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Date: MAR 11 2011
Refer To: EP2011-0003

James 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 Completion Report for Regional Aquifer Well R-60

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the Completion Report for Regional Aquifer Well R-60.

If you have any questions, please contact Ted Ball at (505) 665-3996 (tedball@lanl.gov) or Woody Woodworth at (505) 665-5820 (lwoodworth@doeal.gov).

Sincerely,

B. G. Schappell

Bruce Schappell, Executive Director
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Sincerely,

for L. A. Trujillo

Everett Trollinger, Federal Project Director
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BS/ET/TB/ME:vt

Enclosures: Two hard copies with electronic files – Completion Report for Regional Aquifer Well R-60

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March 2011
EP2011-0003

Completion Report for Regional Aquifer Well R-60

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

EP2011-0003

Completion Report for Regional Aquifer Well R-60

March 2011

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EXECUTIVE SUMMARY

This well completion report describes borehole drilling, well installation, well development, aquifer testing, and dedicated sampling system installation for regional aquifer well R-60, located on the mesa at the head of Ten Site Canyon, Technical Area 50, at Los Alamos National Laboratory in Los Alamos County, New Mexico. This report was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005 (revised 2008), Compliance Order on Consent. The well was installed at the direction of the New Mexico Environment Department (NMED) to monitor groundwater quality in the regional aquifer downgradient of Material Disposal Area C at Los Alamos National Laboratory.

The R-60 monitoring well borehole was drilled between September 13 and 29, 2010, using dual-rotary air-drilling methods. Drilling fluid additives included potable water and foam. Foam-assisted drilling was used only in the vadose zone and ceased approximately 100 ft above the regional aquifer. The original R-60 borehole had to be abandoned because of stuck tooling at 887 ft below ground surface (bgs). The second R-60 borehole was successfully completed to a total depth of 1418 ft bgs using casing-advance and open-hole drilling methods.

The following stratigraphy was encountered during drilling of the R-60 borehole: surficial alluvium, Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, Tschicoma Formation, Puye Formation, and Miocene pumiceous sediments.

Well R-60 was completed with a single screen well with a 20-ft-long screened interval set from 1330 to 1350 ft bgs; the entire screen plus filter pack is within the lower portion of the Puye Formation encountered at R-60. The depth to water after well installation was 1319.5 ft bgs.

The well was completed in accordance with an NMED-approved final well design. It was thoroughly developed and the regional aquifer groundwater met target water-quality parameters. Hydrogeologic testing indicated the screened interval in monitoring well R-60 is poorly productive but will perform effectively enough to meet the planned objectives. A sampling system and water-level transducer have been placed in the well screen in the R-60 monitoring well, and groundwater sampling will be performed as part of the annual Interim Facility-Wide Groundwater Monitoring Plan.

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Acronyms and Abbreviations

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-14	Earth and Environmental Sciences Group 14
Eh	oxidation-reduction potential
EP	Environmental Programs
FD	field duplicate
FTB	field trip blank
F	filtered
gpd	gallons per day
gpm	gallons per minute
HE	high explosives
hp	horsepower
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MDA	material disposal area
NAD	North American Datum
NMED	New Mexico Environment Department
NMSW	New Mexico Special Waste
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
Qal	alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member of the Bandelier Tuff
Qct	Cerro Toledo interval
QP	quality procedure
RPF	Records Processing Facility
SVOC	semivolatile organic compound

TA	technical area
TD	total depth
TOC	total organic carbon
Tjfp	Miocene pumiceous sediments
Tpf	Puye Formation
Tt2	Tschicoma Formation dacitic lavas
U	unfiltered
VOC	volatile organic compound
WCSF	waste characterization strategy form
WES-EDA	Waste and Environmental Services Division–Environmental Data and Analysis
WR	whole rock
wt%	weight percent

1.0 INTRODUCTION

This completion report summarizes borehole drilling, logging, well construction, well development, aquifer testing, and dedicated sampling system installation for regional aquifer groundwater monitoring well R-60. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005 (revised 2008) Compliance Order on Consent (the Consent Order). The first R-60 borehole was abandoned because of stuck tooling at 887 feet (ft) below ground surface (bgs). The second successful R-60 monitoring well borehole was drilled from September 13 to 29, 2010, and the well was completed from October 6 to 18, 2010, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs Directorate.

The R-60 monitoring well is located on the mesa top at the head of Ten Site Canyon within the Laboratory's Technical Area 50 (TA-50) (Figure 1.0-1). R-60 was installed to provide hydrogeologic and groundwater data down gradient of Material Disposal Area (MDA) C (Figure 1.0-1).

The primary objective of the drilling activities at R-60 was to drill and install a single-screen regional aquifer monitoring well. Secondary objectives were to collect drill cuttings samples, conduct borehole geophysical and video logging, and investigate potential perched groundwater zones.

Drilling tools became stuck at approximately 887 ft bgs in the first borehole drilled for the R-60 monitoring well and the borehole was abandoned. The second R-60 borehole was drilled to a total depth (TD) of 1418 ft bgs. During drilling, cuttings samples were collected at 5-ft intervals in both boreholes. A monitoring well was installed with a single 20-ft-long screen set between 1330 and 1350 ft bgs. The depth to water after well installation was 1319.5 ft bgs on October 19, 2010.

Postinstallation activities included well development, aquifer testing, 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, logbooks, 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 with supporting figures, tables, and appendixes associated with the R-60 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 ADMINISTRATIVE PLANNING

The following Laboratory documents were prepared to guide activities associated with the drilling, installation, and sampling of regional aquifer well R-60:

- "Drilling Work Plan for Regional Aquifer Well R-60" Los Alamos National Laboratory document (LANL 2010, 109680)
- "Drilling Plan for Regional Aquifer Well R-60" (TerranearPMC 2010, 109963)
- "IWD [Integrated Work Document] for Drilling and Installation of MTOA Task Order #8 Well R-60 at LANL" (LANL 2010, 111812)
- "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan" (LANL 2006, 092600)

- "Waste Characterization Strategy Form, Amendment #2, Regional Well, MDA C, R-60" .(LANL 2011, 111800)

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-60.

3.1 Drilling Approach

The drilling method and selection of equipment and drill-casing sizes for the R-60 monitoring well were designed to retain the ability to investigate and case off potential perched groundwater zones above the regional aquifer, although perched water was not anticipated at this mesa-top site between relatively dry canyons. The approach also 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-60 borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. Casing-advance drilling is required where soft and poorly consolidated formation materials underlie the Laboratory. The Foremost DR-24HD drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, a deck-mounted air compressor, and general drilling equipment. Auxiliary equipment included two Ingersol-Rand trailer-mounted air compressors. Three sizes of A53 grade B flush-welded mild carbon-steel casing (18-in.-, 16-in.-, and 12-in.-inside diameter [I.D.]) were used for the R-60 project.

The dual-rotary technique at R-60 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 included potable water and a mixture of potable water with Baroid AQF-2 foaming agent. The foaming agent was not used below 1235 ft bgs, roughly 100 ft above the predicted top of the regional aquifer. The total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-60 Well

The drill pad was prepared by Laboratory personnel several weeks before mobilization of the drill rig, air compressors, trailers, and support vehicles to the drill site on July 9 and 10, 2010. Equipment and tooling were decontaminated before mobilization to the site. Alternative drilling tools and construction materials were staged at the Pajarito Road lay-down yard. Potable water used in drilling was obtained from a fire hydrant on Puye Road. Safety barriers and signs were installed around the borehole cuttings containment pit and along the perimeter of the work area.

On July 11, following on-site equipment inspections, the first R-60 monitoring well borehole was initiated at 1045 h using dual-rotary methods with 18-in. drill casing and a 17-in. tricone roller bit.

3.2.1 Drilling Activities at Original Borehole

Drilling and advancing 18-in. casing proceeded rapidly through surface alluvium and the upper portion of the Tshirege Member of the Bandelier Tuff to 200.5 ft bgs, where the casing was landed on July 15. No indications of groundwater were observed while the 18-in. casing was advanced.

On July 16, a string of 16-in. drill casing was started into the borehole. Drilling using dual-rotary methods with the 16-in. casing string and a 14.75-in. tricone bit started on July 18 at 200.5 ft bgs. Drilling progressed through the remaining portion of the Tshirege Member of the Bandelier Tuff and the Otowi Member ash flows to a depth of 478 ft bgs on July 24. No indications of groundwater were observed while the 16-in. casing was advanced.

Open-hole drilling with a 14.75-in. tricone bit commenced late in the day on July 25. Drilling progressed smoothly to the top of Tschicoma Formation dacitic lavas at a depth of 645 ft bgs on July 26. Open-hole drilling continued on July 27 with a 15-in. hammer bit and progressed through fractured dacitic lavas to 787 ft bgs, where cementing was required to stabilize the borehole. Cement was poured on July 30 from 656 to 786 ft bgs. Drilling in dacitic lavas resumed on August 2 after the cement was drilled out. The borehole was cemented again from 779 to 867 ft bgs on August 5. Drilling continued through the cemented interval and back into dacitic lavas on August 7 to a TD of 915 ft bgs. Unstable conditions in the borehole required cementing for a third time, from 789 to 906 ft bgs, on August 9.

On August 10, the 15-in. hammer bit was used to drill into the cement. At 1145 h, the drill rig lost circulation to a void in the cement, and the hammer bit became stuck in the borehole at approximately 887 ft bgs. Efforts to raise the tooling were unsuccessful. Between August 11 and 19, the borehole was cleared of slough above the stuck tooling, multiple video runs were made, but the tooling could not be removed. From August 20 to September 9, with assistance from an oilfield fishing specialist, surface and downhole jars were used during unsuccessful attempts to retrieve the stuck tooling. The decision was made to stop fishing, remove the fishing tools, and prepare to redrill a new borehole on September 9.

3.2.2 Drilling Activities at the Second R-60 Borehole

The second R-60 borehole was located approximately 50 ft west of the first borehole and was initiated at 1930 h on September 13. The drilling approach for the second borehole was to drill and ream out a pilot hole and then advance 16-in. casing into the fractured dacitic lavas to prevent cave in on the tooling. On September 13 and 14, a string of 18-in. casing was advanced to 107 ft bgs. Between September 14 and 18, a 14.75-in. pilot hole was drilled with a tricone bit to 674 ft bgs, 40 ft into the dacitic lavas and reamed with a 20.5-in.-O.D. hole-opening, tricone bit to 630 ft bgs. A string of 16-in. casing was advanced to 647 ft bgs on September 20. The dacitic lavas appeared far less fractured and oxidized than in the first borehole, and the decision was made to drill open-hole if the borehole remained stable.

A 15-in. hammer bit was used for open-hole drilling through the dacitic lavas below 647 ft bgs during the September 20 night shift. On September 21, unstable conditions in the borehole necessitated cementing from 826 to 877 ft bgs. The cement was drilled during the September 21 night shift, and fill was encountered at 867 ft bgs. Drilling continued to 885 ft bgs. On September 22, cement was again poured in the borehole from 814 to 883 ft bgs to further stabilize the borehole. The cement was drilled during the September 22 night shift, and open-hole drilling continued to 905 ft bgs, where unstable borehole conditions were again encountered and the tooling was removed from the borehole.

On September 23, the 16-in. casing shoe was cut at 636 ft bgs, and a 12-in. casing string was started into the borehole. Video, natural gamma, and induction logs were collected on September 24 in the open portion of the borehole between 646 and 901 ft bgs, and the 12-in. casing was advanced below 905 ft bgs with an underreaming hammer bit starting on September 26. Casing advance proceeded smoothly through the Puye Formation sediments, and the use of drilling foam was discontinued at 1235 ft bgs on September 28. The borehole was advanced to a TD of 1418 ft bgs on September 29 in Miocene pumiceous sediments. The 12-in. casing shoe was cut at 1401.4 ft bgs on October 4. No problems were encountered in the second R-60 borehole during 12-in. casing-advance drilling below the dacitic lavas.

