), black opaque clinopyroxene (anhedral or as partial replacement after olivine), and minor olivine. The three mineral phases frequently occur as cumulophyric intergrowths. Strong earthy hematite occurs locally as vesicle linings. Weak hydrothermal alteration appears to affect groundmass feldspars. 425–430 ft similar to 420–425 ft. 430–435 ft +10F: 100% basalt chips exhibit hydrothermal alteration and resultant bleaching of groundmass; bleaching is progressive stronger downward in this flow unit. Olivine phenoscrysts show prominent replacement, or partial replacement, by black Cpx. 435–440 ft similar to 420–425 ft. 440–450 ft +10F: black opaque clinopyroxene becoming more prominent over the occurrence of olivine downward in the section.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA:** 54		**PAGE:** 9 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
420–450	<u>Basalt lava</u>–medium gray (GLEY1 6/1) to dark reddish brown (2.5YR 4/6) vesicular to scoriaceous olivine- and clinopyroxene-phyric basalt, porphyritic with aphanitic groundmass, local strong secondary Fe-oxide. 420–425 ft WR/+10F: 100% basalt chips, partly scoriaceous, phenocrysts (3%–5% by volume) of euhedral plagioclase (up to 3 mm), black opaque clinopyroxene (anhedral or as partial replacement after olivine), and minor olivine. The three mineral phases frequently occur as cumulophyric intergrowths. Strong earthy hematite occurs locally as vesicle linings. Weak hydrothermal alteration appears to affect groundmass feldspars. 425–430 ft similar to 420–425 ft. 430–435 ft +10F: 100% basalt chips exhibit hydrothermal alteration and resultant bleaching of groundmass; bleaching is progressive stronger downward in this flow unit. Olivine phenoscrysts show prominent replacement, or partial replacement, by black Cpx. 435–440 ft similar to 420–425 ft. 440–450 ft +10F: black opaque clinopyroxene becoming more prominent over the occurrence of olivine downward in the section.	Tb4	
450–470	<u>Basalt lava</u>–light gray (GLEY1 7/1) to dark reddish brown (2.5YR 4/6), strongly vesicular olivine- and clinopyroxene-phyric basalt, porphyritic with aphanitic groundmass, local moderate secondary Fe-oxide. 450–455 ft WR/+10F: 100% basalt chips, strongly vesicular, phenocrysts (2%–4% by volume) of anhedral clinopyroxene, euhedral plagioclase (up to 2 mm), and green olivine. Black opaque clinopyroxene frequently replaces or forms rims (overgrowths) on olivine. Moderate hematite frequently lines vesicles. Commonly bleached groundmass indicates weak hydrothermal alteration. 455–470 ft +10F: weak to moderate white clay lining vesicles, local secondary hematite.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA:** 54		**PAGE:** 10 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
470–495	Basaltic cinder deposits–dark reddish brown (2.5YR 4/6) to light gray (GLEY1 7/1), mixed scoriaceous and strongly vesicular basalt, porphyritic with aphanitic groundmass, pervasive ferruginous alteration and local bleaching of groundmass. 470–475 ft +10F/+35F: 100% basalt chips, phenocrysts (2%–4% by volume) of clinopyroxene, plagioclase and olivine (frequently replaced by iddingsite) and plagioclase. Scoria fragments are strongly ferruginous (i.e., hematite), whereas vesicular basalt chips exhibit bleached/altered groundmass with minor white clay. 475–495 ft +10F/+35F: predominantly ferruginous scoria/cinders.	Tb4	
495–525	Basaltic cinders/clastic sediments–dark reddish brown (2.5YR 4/6) and light gray (GLEY1 7/1), mixed basalt cinders, massive basalt and detrital grains composed of Precambrian quartzite and quartzo-feldspathic rocks and volcanic lithologies. 495–500 ft +10F: 95%–98% gray and reddish basalt scoria/cinders. 500–520 ft +10F: similar to 495–500 ft. +35F: 75%–85% basalt chips, scoria/cinders and glassy basalt cinders; 10%–20% subangular sand-size grains of quartz and dacitic volcanics. 520–525 ft +10F: 85%–90% basalt/basalt scoria, 10%–15% rounded detrital pebbles (up to 18 mm) composed of intermediate to felsic volcanic rocks. +35F: no sample preserved of this size fraction.		495–525 ft: Occurrence of ferruginous basalt scoria and frothy basaltic glass mixed with sand-size detritus of Precambrian quartzite and granitic lithologies indicates tuffaceous-clastic layer, possibly of hydromagmatic origin. Estimated contact between base of lava section and top of basalt cinders at 562 ft bgs
525–562	Basalt lava—light gray (GLEY1 7/1),vesicular to massive Cpx-bearing basalt, porphyritic with aphanitic groundmass, limonitic coating of local fracture surfaces. 525–530 ft +10F: 100% basalt chips, phenocrysts (5%–7% by volume) of small (up to 1 mm) black anhedral Cpx and minor plagioclase; groundmass exhibits hydrothermal alteration as seriticization of feldspar microlites and bleaching; +35F: 98% basalt fragments, 2% subangular quartz detritus. 530–535 ft +35F: 100% basalt chips. 535–545 ft +10F: abundant limonite on fracture surfaces and lining vesicles; apparent highly fractured rock. 545–562 ft +10F: increased vesicularity, grading to more massive basalt with depth.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38		**TA:** 54	**PAGE:** 11 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
562–575	Basaltic hydromagmatic deposits—brick red (10YR 6/8) fine-grained basaltic sandstone/tuff with basaltic glass and clay. 562–575 ft +10F: 100% fragments of indurated basaltic sandstone/tuff containing fine- to very fine-grained reddish "frothy" basaltic glass, cinders, Cpx and olivine crystals, abundant subangular quartz grains, and interstitial clay; clast supported.	Tb4	
575–590	Basaltic hydromagmatic deposits—grayish brown (10YR 5/2) to reddish gray (5YR 5/2) fine- to medium-grained basaltic sandstone with mixed volcanic detrital pebbles. 575–580 ft +10F: 85%–90% fragments of indurated fine-grained tuffaceous sandstone containing predominantly grains of basaltic glass cemented by tan palagonitic clay; 10%–15% broken and subangular clasts (up to 13 mm) mixed volcanic rocks (basalt, rhyodacite); +35F: predominantly grains of basaltic glass scoria with adhered clay. 580–595 ft +10F: mixed fragments of indurated fine-grained basaltic sansdstone and anguilar clasts (up to 15 mm) basalt and dacite brown; local grains of quartz at 585–590 ft. .		