During drilling, field crews worked two 12-h shifts each day, 7 d/wk. Drilling operations at R-60 encountered numerous difficulties and delays associated with stuck tooling in the first borehole caused by unstable fractured conditions in the dacite lavas.

3.2.3 Abandonment of original borehole

The Foremost DR-24HD drill rig was mobilized to the site of the original R-60 borehole on October 20 to begin borehole abandonment. The drill rods were removed from the stuck tooling on October 21, leaving approximately 19 ft of tooling and hammer bit in the borehole from approximately 868 to 887 ft bgs. The entire string of 18-in. casing was removed from the borehole on October 22. The 16-in. casing was cut on October 23 at 470 ft bgs, leaving the casing shoe and approximately 8 ft of 16-in. casing in the borehole. On October 24, 455 ft of 16-in. casing was removed from the borehole, leaving 15 ft of casing at the surface for pouring cement. On October 25, the original R-60 borehole was plugged from the top of the stuck tooling to the surface with 43 yd^3 of Portland cement sand grout.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-60. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Bulk cuttings samples were collected at 5-ft intervals in the abandoned R-60 borehole from ground surface to 900 ft bgs and in the final R-60 borehole from ground surface to the TD of 1418 ft bgs. At each interval, approximately 500 mL of bulk cuttings was collected by the site geologist from the drilling discharge cyclone, 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. Sieved chip tray samples for the 0 to 900 ft bgs interval were collected from the first borehole; sieved chip tray samples for the 900 to 1418 ft bgs interval were collected from the second borehole. Recovery of cuttings samples was close to 100% (10 ft of 1418 ft was unrecovered) from the second R-60 borehole. Radiation control technicians screened cuttings before they were removed 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 stratigraphy of R-60 is summarized in section 5.1 and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

One groundwater screening sample was collected on November 1, 2010, at the beginning of the second phase of well development and analyzed for anions and metals. The Laboratory’s Earth and Environmental Sciences Group 14 (EES-14) conducted the anion and metals analyses.

Five samples were collected during aquifer testing, and seven samples were collected during the second phase of well development from the pump’s discharge line for EES-14 analysis of total organic carbon (TOC) only. Table 4.2-1 presents a summary of screening samples collected from the completed R-60 well. The analytical results 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 organic compounds (VOCs) and semivolatile organic compounds (SVOCs); 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-60 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-60 is presented below. The Laboratory's geology task leader and project site geologists examined cuttings and geophysical logs to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, water-level measurements, and geophysical logs were used to characterize groundwater occurrences encountered at R-60.

5.1 Stratigraphy

Stratigraphic units for the R-60 borehole, drilled to a depth of 1418 ft bgs, are presented below in order of occurrence from youngest to oldest units. The stratigraphic descriptions from 0 to 645 ft bgs are based on samples collected from the first borehole, while the descriptions from 645 to 1418 ft bgs are from samples collected from the second R-60 borehole. Lithologic descriptions are based on binocular microscope analysis of drill cuttings samples collected from the discharge hose. Figure 5.1-1 shows the stratigraphy at R-60. A detailed lithologic log is presented in Appendix A.

Alluvium/Construction Fill, Qal (0–10 ft bgs)

Tuffaceous alluvium and fill consisting of mixed constituents, including abundant quartzite and rounded volcanic pebbles (typical of construction base-course gravel), were encountered from 0 to 10 ft bgs.

Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (10–100 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff was encountered from 10 to 100 ft bgs, as interpreted from the degree of welding and rate of penetration while drilling. Unit 3 is a poorly welded ash-flow tuff (i.e., ignimbrite) that is crystal-rich, generally slightly pumiceous and lithic-poor and exhibits a matrix of fine vitric ash. The observed degree of welding varies somewhat within the section and locally ranges from moderately to poorly welded. Drill cuttings from Unit 3 typically contain abundant quartz and sanidine phenocryts and minor tuff fragments.

Unit 2, Tshirege Member of the Bandelier Tuff, Qbt 2 (100–180 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff was intersected from 100 to 180 ft bgs and represents a moderately welded rhyolitic ash-flow tuff that is composed of abundant (up to 30% by volume) quartz and sanidine crystals, moderately compressed devitrified pumice lapilli, and minor volcanic lithic fragments set in a matrix of weathered ash. Cuttings typically contain abundant fragments of indurated tuff and numerous free quartz and sanidine crystals. The level of welding varies through the section from strongly welded, especially in the top 15 ft, to poorly welded.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (180–245 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff was encountered from 180 to 245 ft bgs. Unit 1v is a poorly to moderately welded rhyolitic ash-flow tuff that is pumiceous, generally lithic-poor and crystal-bearing to locally crystal-rich. Abundant ash matrix is locally preserved in cuttings. Cuttings commonly contain numerous fragments of indurated crystal-rich tuff with compressed, strongly devitrified pumice lapilli. Abundant free quartz and sanidine crystals and minor small (generally less than 10 mm in diameter) volcanic lithic inclusions also occur in cuttings.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (245–345 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was intersected in the R-60 borehole from 245 to 345 ft bgs. Unit 1g is a poorly welded rhyolitic ash-flow tuff that is strongly pumiceous, crystal-bearing, and lithic-poor. Unit 1g cuttings locally exhibit fragments of indurated tuff near the top of the section and a lack of tuff fragments below 255 ft, suggesting poor welding below that depth.

Cerro Toledo Interval, Qct (345–450 ft bgs)

The Cerro Toledo interval, a layer of poorly consolidated volcaniclastic sediments that occurs stratigraphically between the Tshirege and Otowi Members of the Bandelier Tuff, is believed to be present from 345 to 450 ft bgs. Locally, these sediments consist of poorly sorted pebble gravels with silty fine to coarse sands comprised of volcanic and tuffaceous debris. Commonly subrounded detrital clasts are composed of various (predominantly hornblende-phyric) dacites, flow-banded rhyolite, andesite, abundant vitric pumices, and quartz and sanidine crystals. At nearby borehole R-46, the Cerro Toledo interval was thought to be considerably thicker (185 ft), but pinpointing the contacts of the unit was based partly on natural gamma log interpretation. Since the gamma log is somewhat ambiguous through this interval and Otowi Member tuffs were observed below 450 ft, the lower contact of the Cerro Toledo interval at R-60 was placed at 450 ft bgs, and the thickness of the Cerro Toledo in the surrounding area may be subject to revision.

Otowi Member of the Bandelier Tuff, Qbo (450–622 ft bgs)

The Otowi Member of the Bandelier Tuff was present in the R-60 section from 450 to 622 ft bgs. The Otowi Member is a poorly welded rhyolitic ash-flow tuff that is pumiceous, crystal-bearing, and locally lithic-rich. Abundant pale orange to white pumice lapilli noted in cuttings are typically glassy, with quartz and sanidine phenocrysts. Locally abundant volcanic lithics occur in cuttings as subangular to subrounded fragments of intermediate composition, including porphyritic dacites and andesite. Cuttings locally exhibit abundant fine volcanic ash and numerous quartz and sanidine crystals.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (622–636 ft bgs)

The Guaje Pumice Bed occurred from 622 to 636 ft bgs. This pumice- and ash-fall tephra deposit forms the base of the Otowi Member. The unit contains abundant subrounded, lustrous, vitric, phenocryst-poor pumice lapilli with minor occurrences of small volcanic lithic fragments and quartz and sanidine crystals.

Tschicoma Formation Dacite Lava, Tt2 (636–880 bgs)

A thick section of generally massive, light gray dacite lava was encountered from 636 to 880 ft bgs. The dacites are generally aphanitic with rare phenocrysts of plagioclase and pyroxene. Dacite from the original borehole was highly fractured, strongly oxidized (up to 80% of chips), and posed difficult drilling conditions.

In contrast, the dacitic lava from the second R-60 borehole was more massive, less fractured and more competent with alternating intervals of weak and strong oxidation. It was highly fractured below 840 ft bgs and was strongly oxidized between 860 and 880 ft bgs. Rounded dacite clasts and traces of quartz and microcline were observed from 865 to 870 ft bgs, suggesting the base of the Tschicoma Formation dacitic lava could be at 865 ft bgs. The lithologic log in Appendix A provides more detail regarding possible interpretations of the base of the Tschicoma Formation dacite lava.

Puye Formation, Tpf (880–1393 ft bgs)

The Puye Formation volcaniclastic sediments consisted of poorly sorted to unsorted, moderately indurated, medium to coarse gravels, fine to coarse sand, and varying amounts of silt. Subangular to well-rounded detrital constituents throughout the typical Puye Formation section are predominantly composed of gray biotite- and/or hornblende-phyric dacites and glassy dacites, plus fewer fine-grained siliciclastic sediments, mostly quartzites. A section containing minor pale orange clay was observed from 930 to 955 ft bgs. Sediments are poorly sorted, are generally gravel-rich, and contain varying amounts of medium and fine sand and silt. Volcaniclastic fragments vary in oxidation, and relative proportions of various lithologies indicate changing source areas through the section.

Miocene Pumiceous Sediments, Tjfp (1393–1418 ft bgs)

A pumice-rich volcaniclastic section, referred to as Miocene pumiceous sediments, was intersected from 1393 ft bgs to the bottom of the R-60 borehole at 1418 ft bgs. This unassigned unit is locally interfingered with Puye Formation sediments. These sediments consist of fine to medium gravels with fine to coarse sands and are moderately to poorly sorted, are weakly cemented and contain detrital pumices and perlite clasts making up 40% of samples by volume.

5.2 Groundwater

Drilling proceeded without any groundwater indications until 1325 ft bgs in the Puye Formation, as indicated by the drilling crew. Water production was estimated at 7.5 gallons per minute (gpm) after drilling to 1325 ft bgs. The borehole was advanced to a TD of 1418 ft bgs, where the groundwater production rate was estimated at 30 gpm. Water levels stabilized at 1318.7 ft bgs on October 6, 2010, before well installation.

6.0 BOREHOLE LOGGING

Several video logs and several suites of geophysical logs were collected during the R-60 drilling project. A summary of video and geophysical logging runs is presented in Table 6.0-1. Video logging is included on a DVD in Appendix D of this report; geophysical logs are included on a CD in Appendix E of this report.

6.1 Video Logging

Laboratory video equipment was run from the surface in the original borehole on July 30, 2010, before the borehole was cemented above 787 ft bgs. Laboratory personnel stopped the camera at 660 ft bgs because the borehole walls were very rough. On August 5, an additional video log was made before cementing using the drilling subcontractor’s camera.

In the replacement R-60 borehole, a Laboratory video survey was run on September 24 from ground surface to 901 ft bgs to record the open borehole interval (646 to 901 ft bgs) before 12-in. casing was installed. The Laboratory camera was also used on October 5 to confirm the 12-in. casing had been cut at 1401.4 ft bgs.

A Laboratory video log was recorded within the well following aquifer testing on October 28 to show that the well screen was intact. Table 6.0-1 details the video logging runs.

6.2 Geophysical Logging

No geophysical logs were recorded in the original borehole. Natural gamma and induction logs were run in the second R-60 borehole on September 24, 2010, before 12-in. casing was installed. The natural gamma log was run from ground surface to 901 ft bgs, and the induction log was run from 646 to 901 ft bgs. A natural gamma log was run inside the 12-in. casing on September 30 from ground surface to 1405 ft bgs. A natural gamma log was run inside the well casing on October 28 from 1300 to 1350 ft bgs (the bottom of the well screen) to determine if the low water production rate observed in the well was from poor well construction. The gamma log indicated that the filter pack was installed correctly around the well screen and that the low production rate was caused by the low-yield aquifer. The geophysical logging is summarized in Table 6.0-1.

7.0 INSTALLATION OF R-60 MONITORING WELL

The R-60 well was installed between October 6 and 18, 2010.

7.1 Well Design

The R-60 well was designed in accordance with the approved drilling work plan and the final well design that was developed after TD was reached. NMED approved the final well design before well construction began (Appendix F). The well was designed with a single screen to monitor groundwater quality near the top of the regional aquifer within the Puye Formation sediments from 1330 to 1350 ft bgs.

7.2 Well Construction

The R-60 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 two (2) 10-ft lengths of 5.0-in.-I.D. rod-based 0.020-in. wire-wrapped screens to make up the 20-ft-long well screen interval. 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 screens were steam- and pressure-washed on-site before installation. A 2-in.-I.D. threaded steel tremie pipe (decontaminated before use) was utilized to deliver backfill and annular fill materials down-hole during well construction. Short lengths of 12-in. drill casing (15.6-ft casing and shoe from 1401.4 to 1417 ft bgs) and 16-in. drill casing (10.2-ft casing and shoe from 636 to 646.2 ft bgs) remain in the borehole. The 12-in. casing stub was encased in the lowermost bentonite backfill, while the 16-in. casing stub was encased in the upper bentonite seal.

A 10-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 2.0 ft above and below the screen. The stainless-steel well casing and screen were decontaminated on October 2, along with the mobilization of initial well construction materials to the site. A Pulstar work-over rig was used for well construction activities. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

On October 6, 2010, at 1540 h, the 5-in. stainless-steel well casing was started into the borehole. After setting the bottom of the well casing at 1360.9 ft bgs, the drill crew began to emplace annular fill materials on October 8. A lower seal composed of 3/8-in. bentonite chips (42.0 ft^3) was placed from 1404.2 to

1355.6 ft bgs, above slough at the bottom of the borehole. A 10/20 silica sand filter pack (30.5 ft^3) was installed from 1355.6 to 1325.2 ft bgs; the well was then surged to promote filter pack compaction. Approximately 40% more sand was used during construction than had been calculated, indicating the borehole diameter was slightly enlarged across this interval. A 20/40 silica sand transition collar (2.5 ft^3) was placed on top of the screen filter pack from 1322.2 to 1325.2 ft bgs.

Between October 9 and 17, the well's upper bentonite seal was installed from 1322.2 to 198.8 ft bgs using 1638.3 ft^3 of 3/8-in. bentonite chips. The final surface seal of neat Portland cement was placed above the upper bentonite seal from 198.8 to 3 ft bgs. The volume of cement used for the upper seal, 731.3 ft^3, exceeded the calculated volume of 377.7 ft^3 and is likely because cement infiltrated fractures in the Bandelier Tuff. Well construction was completed on October 18. Table 7.2-1 summarizes volumes of all materials used during well construction.

Operationally, well construction proceeded smoothly, 24 h/d, 7 d/wk.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation, the well was developed and aquifer pumping tests were conducted. The wellhead and surface pad were constructed, a geodetic survey was performed and a dedicated sampling system 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 19 and 22, 2010, and then was paused to allow aquifer testing to be conducted. Well development resumed on October 29 and continued to November 21. Initially, the screened interval was bailed and swabbed to remove formation fines in the filter pack and well sump. Bailing continued until water clarity visibly improved. Final development was then performed with a submersible pump.

The swabbing tool employed was a 4.5-in.-O.D., 1-in.-thick nylon disc attached to a weighted steel rod. The wireline-conveyed tool was repeatedly drawn across the screened interval, causing a surging action across the screen and filter pack. The bailing tool employed was a 4.0-in.-O.D. by 21-ft-long carbon-steel bailer with a total capacity of 12 gal. After bailing, a 5-horsepower (hp), 4-in. submersible pump was used for well development.

The screen was purged from top to bottom in 2-ft increments from 1330 to 1350 ft bgs. Then the pump intake was lowered to 1355 ft bgs for additional pumping. Well development continued on October 29 after aquifer testing was completed. The screen was swabbed again and additional groundwater was removed with the bailing tool. The submersible development pump was then used to complete well development between October 30 and November 21.

Total Volumes of Water Introduced and Purged in the Regional Aquifer

Approximately 8000 gal. of potable water was used during borehole drilling below the regional aquifer water table. Approximately 10,200 gal. of water was used below the water table during well construction, for a total introduced volume of 18,200 gal.

Of this total volume of water used below the water table, approximately 1200 gal. was used during drilling from 1356 to 1325 ft bgs, the eventual filter pack interval in the completed well. During well installation, approximately 5000 gal. was used to install the filter pack across the screened interval. Total potable water used between 1356 and 1325 ft bgs, the filter pack interval of the completed well, was approximately 6200 gal.

Approximately 17,257 gal. of groundwater was purged at R-60 during well development activities. Another 943 gal. was purged during aquifer testing. Total groundwater purged during postinstallation activities was 18,200 gal.

8.1.1 Well Development Field Parameters

Field parameters were measured at well R-60 by collecting aliquots of groundwater from the discharge pipe with a flow-through cell. Water quality parameters of pH, temperature, specific conductivity, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity were measured during well development and aquifer testing. The final parameters at the end of well development were pH of 7.60, temperature of 24.05°C, specific conductance of 136 µS/cm, and turbidity of 0.8 nephelometric turbidity units.

Appendix B presents a summary of the field parameters measured during well development and aquifer testing. Table B-2.3-1 in Appendix B presents all field parameters and purge volumes from well development and aquifer testing. Figure B-2.3-1 shows a graph with the field parameters measured over the course of well development and aquifer testing.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-60 between October 23 and 27, 2010. A 24-h constant rate pump test was performed on October 26. A 5-hp pump was used for the aquifer test. The pump rate was set to approximately 0.57 gpm, and approximately 943.1 gal. of groundwater was purged from the well. A 24-h recovery period followed the 24-h pump test.

Turbidity, temperature, pH, DO, ORP, and specific conductance parameters were measured during the 24-h test. Field parameters are summarized in Appendix B and detailed in Table B-2.3-1 of Appendix B. The results of the R-60 aquifer test are presented in Appendix C.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-60 was installed on December 3 and 4, 2010. The pumping system utilizes an environmentally retrofitted 4-in. 5-hp Grundfos submersible pump set near the bottom of the screened interval. Because the top of the water table is within the well screen, the pump was set within the screened interval inside a stainless-steel pump shroud; the bottom of the shroud is set at 1349.6 ft bgs. The pump column is constructed of 1 in. threaded/coupled passivated stainless-steel pipe. A weep valve was installed at the bottom of the uppermost pipe joint to protect the pump column from freezing. To measure water levels in the well, two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) pipes are installed to sufficient depth to set a dedicated transducer and to provide access for manual water-level measurements. The PVC transducer tubes are equipped with 6-in. sections of 0.010 in. slot screen with a threaded end cap on the bottom of each tube. An In-Situ Level Troll 500 30 pounds per square inch gage transducer is installed in one of the PVC tubes to monitor the water level in the screened interval.

Sampling system details for R-60 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for the well.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-60 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, are set at the outside edges of the pad to protect the well from traffic. The 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 December 16, 2010 (Table 8.5-1). The survey data 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 relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevations are expressed in feet 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 marker in the concrete pad, the top of the stainless-steel well casing, and the top of the protective casing for the R-60 monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-60 project included drilling fluids, drilled-out concrete chips and concrete slurry, drill cuttings, development water, decontamination water, municipal solid waste, petroleum contaminated soils, and contact waste. A summary of the waste characterization samples collected during drilling, construction and development of the R-60 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, Amendment #2, Regional Well, MDA C, R-60" (LANL 2010, 111800).

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 ENV-RCRA-QP-10.1, Land Application of Groundwater. If it is determined drilling fluids are nonhazardous but cannot meet the criteria for land application, they will be evaluated for treatment and disposal at one of the Laboratory's wastewater treatment facilities. If analytical data indicate 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-QP-11.1, 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 equipment was 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 procedures, 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-60 were performed as specified in "Drilling Plan for Regional Aquifer Well R-60" (TerranearPMC 2010, 109963). The first R-60 borehole was abandoned after the hammer bit became stuck around 887 ft bgs and could not be removed from the borehole. The second R-60 borehole was drilled successfully to 1418 ft bgs.

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-60 monitoring well.

David C. Schafer designed, implemented and analyzed the aquifer tests.

LANL personnel ran downhole video and geophysical logging equipment.

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

11.0 REFERENCES AND MAP DATA SOURCES

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 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.

11.1 References

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), June 2010. "Drilling Work Plan for Regional Aquifer Well R-60," Los Alamos National Laboratory document LA-UR-10-3537, Los Alamos, New Mexico. (LANL 2010, 109680)

LANL (Los Alamos National Laboratory), June 30, 2010. "IWD [Integrated Work Document] for Drilling and Installation of MTOA Task Order #8 Well R-60 at LANL," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2010, 111812)

LANL (Los Alamos National Laboratory), February 28, 2011. "Waste Characterization Strategy Form, Amendment #2, Regional Well, MDA C, R-60," EP2011-0036, Los Alamos, New Mexico. (LANL 2011, 111800)

TerranearPMC, June 2010. "Drilling Plan for Regional Aquifer Well R-60," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2010, 109963)

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; December 2010.

Hypsography, 100 and 20 Foot 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 & Project Initiation Group, Infrastructure Planning Division; September 2009.