590–605	Basaltic hydromagmatic deposits—reddish gray (5YR 5/2) to pinkish tan (5YR 7/3) basaltic sandstone/tuff, matrix supported with abundant silt and clay; becoming finer grained, more clay rich with depth. 595–600 ft +10F: 80% indurated silt fragments with very fine-grained volcanic sand and clasts (up to 10 mm) of basaltic glass. 600–605 ft +10F: pinkish tan (5YR 7/3) fragments of indurated silt/clay with mixed volcanic clasts (10%–15% by volume, up to 10 mm) including basalt, dacite, and basaltic glass.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-43	**TA** 72		**PAGE:** 12 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
605–615	Fine clastic sediments—light pinkish tan (5YR 7/3) clay, high plasticity, with volcanic pebble gravel. 605–610 ft WR: abundant clay: +10F: 100% subrounded light gray dacite clasts (up to 3.2 cm). +35F: mixed grains of basalt and fragments of very fine-grained sandstone. 610–615 ft WR: abundant clay: +10F/+35F: no sample preserved (apparently no coarse clastic component).	Tb4	
615–638	Fine clastic sediments—light pinkish tan (5YR 7/3) clay, hard dessicated clay. 615–638 ft WR/ +10F: brittle clay fragments having pseudoconcoidal fracture and apparent siliceous chertlike quality.		615–638 ft siliceous cherty clay possibly of lucustrine origin.
638–670	Basalt lava—medium gray (GLEY1 5/1), massive (nonvesicular) basalt, weakly porphyritic with aphanitic groundmass, olivine-phyric. 638–650 ft +10F: 99% basalt chips, phenocrysts (2%–4% by volume) green subhedral olivine (up to 3 mm); 1% pinkish siliceous clay. 650–660 ft +10F/+35F: 95%–98% basalt chips partly rounded to subrounded, groundmass partly bleached, weakly altered; 2%–5% pink siltstone fragments. 660–670 ft +10F: 100% chips olive-basalt with bleached (altered) groundmasss, local fractured surfaces coated with white clay and/or SiO_2.		650–670 ft rounded basalt pebbles suggest basalt gravel layer.
670–685	Basalt lava—light gray (GLEY1 7/1), massive basalt, porphyritic with aphanitic groundmass, olivine-phyric, groundmass weakly altered/bleached. 670–680 ft +10F: 99%–100% angular basalt chips, phenocrysts (3%–5% by volume) anhedral olivine (up to 2 mm); altered groundmass feldspars; trace pinkish clay flakes. 680–685 ft +10F: 99% well-rounded basalt clasts (up to 4.0 cm) suggesting detrital pebbles; 1% white fine-grained sandstone with quartz grains.	Tb4	680–685 ft rounded basalt clasts indicate thin basalt gravel layer.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA** 54		**PAGE:** 13 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
685–733	<u>Basalt lava</u>—light gray (GLEY1 7/1), massive basalt, weakly porphyritic with aphanitic groundmass, olivine-phyric, groundmass weakly altered/bleached. 685–705 ft +10F: 100% angular basalt chips, phenocrysts (2%–4% by volume) of olivine (up to 2 mm); groundmass altered/bleached resulting in very fine particles making up WR. 705–733 ft +10F: 99% angular basalt with altered/bleached groundmass; 1% very pale secondary SiO_2 fragments (i.e., likely fracture filling, veinlet).	Tb4	
733–760	<u>Basaltic fine clastic sediments</u>—varicolored, light pinkish tan (5YR 7/4) to medium gray (GLEY1 5/1) clay and clay with vesicul;ar basalt fragments/clasts. 740–50 ft 50% angular chips basalt scoria; 50% chips/flakes of brittle clay and minor very fine-grained sandstone. 750–755 ft +10F: 40% black scoriaceous basalt; 20% pinkish clay, 5%–10% white earthy pumices, 30% very fine-grained silty sandstone with abundant with pumice particles. 755–760 ft +10F: 100% vesicular subrounded basalt clasts with adhered rinds of pumiceous very fine-grained sandstone; +35F: mixed basalt chips, clay flakes and white pumice fragments.		