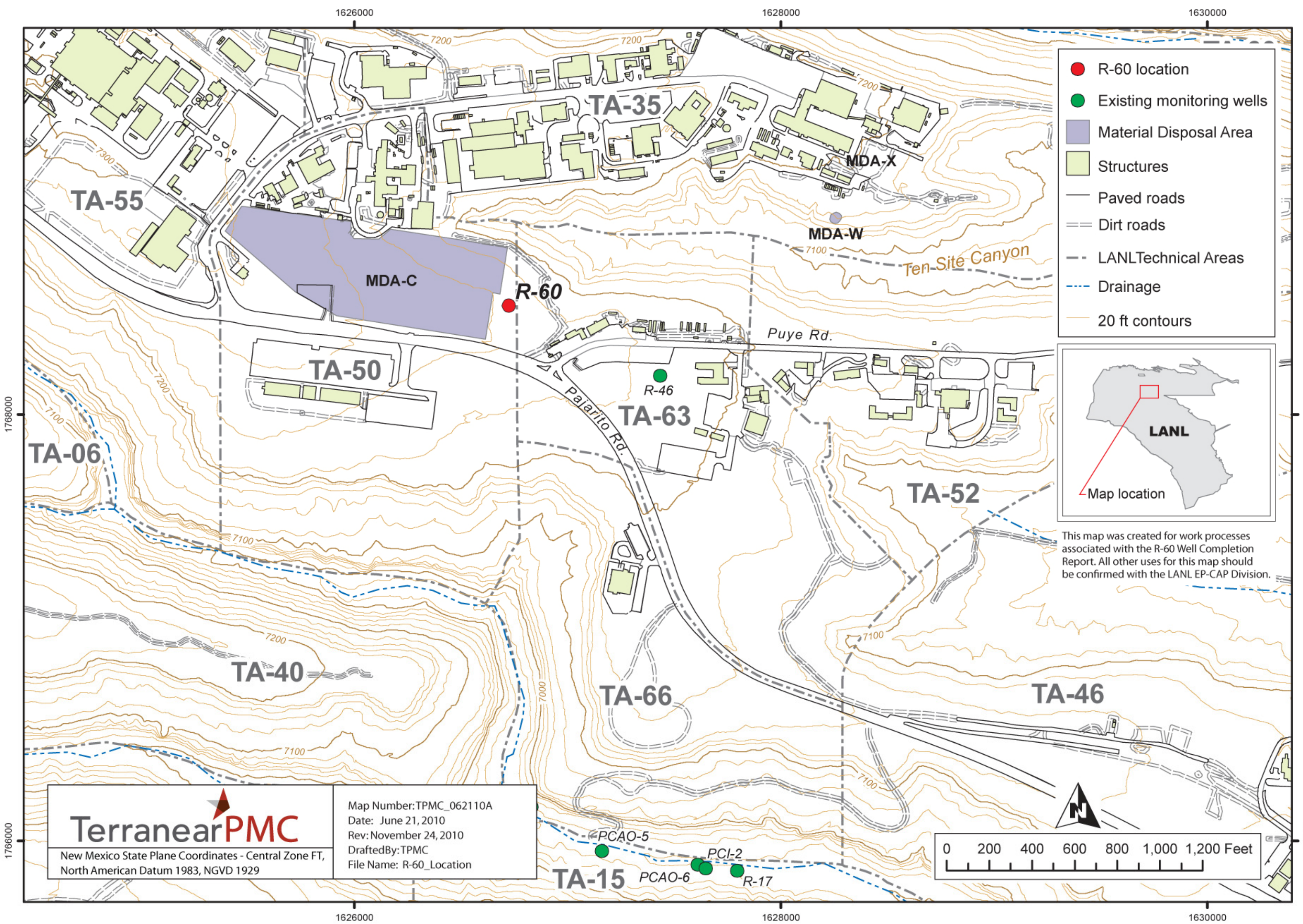

Figure 1.0-1 Location of regional monitoring well R-60

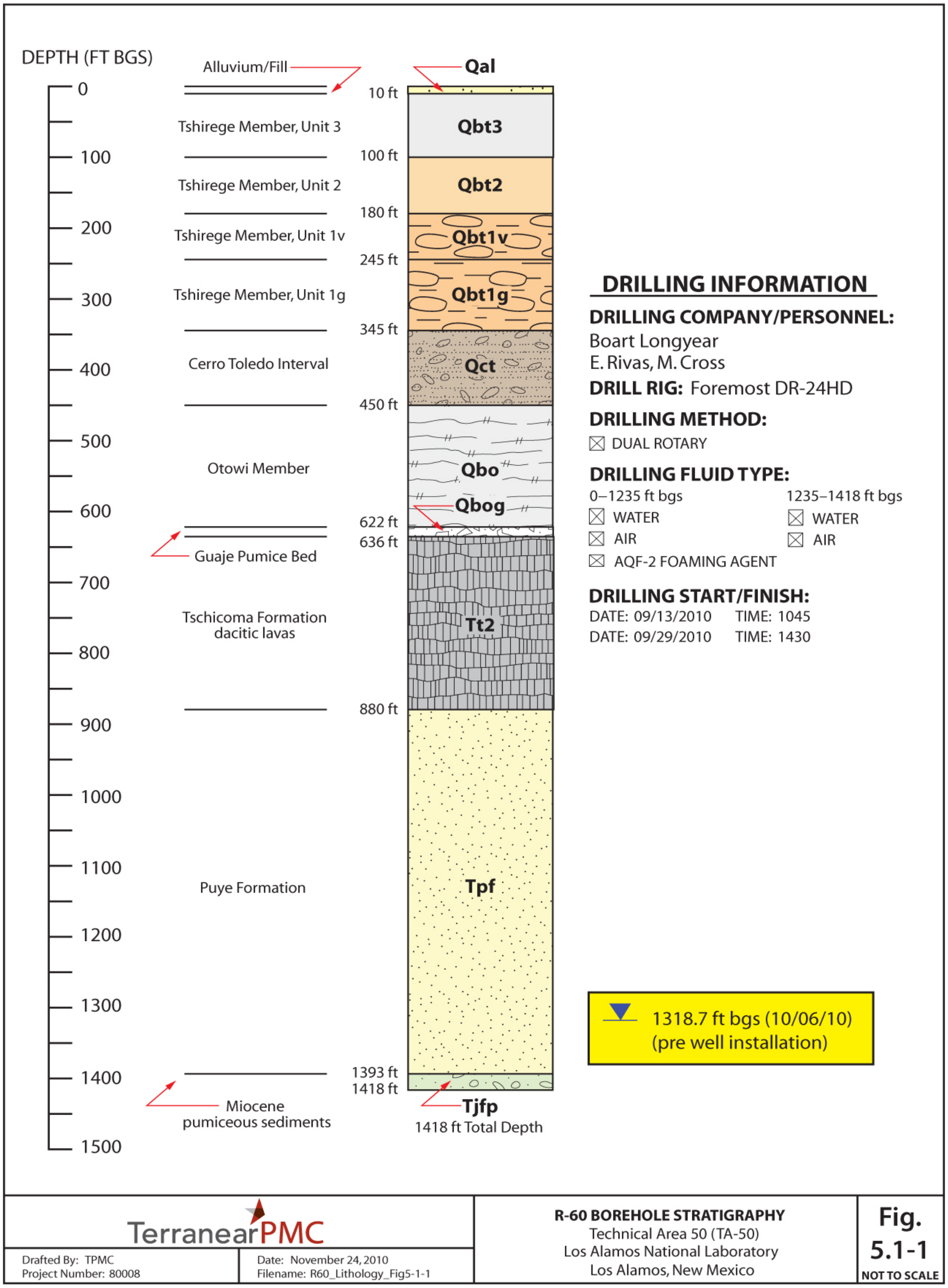

Figure 5.1-1 Regional monitoring well R-60 borehole stratigraphy

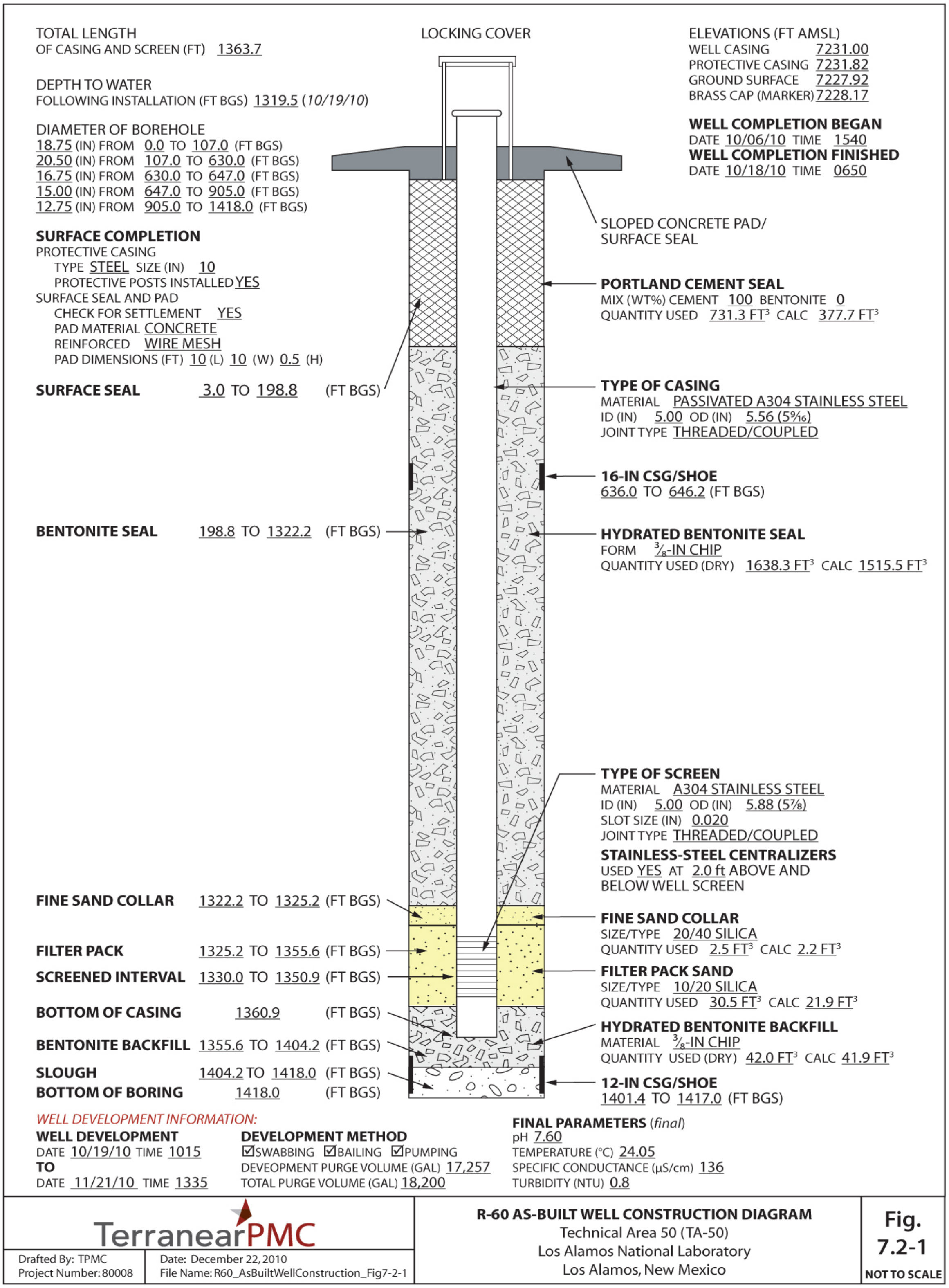

Figure 7.2-1 Regional monitoring well R-60 as-built well construction diagram

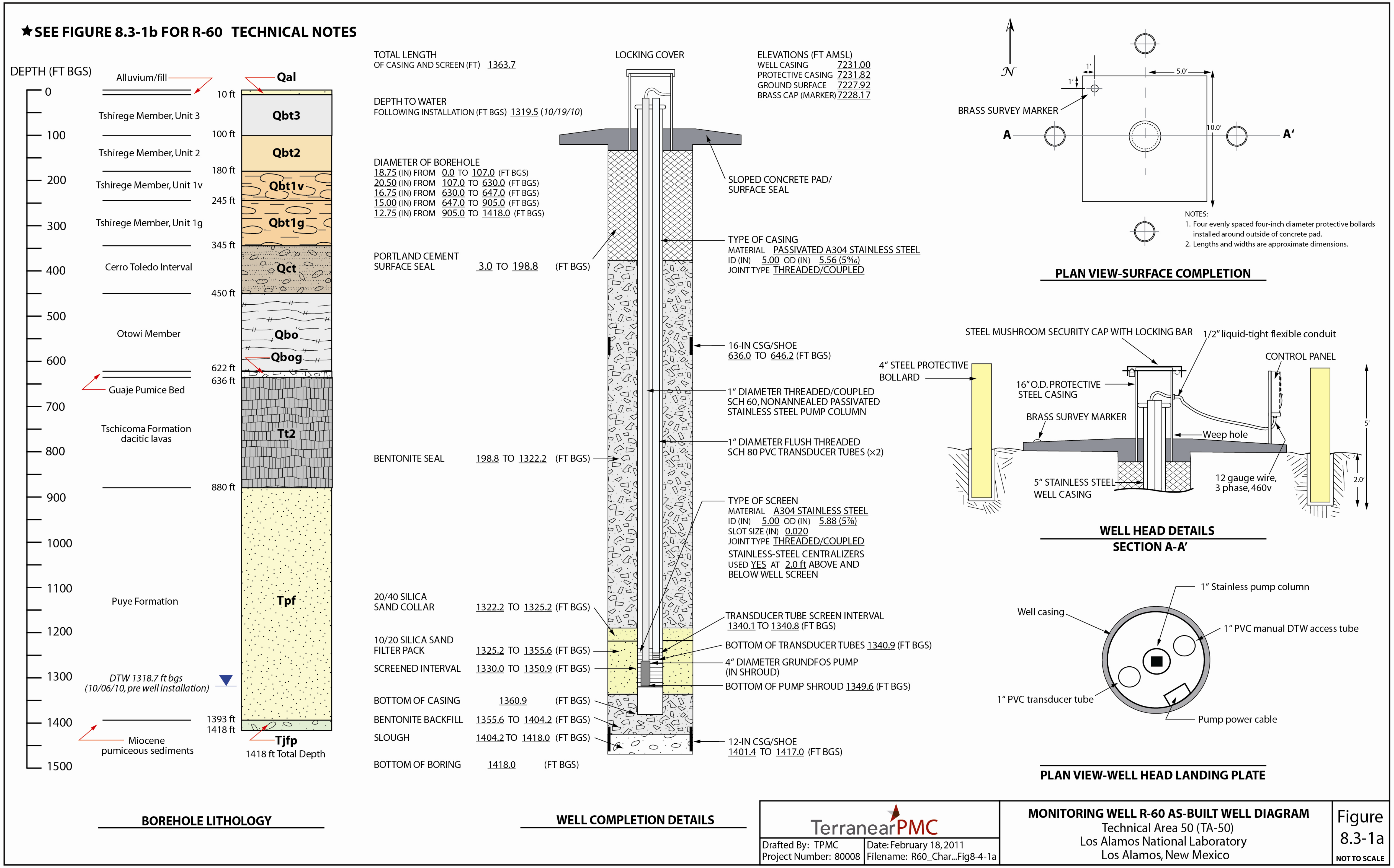

Figure 8.3-1a As-built schematic for regional monitoring well R-60

R-60 TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker
Northing: 1768514.75 ft
Easting: 1626734.38 ft
Elevation: 7228.17 ft AMSL

Well Casing (top of stainless steel)
Northing: 1768509.82 ft
Easting: 1626736.74 ft
Elevation: 7231.00 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

LANL: video (×3), natural gamma ray (×2), induction

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual Rotary
Fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF-2 Foam (to 1235 ft bgs)

MILESTONE DATES

Drilling
Start: 09/13/2010
Finished: 09/29/2010

Well Completion
Start: 10/06/2010
Finished: 10/18/2010

Well Development
Start: 10/19/2010
Finished: 11/21/2010

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 17,257 gal

Parameter Measurments (Final)
pH: 7.60
Temperature: 24.05°C
Specific Conductance: 136 µS/cm
Turbidity: 0.8 NTU

AQUIFER TESTING

Constant Rate Pumping Test
Water Produced: 943 gal.
Average Flow Rate: 0.6 gpm
Performed on: 10/23–27/2010

DEDICATED SAMPLING SYSTEM

Pump (Shrouded)
Make: Grundfos
Model: 10S50-1125CBM
S/N: B96845912-P11041366
10 U.S. gpm
Bottom pump shroud: 1349.6 ft bgs
Environmental retrofit

Motor
Make: Franklin Electric
S/N: 10K14-06-00695C
5 hp, 3-phase

Pump Column
1-in. threaded/coupled schd. 60, ASTM pickled and passivated A312 stainless steel tubing

Transducer Tubes
2 × 1-in. flush threaded schd. 80 PVC tubing
0.01-in. slot screen at 1340.1–1340.8 ft bgs

Transducer
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/N: 177876

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

TerranearPMC
Drafted By: TPMC
Project Number: 80008
Date: March 4, 2011
Filename: R60_TechnicalNotes_Fig8-3-1b

R-60 TECHNICAL NOTES
Technical Area 50 (TA-50)
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure 8.3-1b
NOT TO SCALE

Figure 8.3-1b As-built technical notes for regional monitoring well R-60

Table 3.1-1
Fluid Quantities Used during R-60 Drilling and Well Construction

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling					
9/13/10	0–85	1500	1500	0	0
9/14/10	85–537	4850	6350	25	25
9/15/10	537–674	8500	14,850	33	58
9/16/10	Ream 324–644	4000	18,850	50	108
9/17/10	Ream 112–580	5200	24,050	30	138
9/18/10	Ream 580–630	1000	25,050	10	148
9/19/10	Ream 537–595	1200	26,250	8	156
9/20/10	595–860	4500	30,750	30	186
9/21/10	860–885	4500	35,250	30	216
9/22/10	885–905	4200	39,250	20	236
9/26/10	905–1024	2800	42,050	30	266
9/27/10	1024–1218	7000	49,050	95	361
9/28/10	1218–1369[a]	5800	54,850	5	366
9/29/10	1369–1418	0	54,850	0	366
10/5/10	Cut casing	3000	57,850	n/a[b]	n/a
Well Construction					
10/8/10	1404–1344	5200	5200	n/a	n/a
10/9/10	1344–1309	5000	10,200	n/a	n/a
10/10/10	1309–1245	4800	15,000	n/a	n/a
10/11/10	1245–1140	9000	24,000	n/a	n/a
10/12/10	1140–998	10,500	34,500	n/a	n/a
10/13/10	998–800	1600	36,100	n/a	n/a
10/14/10	800–668	750	36,850	n/a	n/a
10/15/10	668–428	2000	38,850	n/a	n/a
10/16/10	428–199	5000	43,850	n/a	n/a
10/17/10	199-3	2600	46,450	n/a	n/a
10/18/10	Top off cement to 3 ft bgs.	36	46,486	n/a	n/a
Total Water Volume (gal.)					
R-60	**104,336**				

[a] Foam use terminated at approximately 1235 ft bgs.
[b] n/a = Not applicable.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Well Development and Aquifer Testing of Well R-60

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Development					
R-60	GW60-10-24563	10/22/2010	1352.00	Groundwater, pumped	TOC
R-60	GW60-10-24557	11/1/2010	1353.72	Groundwater, pumped	Anions, metals
R-60	GW60-10-24569	11/1/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24570	11/2/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24571	11/3/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24572	11/4/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24573	11/6/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24574	11/7/2010	1353.72	Groundwater, pumped	TOC
Aquifer Testing					
R-60	GW60-10-24564	10/26/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24565	10/26/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24566	10/27/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24567	10/27/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24568	10/27/2010	1338.46	Groundwater, pumped	TOC

Table 6.0-1
R-60 Video and Geophysical Logging Runs

Date	Type	Depth (ft bgs)	Description
First R-60 Borehole			
7/30/10	Video	0–660	LANL personnel ran a video log before cementing the borehole above 787ft. The camera was removed at 660 ft bgs due to rough borehole walls. Video shows open hole between 478 and 660 ft bgs.
8/5/10	Video	0–867	Drilling subcontractor ran video log before cementing.
Final R-60 Borehole and Completed Well			
9/24/10	Video, natural gamma, induction	0–901	LANL personnel ran video and induction logs in the open portion of the borehole (646 to 901 ft bgs) before hanging 12-in. casing. Natural gamma log was run from 0 to 901 ft bgs.
9/30/10	Natural gamma	0–1405	LANL personnel ran a natural gamma log inside the 12-in. casing to 1405 ft bgs after TD was reached.
10/5/10	Video	0–1401.4	LANL personnel ran a video to confirm the 12-in. casing had been cut at 1401.4 ft bgs.
10/28/10	Natural gamma, video	1300–1350	Natural gamma and video logs were run in the completed well after aquifer testing to confirm the well screen was installed properly and that the filter pack was still in place.

Table 7.2-1
R-60 Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: cement slurry	731.3 ft^3
Upper bentonite seal: bentonite chips	1638.3 ft^3
Fine sand collar: 20/40 silica sand	2.5 ft^3
Filter pack: 10/20 silica sand	30.5 ft^3
Backfill: bentonite chips	42.0 ft^3

Table 8.5-1
R-60 Survey Coordinates

Identification	Northing	Easting	Elevation
R-60 brass cap embedded in pad	1768514.75	1626734.38	7228.17
R-60 ground surface near pad	1768512.61	1626731.65	7227.92
R-60 top of 10-in. protective casing	1768509.80	1626736.72	7231.82
R-60 top of stainless-steel well casing	1768509.82	1626736.74	7231.00

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-60

Location ID	Sample ID	Date Collected	Description	Sample Type
R-60	WST60-10-23981(VOCs and SVOCs)	7/12/2010	Drill cuttings	Solid
R-60	WST60-10-23984(FTB)	7/12/2010	Drill cuttings	Solid
R-60	WST60-10-25002	8/23/2010	NMSW	Solid
R-60	WST60-10-25000(FTB)	8/23/2010	NMSW	Solid
R-60	WST60-10-26077(UF)	9/14/2010	Drill rig decon water	Liquid
R-60	WST60-10-26076(F)	9/14/2010	Drill rig decon water	Liquid
R-60	WST60-10-26078(FD)	9/14/2010	Drill rig decon water	Liquid
R-60	WST60-10-26079(FTB)	9/14/2010	Drill rig decon water	Liquid
R-60	WST60-10-23982(VOCs and SVOCs)	9/18/2010	Drill cuttings	Solid
R-60	WST60-10-23985(FTB)	9/18/2010	Drill cuttings	Solid
R-60	WST60-10-23983(VOCs and SVOCs)	9/29/2010	Drill cuttings	Solid
R-60	WST60-10-23986(FTB)	9/29/2010	Drill cuttings	Solid
R-60	WST60-10-26082(UF)	10/8/2010	Well casing decon water	Liquid
R-60	WST60-10-26081(F)	10/8/2010	Well casing decon water	Liquid
R-60	WST60-10-26080(FD)	10/8/2010	Well casing decon water	Liquid
R-60	WST60-10-26083(FTB)	10/8/2010	Well casing decon water	Liquid
R-60	WST60-10-26092	10/8/2010	Drill cuttings	Solid

Table 8.6-1 (continued)

Location ID	Sample ID	Date Collected	Description	Sample Type
R-60	WST60-10-26093(FTB)	10/8/2010	Drill cuttings	Solid
R-60	WST60-10-26086(UF)	10/27/2010	Drill rods decon water (w/ HE)	Liquid
R-60	WST60-10-26085(F)	10/27/2010	Drill rods decon water (w/ HE)	Liquid
R-60	WST60-10-26084(FD)	10/27/2010	Drill rods decon water (w/ HE)	Liquid
R-60	WST60-10-26087(FTB)	10/27/2010	Drill rods decon water (w/ HE)	Liquid
R-60	WST60-10-26090(UF)	10/28/2010	Downhole equip. decon water	Liquid
R-60	WST60-10-26089(F)	10/28/2010	Downhole equip. decon water	Liquid
R-60	WST60-10-26088(FD)	10/28/2010	Downhole equip. decon water	Liquid
R-60	WST60-10-26091(FTB)	10/28/2010	Downhole equip. decon water	Liquid
R-60	WST60-10-26072(UF)	11/1/2010	Development water	Liquid
R-60	WST60-10-260071(F)	11/1/2010	Development water	Liquid
R-60	WST60-10-26073(FD)	11/1/2010	Development water	Liquid
R-60	WST60-10-26074(FTB)	11/1/2010	Development water	Liquid
R-60	WST60-11-1386	11/3/2010	Last use of drill rig at R-60 decon water	Liquid
R-60	WST60-11-1293(UF)	11/4/2010	Drill fluids—south pit	Liquid
R-60	WST60-11-1292(F)	11/4/2010	Drill fluids—south pit	Liquid
R-60	WST60-11-1294(FD)	11/4/2010	Drill fluids—south pit	Liquid
R-60	WST60-11-1295(FTB)	11/4/2010	Drill fluids—south pit	Liquid
R-60	WST60-10-26068(UF)	11/4/2010	Drill fluids—north pit	Liquid
R-60	WST60-10-26067(F)	11/4/2010	Drill fluids—north pit	Liquid
R-60	WST60-10-26069(FD)	11/4/2010	Drill fluids—north pit	Liquid
R-60	WST60-10-26070(FTB)	11/4/2010	Drill fluids—north pit	Liquid
R-60	WST60-10-25003	11/12/2010	NMSW	Solid
R-60	WST60-10-25001(FTB)	11/12/2010	NMSW	Solid

Notes: F = Filtered sample, FD = field duplicate, FTB = field trip blank, HE = high explosives, NMSW = New Mexico Special Waste, UF = unfiltered sample.