760–815	<u>Basalt lava</u>—very light gray (GLEY1 7/1), weakly vesicular basalt, phenocryst-poor, aphanitic groundmass, olivine-phyric, groundmass altered/bleached. 760–765 ft +10F: 100% angular basalt chips, phenocrysts (less than 1% by volume) olivine (up to 1 mm); bleaching indicates moderate hydrothermal alteration and seritization of groundmass feldspars. 765–775 ft +10F: scoriaceous basalt, moderate to strong pervasive hydrothermal alteration/bleaching of groundmass. 775–780 ft +10F: 85% gray scoriaceous basalt chips; 15% subrounded detrital pebbles (up to 10 mm) composed of quartzite, granite. 780–814 ft similar to 760–765 ft.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38	**TA** 54		**PAGE:** 14 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
815–820	Basalt lava/clastic sediments—varicolored mixed basalt, clay, and sandstone. 815–820 ft +10F: 50% dark gray chips vesicular basalt; 50% light pink (5YR 8/2) fragments of claystone with minor fine -grained sandstone. +35F: 60% basalt chips; 40% claystone fragments.	Tb4	815–820 ft interpreted to be a rubbly breccia zone at base of lowermost Tb4 basalt flow. Tb4-Tpf contact estimated at 820 ft bgs.
820–834	**PUYE FORMATION:** Basaltic clastic sediments—varicolored, medium gray (GLEY1 4/1) to light pinkish tan (5YR 7/4) coarse basalt gravel, siltstone/claystone and fine-grained sandstone. 820–825 ft WR/+10F: 100% chips of gray strongly vesicular basalt pebble clasts (up to 3.0 cm) exhibiting significant rounding/subrounding. 825–830 ft WR/+10F: predominantly angular chips phenocryst-poor basalt with minor fragments of siltone/claystone; +35F: 50% dark gray basalt and minor reddish basalt scoria/cinders; 40% fragments of siltsone/claystone; 10% indurated fine-grained volcanic sandstone. 830–834 ft WR/+10F: 85%–90% basalt chips and subrounded clasts; 10%–15% fragments of siltone/claystone; +35F: 50% dark gray basalt and minor reddish basalt scoria/cinders; 40% fragments of siltsone/claystone; 10% indurated fine-grained volcanic sandstone.	Tpf	Lower section of Puye Formation encountered from 820 to 915 ft bgs, estimated to be 95 ft thick. 820–834 ft predominance of basalt chips may be fragments of larger clasts that are subrounded to rounded (i.e., coarse gravels); possible soil or colluvial layer.
870–875	Contains trace rounded quartzite grains. 870–875 ft +10F: 60%–70% subrounded to rounded dacite clasts; 30%–40% fragments of indurated fine-grained sandstone; +35F: also minor basaltic glass, up to 5% quartzite and quartz crystal grains.		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-38		**TA** 74	**PAGE:** 15 of 15
DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
875–915	Quartzose volcaniclastic sediments—pinkish white (5YR 8/23) pebble- to coarse gravels with fine to coarse sand subrounded to rounded detritus composed of diverse volcanic lithologies and Precambrian quartzites and granitic rocks. 875–890 ft WR: abundant silt matrix. +10F: detritus subrounded to rounded; 60%–70% volcanic clasts (dacites, minor basalt); 15%–20% well-rounded quartzites (up to 15 mm) and minor granites, microcline feldspar; 10%–15% fine-grained volcanic sandstone fragments. 890–900 ft +10F: subrounded rounded detrital clasts composed of 80%–95% volcanic rocks (dacite, andesite); 15%–20% clasts (up to 2.0 cm) of Precambrian quartzites and granites. 900–915 ft +10F: 90%–95% subrounded to rounded detrital clasts (up to 2.3 cm) composed of dacites and rhyodacites; 5%–15% Precambrian quartzites and granitic clasts; up to 5% sandstone fragments.	Tpf	875–915 ft interpreted to be quartz-bearing axial river-gravel deposits. 900–915 ft frequency of Precambrian constituents diminishes downward. Note: R-38 borehole drilling concluded at a total depth of 915 ft bgs.

ABBREVIATIONS

5YR 8/1 = Munsell soil color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g.,1) 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.

bgs = below ground surface
cpx = clinopyroxene
ft = foot
GM = groundmass
ol = olivine
Qal = Quaternary Alluvium
Qbo = Otowi Member of Bandelier Tuff.
Qbog = Guaje Pumice Bed
Tb4 = Cerros del Rio basalt
Tpf = Puye Formation
Tmps = Miocene pumiceous sediments
Y = yellow
YR = yellow red
+10F = plus No. 10 sieve sample fraction
+35F = plus No. 35 sieve sample fraction