Appendix A

Borehole R-60 Lithologic Log

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 1 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
0–10	**ALLUVIUM/FILL:** Construction fill and tuffaceous sediments—quartz and quartzite-rich, unconsolidated, silty, fine to coarse sand with quartzite, granite, and volcanic pebble gravels. Note: presence of quartzite and granite in this interval indicates material imported for drill pad construction.	Qal	Note: Descriptions for 0–645 ft bgs are from samples from the first abandoned R-60 borehole. Descriptions for the 645–1418 ft bgs interval are from the final R-60 borehole, approximately 50 ft west of the first borehole. Quaternary alluvial sediments, from 0 to 10 ft bgs, are estimated to be 10 ft thick. Qal–Qbt3 contact is placed at 10 ft bgs based on lack of tuff in cuttings above 10 ft bgs.
10–35	**UNIT 3, TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff—Pale yellowish brown (10YR 7/2), weathered crystal-rich tuff, moderately welded. 10'-35' +10F: fragments of crystal-rich tuff, free quartz and sanidine crystals, few lithic fragments, few pieces of construction fill; +35F 99% quartz and sanidine crystals, 1% lithic fragments, rare chert or quartzite grain from construction fill.	Qbt 3	Unit 3, Tshirege Member of the Bandelier Tuff, encountered from 10–100 ft bgs, is estimated to be 90 ft thick.
35–50	Tuff—Pale yellowish brown (10YR 7/2), weathered crystal-rich tuff, moderately welded with clasts of porphyritic andesite and dacite. 35'–50' +10F: 90–95% welded tuff fragments, phenocrysts (20–30% by volume) of quartz and sanidine, minor pumice and lithics, matrix of fine ash; 5–10% volcanic lithic fragments (up to 10 mm in diameter) composed of varieties of porphyritic andesite, 2–3% coarse quartz and sanidine crystals, few pieces of construction fill; +35F: 90–95% quartz and sanidine crystals, 5–10% fragments of welded tuff, 2–3% volcanic lithics.	Qbt 3	

Borehole Identification (ID): R-60	Technical Area (TA): 50		Page: 2 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
50–95	Tuff—Poorly welded crystal-rich tuff. 50'–95' WR/+10F: 75–85% quartz and minor sanidine crystals with light gray silty ash on unwashed samples, 15–25% dacite lithics, minor crystal-rich tuff fragments. Volcanic lithics increase with depth to 95'. +35F: 95–99% quartz and sanidine crystals, 1–5% andesite and altered dacite fragments.	Qbt 3	
95–100	Tuff—Poorly welded crystal-rich tuff. 95'–100' WR/+10F: 85–90% quartz and minor sanidine crystals with light gray silty ash on unwashed samples, 5–10% andesite/dacite lithics, 5–10% crystal-rich tuff fragments. +35F: 95–99% quartz and sanidine crystals, 1–5% andesite and altered dacite fragments.	Qbt 3	Qbt 3–Qbt 2 contact is placed at 100 ft bgs based on drillers' observation of slower penetration rate and the first appearance of oxidized, reddish tuff below 100 ft bgs.
100–115	**UNIT 2, TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff—Poorly welded crystal-rich tuff. 100'–115' WR/+10F: 85–90% quartz and minor sanidine crystals with light gray silty ash on unwashed samples, 5–10% andesite/dacite lithics, 5–10% crystal-rich tuff fragments. +35F: 95–99% quartz and sanidine crystals, 1–5% andesite and altered dacite fragments.	Qbt 2	Unit 2, Tshirege Member of the Bandelier Tuff, encountered from 100 to 180 ft bgs, is estimated to be 80 ft thick.
115–140	Tuff—Pale yellowish brown (10YR 7/2), moderately welded tuff, crystal-rich, lithic-bearing, pumice-poor. 115'–140' +10F: 60–70% welded tuff fragments, with phenocrysts of quartz and sanidine and lithic clasts in a friable matrix of fine ash; 10–15% coarse quartz and sanidine crystals, 5–10% volcanic lithic fragments including a variety of lithologies (gray porphyritic dacites, brown andesite, flow-banded rhyodacite). +35F: 55–65% quartz and sanidine crystals, 30–40% welded tuff fragments, <5% volcanic lithic fragments.	Qbt 2	

<table>
<tr><td colspan="2">Borehole Identification (ID): R-60</td><td colspan="2">Technical Area (TA): 50</td><td>Page: 3 of 20</td></tr>
<tr><td colspan="2">Drilling Company: Boart Longyear Company</td><td colspan="2">Start Date/Time: 9/13/10: 1930</td><td>End Date/Time: 9/29/10: 1430</td></tr>
<tr><td colspan="2">Drilling Method: Dual Rotary</td><td colspan="2">Machine: Foremost DR24 HD</td><td>Sampling Method: Grab</td></tr>
<tr><td colspan="4">GROUND ELEVATION: 7227.92 ft amsl</td><td>Total Depth: 1418 ft bgs</td></tr>
<tr><td colspan="2">DRILLERS: E. Rivas, M. Cross</td><td colspan="3">Site Geologists: T. Naibert, M. Jojola</td></tr>
<tr><td>Depth (ft bgs)</td><td colspan="2">Lithologic description</td><td>Lithologic Symbol</td><td>Notes</td></tr>
<tr><td>140–180</td><td colspan="2">Tuff—Pale yellowish brown (10YR 7/2), moderately welded tuff, crystal-rich, lithic-bearing, pumice-poor.
140’–180’ WR/+10F: 65–75% welded tuff fragments, with phenocrysts of quartz and sanidine and lithic clasts in a friable matrix of fine ash; 15–25% coarse quartz and sanidine crystals, 0–5% volcanic lithic fragments including a variety of lithologies (gray porphyritic dacites, brown andesite, flow-banded rhyodacite); +35F: 70–80% quartz and sanidine crystals, 15–20% welded tuff fragments, <5% volcanic lithic fragments.</td><td>Qbt 2</td><td>Qbt 2–Qbt 1v contact is placed at 180 ft bgs based on natural gamma log geophysical data.</td></tr>
<tr><td>180–185</td><td colspan="2">UNIT 1v, TSHIREGE MEMBER OF THE BANDELIER TUFF:
Tuff— Pale yellowish brown (10YR 7/2), moderately welded tuff, crystal-rich, lithic-bearing, pumice-poor.
180’–185’ +10F: 65–75% free quartz and sanidine crystals, 25–30% welded tuff fragments, with phenocrysts of quartz and sanidine and lithic clasts in a friable matrix of fine ash; <5% lithic fragments. +35F: 95–98% quartz and sanidine crystals, 1–3% fragments of moderately welded tuff, 1–3% lithic fragments.</td><td>Qbt 1v</td><td>Unit 1v, Tshirege Member of the Bandelier Tuff, encountered from 180–245 ft bgs, is estimated to be 65 ft thick.</td></tr>
<tr><td>185–190</td><td colspan="2">Tuff—Pale yellowish brown (10YR 7/2), moderately welded tuff, crystal-rich, lithic-bearing, pumice-poor.
185’–190’ +10F: 65–75% volcanic lithic fragments of various lithologies (andesite, banded rhyolite, dacite), 15–20% quartz crystals, 5–10% welded tuff fragments. +35F: 95–98% quartz and sanidine crystals, 1–3% fragments of moderately welded tuff, 1–3% lithic fragments.</td><td>Qbt 1v</td><td></td></tr>
</table>

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 4 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
190–195	Tuff—Pale yellowish brown (10YR 7/2), moderately welded tuff, crystal-rich, lithic-bearing, pumice-poor. 190’–195’ +10F: 65–75% free quartz and sanidine crystals, 25–30% welded tuff fragments, with phenocrysts of quartz and sanidine and lithic clasts in a friable matrix of fine ash; <5% lithic fragments. +35F: 95–98% quartz and sanidine crystals, 1–3% fragments of moderately welded tuff, 1–3% lithic fragments.	Qbt 1v	
195–205	Tuff—Poorly welded crystal-rich tuff. 195’–205’ WR/+10F:80–90% free quartz and sanidine crystals, 5–15% volcanic lithic fragments, 5–10% welded tuff fragments; +35F: 98–99% quartz and sanidine crystals, 1–2% volcanic lithic fragments.	Qbt 1v	
205–220	Tuff—Light gray (N7) crystal-rich poorly welded tuff 205’–215’ +10F: 40–65% fragments (up to 20 mm) of welded tuff composed of phenocrysts (15–25% by volume) of quartz and sanidine, plus minor dacite lithics in a matrix of fine volcanic ash, 35–55% quartz and sanidine crystals, 5% volcanic lithics; +35F: 98–99% quartz and sanidine crystals, 1–2% volcanic lithic fragments. 215’–220’ +10F: 80–90% quartz and sanidine crystals, 5–20% volcanic lithics, <5% welded tuff fragments; +35F: 98–99% quartz and sanidine crystals, 1–2% volcanic lithic fragments.	Qbt 1v	

Borehole Identification (ID): R-60	Technical Area (TA): 50		Page: 5 of 20
Drilling Company: Boart Longyear Company	Start Date/Time: 9/13/10: 1930		End Date/Time: 9/29/10: 1430
Drilling Method: Dual Rotary	Machine: Foremost DR24 HD		Sampling Method: Grab
GROUND ELEVATION: 7227.92 ft amsl			Total Depth: 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	Site Geologists: T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
220–230	Tuff—Light gray (N7), indurated tuff, crystal-rich, weakly pumiceous; grayish brown (5YR 3/2) dacitic fragments. 220'–230' +10F: 60–65% indurated fragments of crystal-rich tuff with phenocrysts (20–30% by volume) of quartz and sanidine, minor small devitrified pumices; rare volcanic lithics set in a matrix of granular (i.e., devitrified) volcanic ash; 25–30% angular volcanic lithics (light gray porphyritic dacites and grayish brown aphanitic dacites), 5–10% free quartz grains, 5% devitrified pumice clasts. +35F: 98–99% quartz and sanidine crystals, 1–2% volcanic lithic fragments.	Qbt 1v	
230–235	Tuff—Light gray (N7), crystal-rich tuff; gray to brown rhyolite and dacite lithics 230'–235' +10F: 80–85% free crystals of quartz and sanidine; 10–15% fragments of dacite and rhyolite; 5% pale orange to gray devitrified pumice clasts. +35F: 98–99% quartz and sanidine crystals, 1–2% volcanic lithic fragments.	Qbt 1v	
235–245	Tuff—Very pale orange (10YR 8/2), crystal-rich pumice-bearing tuff; fragments of light gray rhyolite. 235'–245' WR/+10F: 70–80% very pale orange poorly welded tuff fragments with phenocrysts of quartz, volcanic lithics, and minor devitrified pumice; 10–20% medium to light gray rhyolite clasts, 5–10% free quartz and sanidine crystals, <5% pumice clasts. +35F; 90–95% quartz and sanidine crystals, 5–10% tuff fragments, 1–2% volcanic lithic fragments.	Qbt 1v	Qbt 1v–Qbt 1g contact is placed at 245 ft bgs based on first appearance of glassy pumice clasts.

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 6 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		
Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
245–255	**UNIT 1g, TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff—Very pale orange (10R 8/2) indurated ignimbrite tuff, pumiceous (glassy pumices), crystal-bearing, lithic-poor. 245’–255’ WR/+10F: 40–60% fragments of poorly welded tuff containing vitric pumice lapilli, phenocrysts (10–20% by volume) of quartz and sanidine and minor volcanic lithics in a matrix of pale tan volcanic ash; 40–50% large (up to 20 mm in diameter) vitric quartz- and sanidine-phyric pumice lapilli; <5% dacitic lithic fragments. 245’–250’ +35F: 40–50% fragments of welded tuff and glassy pumice; 50–60% quartz and sanidine crystals; 1–2% volcanic lithics. 250’–255’ +35F: 20–30% fragments of welded tuff and glassy pumice; 65–75% quartz and sanidine; 2–5% obsidian clasts; 2–3% dacitic or rhyolitic lithic fragments.	Qbt 1g	Unit 1g, Tshirege Member of the Bandelier Tuff, encountered from 245 to 345 ft bgs, is estimated to be 100 ft thick.
255–295	Tuff—Very pale orange (10R 8/2) nonwelded tuff, pumiceous (with glassy pumices), crystal-bearing, lithic-poor. 255’–295’ WR/+10F: 90–100% vitric quartz- and sanidine-phyric pumices; 0–10% volcanic lithics (rhyolites, vitrophyre). 255’–285’ +35F: 60–80% quartz and sanidine phenocrysts (increasing down section); 20–40% glassy pumices; <5% volcanic lithic fragments. 285’–295’ +35F: 50–60% quartz and sanidine phenocrysts; 40–50% glassy pumices; <5% volcanic lithic fragments.	Qbt 1g	Note disappearance of welded tuff fragments, suggesting diminishing degree of welding with depth in this interval.
295–305	No samples collected.	Qbt 1g	

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 6 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
305–345	Tuff—Very pale orange (10R 8/2) nonwelded tuff, pumiceous (with glassy pumices), crystal-bearing, lithic-poor. 305'–345' WR/+10F: 90–100% vitric quartz- and sanidine-phyric pumices; 0–10% volcanic lithics (rhyolites, vitrophyre). +35F: 60–80% quartz and sanidine phenocrysts; 20–40% glassy pumices; <5% volcanic lithic fragments.	Qbt 1g	The Qbt 1g–Qct contact is placed at 345 ft bgs, as interpreted from natural gamma log geophysical data and first appearance of sediments.
345–370	**CERRO TOLEDO INTERVAL:** Tuffaceous sediments—Very pale orange (10YR8/1) pumice clasts and varicolored volcanic lithics (predominantly dacites) as unconsolidated pebble gravels and coarse sand containing quartz and sanidine grains. 345'–370' +10F: 50–60% Volcaniclastic rocks of various lithologies (porphyritic and aphanitic dacites, minor andesites and rhyolites); 40–50% white to pale orange vitric pumice clasts with minor limonite staining. +35F: 40–50% volcaniclastics of various lithologies; 40–50% white glassy pumice and ash-flow tuff fragments, 10–20% quartz and sanidine grains.	Qct	The Cerro Toledo interval, encountered from 345 to 450 ft bgs, is estimated to be 105 ft thick.
370–385	Tuffaceous sediments—White to pale orange-tan (10YR 7/6) unconsolidated pebble gravels and fine to coarse sand, detritus predominantly pumice and minor dacite. 370'–385' +10F: 97–99% rounded to subrounded detrital granules (up to 15 mm in diameter) pale orange and white vitric pumices; 1–3% detrital volcanic clasts. +35F: 50–60% pumice grains; 30–40% volcaniclastic and obsidian grains; 10–20% quartz and sanidine crystals.	Qct	

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 8 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
385–390	Tuffaceous sediments—Very pale orange-tan (10YR 8/2) unconsolidated fine to medium gravels with fine to coarse sand, mixed pumice and volcaniclastic detritus. 385’–390’ +10F: 50–60% Volcaniclastic rocks of various lithologies (porphyritic and aphanitic dacites, minor andesites and rhyolites); 40–50% white to pale orange vitric pumice clasts. +35F: 40–50% volcaniclastics of various lithologies; 40–50% white glassy pumice and ash-flow tuff fragments, 10–20% quartz and sanidine grains.	Qct	
390–450	Tuffaceous sediments—Very pale orange tan (10YR 8/2) unconsolidated fine to medium gravels with fine to coarse sand, mixed pumice and volcaniclastic detritus. 390’–450’ +10F: 10–40% Volcaniclastic rocks of various lithologies (porphyritic and aphanitic dacites, minor andesites and rhyolites); 60–90% rounded white to pale orange vitric pumice clasts (up to 10 mm) with minor oxidation/limonite alteration. +35F: 30–50% volcaniclastics of various lithologies; 30–50% white glassy pumice and ash-flow tuff fragments, 10–40% quartz and sanidine grains.	Qct	The Qct–Qbo contact is placed at 450 ft bgs, as interpreted from rounding and oxidation of pumice grains above the contact.

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 9 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
450–490	**OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—White (N9), poorly welded, pumiceous, crystal-bearing, lithic-rich tuff. 450'–455' +10F: 80–90% fragments of white, glassy, quartz- and sanidine-phyric pumices; 10–20% subangular clasts of light to medium gray dacite. 455'–465' +10F: 30–50% fragments of white, glassy quartz- and sanidine-phyric pumices; 50–70% subangular clasts of light to medium gray dacite and reddish gray andesite. 465'–490' + 10F: 80–90% fragments of white, glassy, quartz- and sanidine-phyric pumices; 10–20% subangular clasts of light to medium gray dacite. 450'–490' +35F: 40–60% pumice fragments; 20–40% quartz and sanidine crystal grains; 10–40% volcanic lithic grains.	Qbo	The Otowi Member of the Bandelier Tuff, encountered from 450 ft to 622 ft bgs, is estimated to be 172 ft thick.
490–530	Tuff—White (N9) to very pale orange (10YR 8/2), poorly welded, pumiceous, crystal-bearing, lithic-rich tuff. 490'–530' +10F: 70–90% small (up to 7 mm in diameter) pale to white vitric pumice fragments; 10–30% broken chips and subangular varicolored volcanic lithic fragments including andesite, dacite, and rhyolite; trace welded crystal and pumice-bearing tuff fragments. +35F: 10–20% quartz and sanidine crystals; 30–50% volcanic lithic fragments; 40–60% pumice fragments.	Qbo	
530–545	Tuff— White (N9) to very pale orange (10YR 8/2), poorly welded, pumiceous, crystal-bearing, lithic-rich tuff. 530'–545' +10F: 5–20% white vitric pumice fragments; 80–95% angular volcanic lithic fragments (predominantly dark gray dacite). +35F: 60% quartz and sanidine crystals; 20% volcanic lithic grains; 20% tuff and pumice fragments.	Qbo	

Borehole Identification (ID): R-60	**Technical Area (TA):** 50		**Page:** 10 of 20
Drilling Company: Boart Longyear Company	**Start Date/Time:** 9/13/10: 1930		**End Date/Time:** 9/29/10: 1430
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
545–570	Tuff—White (N9) to very pale orange (10YR 8/2), moderately welded, pumiceous, crystal-bearing, lithic-rich tuff. 545'–570' +10F: 50–80% white vitric pumice fragments; 20–50% angular volcanic lithic fragments (predominantly dark gray dacite). +35F: 30–40% quartz and sanidine crystals; 20–30% volcanic lithic grains; 40–50% tuff and pumice fragments.	Qbo	
570–620	Tuff—White (N9) to very pale orange (10YR 8/2), poorly welded, pumiceous, crystal-bearing, lithic-rich tuff. 570'–620' 10F: 75–90% white glassy quartz-rich pumices; 10–25% dacitic and andesitic lithics; trace obsidian fragments. +35F: 30–40% quartz and sanidine crystals; 20–30% volcanic lithic grains; 40–50% glassy pumice fragments, trace obsidian.	Qbo	
620–622	Tuff—White (N9) to very pale orange (10YR 8/2), poorly welded, pumiceous, crystal-bearing, lithic-rich tuff. 620'–622' +10F: 90% broken (up to 10 mm in diameter) volcanic lithics (predominantly varieties of dacite, minor andesites and oxidized basalts); 10% white to pale orange glassy pumice; trace obsidian. +35F: 70–80% quartz and sanidine crystals; 10–25% volcanic lithic grains; 5–20% glassy pumice fragments, trace obsidian.	Qbo	The Qbo–Qbog contact is placed at 622 ft bgs based upon the natural gamma log.
622–636	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—White (N9) to very pale orange (10YR 8/2), poorly welded, pumiceous, crystal-bearing, lithic-rich tuff. 622'–636' +10F: 70–80% white glassy quartz-rich pumices; 20–30% dacitic and andesitic lithics; trace obsidian fragments. +35F: 50–60% quartz and sanidine crystals; 10–20% volcanic lithic grains; 20–30% glassy pumice fragments, trace obsidian.	Qbog	The Guaje Pumice Bed, from 622–636 ft bgs, is estimated to be 14 ft thick. The Qbog-Tt2 contact is placed at 636 based on the natural gamma log.

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GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
636–645	**TSCHICOMA FORMATION DACITIC LAVA:** Tuff—White (N9) to very pale orange (10YR 8/2), poorly welded, pumiceous, lithic-rich tuff. 636’–645’ +10F: 70–80% white glassy pumices (up to 25 mm); 20–30% dacitic and andesitic lithics; trace obsidian fragments. +35F: 50–60% quartz and sanidine crystals; 10–20% volcanic lithic grains; 20–30% glassy pumice fragments, trace obsidian.	Tt2	The Tschicoma Formation dacitic lava section, from 636–880 ft bgs, is estimated to be 244 ft thick. Note: Dacite clasts do not appear in drill cuttings above 645 ft bgs.
645–655	Dacite lavas—Light to medium gray (N7 to N6) massive dacites with rare plagioclase phenocrysts. 645’–655’ WR: 60% massive, unaltered dacite chips; 30% rounded pumice and perlite clasts; 10% subhedral quartz grains. >90% chips less than 2 mm.	Tt2	Note: Descriptions from 645–900 ft bgs are from whole rock samples obtained from the final R-60 borehole.
655–665	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) massive, fine-grained dacites. 655’–665’ WR: 80% chips of dacite (~50% oxidized to reddish gray); 15% pumice and perlite clasts; 5% quartz grains. >90% chips less than 2 mm.	Tt2	
665–670	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) massive, fine-grained dacites. 665’–670’ WR: 95% chips of dacite (~30% oxidized); 5% quartz grains. >90% chips less than 2 mm.	Tt2	
670–685	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) massive, fine-grained dacites. 670’–685’ WR: 95–99% massive dacites (<10% oxidized); 1–5% quartz; trace pumice. >90% chips less than 2 mm.	Tt2	
685–695	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) massive, fine-grained dacites. 685’–695’ WR: 100% dacite chips (~60% oxidized, vesicular, and larger than 5 mm).	Tt2	

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GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		
Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
695–750	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 695'–750' WR: 100% dacite chips (~95% oxidized and up to 20 mm).	Tt2	
750–775	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 750'–775' WR: 100% dacite chips (~98% oxidized and up to 25 mm).	Tt2	
775–780	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 775'–780' WR: 100% dacite chips (~90% oxidized and up to 25 mm).	Tt2	
780–800	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 780'–800' WR: 100% dacite chips (<20% oxidized and up to 15 mm) with rare pyroxene phenocrysts.	Tt2	
800–820	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 800'–820' WR: 100% massive dacite chips (<5% oxidized and up to 10 mm).	Tt2	
820–845	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 820'–845' WR: 100% angular dacite chips (60–70% oxidized and up to 25 mm).	Tt2	
845–860	Dacite lavas—Light gray (N7) to grayish red (5R 4/2) fine-grained dacites. 845'–860' WR: 100% angular dacite chips (40–50% oxidized and up to 25 mm).	Tt2	

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GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
860–870	Altered dacite lavas—Grayish red (5R 4/2) to orange fine-grained dacites. 860'–870' WR: 95–98% angular dacite chips (99% oxidized); 2–5% quartzite, quartz, and microcline grains. +35F: 30–80% dacitic and oxidized dacitic fragments, 20–70% quartz and quartzite grains.	Tt2	Note: Although the lower contact of the Tt2 lavas has been chosen at 880 ft bgs, an alternate pick might be at 865 ft bgs based on the following observations. Some quartz and microcline grains begin to appear in the +35 fraction of the 865–870 ft bgs samples. Also, rounded dacite gravels are present from 865–880 ft bgs and may be derived from Tt2 and an exotic sediment source. A possible alternate stratigraphic interpretation would be to place the base of the Tt2 lavas at 865 ft bgs instead of 880 ft bgs. The induction log has a conductive interval at 855–865 ft bgs that may be indicative of these sediments.
870–880	Altered dacite lavas—Grayish red (5R 4/2) to orange fine-grained dacites. 870'–880' WR: 98–99% angular dacite chips (90% oxidized); 1–2% quartzite, quartz, and microcline grains. +35F: 40–60% dacitic and oxidized dacitic fragments, 40–60% quartz and quartzite grains.	Tt2	The Tt2-Tpf contact is interpreted to be at 880 ft bgs based on the first occurrence of rounded volcanic clasts and siliciclastic sediments in cuttings samples below that depth.
880–895	**PUYE FORMATION:** Siliciclastic sediments, granule and sand-sized quartzite sediments. 880'–895' WR: 90% rounded quartz and quartzite clasts (up to 5 mm); 10% dacite chips.	Tpf	The Puye Formation, from 880 to 1393 ft bgs, is estimated to be 513 ft thick.
895–900	Mixed volcaniclastic and siliciclastic sediments-granule and sand-sized quartzite sediments and dacite chips. 895'–900' WR: 20–50% rounded quartz and quartzite clasts (up to 5 mm); 50–70% subangular to subrounded dacite clasts (<50% oxidized).	Tpf	

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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
900–905	Volcaniclastic sediments—Abundant light gray dacite clasts and few glassy dacite/rhyolite clasts. Medium sand to gravel. 900'–905' WR/+10F/+35F: 90–95% subangular dacite clasts (up to 20 mm). Color from grayish red (5R 4/2) to light gray (N7); 5–10% subangular or broken rounded quartz and quartzite clasts (up to 4 mm); trace pumice clasts.	Tpf	
905–920	Volcaniclastic sediments—Abundant light gray dacite clasts and few glassy dacite/rhyolite clasts. Medium sand to gravel. 905'–920' WR/+10F/+35F: 90–95% angular to subangular dacite clasts (up to 30 mm) with rare phenocrysts up to 1 mm; 5–10% subrounded to rounded quartz and quartzite clasts.	Tpf	
920–930	Volcaniclastic sediments—Abundant light gray dacite clasts and few glassy dacite/rhyolite clasts. Medium sand to gravel (less sand than above). 920'–930' WR/+10F/+35F: 95–98% angular to subangular dacite clasts (up to 30 mm) with rare phenocrysts up to 1 mm; 2–5% subrounded to rounded quartz and quartzite clasts.	Tpf	
930–955	Volcaniclastic sediments—Abundant light gray dacite clasts and few glassy dacite/rhyolite clasts. Very fine sand to gravel. 930'–955' WR/+10F/+35F: 95–98% subangular to subrounded dacite clasts (up to 20 mm) with plagioclase and quartz phenocrysts up to 0.5 mm; 2–5% very pale orange (10YR 8/2) claystone clasts composed of very fine quartz grains. Abundance of claystone increases downward to 945 ft bgs and decreases to 955 ft bgs; trace quartz in +35F.	Tpf	

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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
955–980	Volcaniclastic sediments—Abundant light gray dacite clasts and few glassy dacite/rhyolite clasts. Medium sand to gravel. 955'–980' WR/+10F/+35F: 98% partially altered, subangular, massive dacite clasts and flow banded, glassy rhyolite/dacite clasts; trace quartz grains; trace claystone clasts.	Tpf	
980–990	Volcaniclastic sediments—Abundant light gray dacite clasts. Fine sand to gravel. 980'–990' WR/+10F: 99–100% dacite clasts as from 955–980 ft bgs. +35F: 98% dacite clasts; 1% quartz, trace pale orange quartz-rich claystone.	Tpf	
990–1000	Volcaniclastic sediments—Abundant light gray dacite clasts. Medium sand to gravel, with more gravel than sand. 990'–1000' WR/+10F: 100% partially weathered/oxidized dacite clasts. +35F: 98% dacite clasts; 1% quartz, trace pale orange quartz-rich claystone.	Tpf	
1000–1005	Volcaniclastic sediments—Abundant light gray dacite clasts. Fine sand to gravel, with more sand than gravel (largest clasts ~10 mm). 1000'–1005' WR/+10F: 100% partially weathered/oxidized dacite clasts. +35F: 98% dacite clasts; 1% quartz, trace pale orange quartz-rich claystone.	Tpf	
1005–1030	Volcaniclastic sediments—Abundant light gray dacite clasts. Medium sand to gravel (up to 30 mm). 1005'–1030' WR/+10F: 99–100% fresh, unaltered dacite clasts. +35F: 99% partially altered dacite clasts; 1% quartz, trace pale orange quartz-rich claystone.	Tpf	

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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
1030–1050	Volcaniclastic sediments—Light gray to reddish gray dacite clasts. Very fine sand to gravel. 1030'–1050' WR/+10F: 99–100% partially altered and oxidized dacite clasts. +35F: 98% dacite clasts; 1% quartz, trace pale orange quartz-rich claystone.	Tpf	
1030–1050	Volcaniclastic sediments—Light gray to reddish gray dacite clasts. Very fine sand to gravel. 1030'–1050' WR/+10F: 99–100% partially altered and oxidized dacite clasts. +35F: 98% dacite clasts; 1% quartz, trace pale orange quartz-rich claystone.	Tpf	
1050–1065	Volcaniclastic sediments—Light gray to reddish gray dacite clasts. Very fine sand to gravel, with more sand than above. 1050'–1065' WR/+10F: 99–100% largely unaltered dacite clasts. +35F: 98% dacite clasts; 1% quartz.	Tpf	
1065–1075	Volcaniclastic sediments—Light gray to reddish gray dacite clasts. Medium sand to gravel, with <15% sand. 1065'–1075' WR/+10F: 99–100% partially altered and oxidized subangular dacite clasts. +35F: 98% massive and less abundant glassy dacite clasts; 1% quartz.	Tpf	
1075–1105	Volcaniclastic sediments—Light gray to reddish gray dacite clasts. Very fine sand to gravel, with more sand than above. 1075'–1105' WR/+10F: 99–100% largely unaltered subangular dacite clasts. +35F: 97% dacite clasts; 2–3% quartz.	Tpf	
1105–1115	Volcaniclastic sediments—Light gray to reddish gray dacite clasts. Very fine sand to gravel (up to 15 mm) 1105'–1115' WR/+10F: 100% altered and oxidized, subangular dacite clasts. +35F: 99–100% dacite clasts; <1% quartz.	Tpf	

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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
1115–1125	Volcaniclastic sediments—Light gray dacite clasts. Medium sand to gravel, with <15% sand. 1115'–1125' WR/+10F: 100% subangular to angular, fresh dacite clasts. 1115'–1120' No returns finer than +10F. 1120'–1125' +35F: 100% subangular dacite clasts.	Tpf	
1125–1155	Volcaniclastic sediments—Light gray dacite clasts. Fine sand to gravel (up to 10 mm). 1125'–1155' WR/+10F/+35F: 100% subangular, fresh dacite clasts.	Tpf	
1155–1165	Volcaniclastic sediments—Light gray dacite clasts. Fine sand to gravel (up to 25 mm), with less sand than above. 1155'–1165' WR/+10F/+35F: 100% subangular, partially altered and oxidized dacite clasts.	Tpf	
1165–1170	Volcaniclastic sediments—Light gray dacite clasts. Medium sand to gravel, with <10% sand. 1165'–1170' WR/+10F/+35F: 100% subangular, partially altered and oxidized dacite clasts.	Tpf	
1170–1180	Volcaniclastic sediments—Light gray dacite clasts. Medium sand to gravel, with more sand than gravel. 1170'–1180' WR/+10F/+35F: 100% subangular, fresh dacite clasts.	Tpf	
1180–1195	Volcaniclastic sediments—Light gray dacite clasts. Very fine sand and silt to gravel (<20 mm). 1180'–1195' WR/+10F/+35F: 97% subangular, fresh dacite clasts; 3% quartz as very fine sand and silt size grains.	Tpf	
1195–1205	Volcaniclastic sediments—Light gray dacite clasts. Fine sand to gravel. 1195'–1205' WR/+10F/+35F: 100% subangular, fresh dacite clasts.	Tpf	
1205–1210	No returns.	Tpf	

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GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
DRILLERS: E. Rivas, M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
1210–1220	Volcaniclastic sediments—Light gray dacite clasts. Fine sand to gravel. 1210'–1220' WR/+10F/+35F: 100% subangular, fresh dacite clasts.	Tpf	
1220–1245	Volcaniclastic sediments—Light gray dacite clasts. Very fine sand to gravel, more sand than gravel. 1220'–1245' WR/+10F: 100% subangular, fresh dacite clasts. +35F: 95–99% subangular, fresh dacite clasts; 1–5% quartz grains.	Tpf	
1245–1250	No returns.	Tpf	
1250–1255	Volcaniclastic sediments—Light gray dacite clasts. Very fine sand to gravel, more sand than gravel. 1250'–1255' WR/+10F: 100% subangular, fresh dacite clasts. +35F: 95–99% subangular, fresh dacite clasts; 1–5% quartz grains.	Tpf	
1255–1265	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts. Medium sand to gravel (up to 25 mm). Less sand from 1260–1265 ft bgs. 1255'–1265' WR/+10F/+35F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray.	Tpf	
1265–1315	Volcaniclastic sediments—Light gray to reddish gray, partially altered dacite clasts. Fine sand to gravel with some silt. 1265'–1315' WR/+10F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray. +35F: 98% dacite clasts; 2% quartz grains.	Tpf	
1315–1320	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts. Very fine sand and silt to gravel. 1315'–1325' WR/+10F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray. +35F: 98% dacite clasts; 2% quartz grains.	Tpf	

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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
1320–1335	Volcaniclastic sediments—Light gray to reddish-gray partially, altered dacite clasts. Fine sand to gravel. 1320'–1335' WR/+10F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray. +35F: 95% dacite clasts; 2–5% quartz grains; 1–3% feldspar/biotite/ pyroxene grains.	Tpf	
1335–1345	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts. Very fine sand and silt to gravel (up to 15 mm). 1335'–1345' WR/+10F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray. +35F: 95–98% dacite clasts; 1–3% biotite/pyroxene grains; <2% quartz grains.	Tpf	
1345–1355	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts. Fine subrounded sand to angular gravel (up to 25 mm). No silt. 1345'–1355' WR/+10F: 100% dacite clasts, partially altered and oxidized to reddish gray. +35F: 98% dacite clasts; <2% quartz grains.	Tpf	
1355–1370	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts. Very fine sand and silt to gravel (up to 15 mm). 1355'–1370' WR/+10F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray. +35F: 98% dacite clasts; <2% quartz grains.	Tpf	
1370–1385	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts. Very fine sand to gravel (up to 15 mm). Most sand larger than 0.5 mm. 1370'–1385' WR/+10F: 100% subrounded to rounded dacite clasts, partially altered and oxidized to reddish gray. +35F: 95–98% dacite clasts; 2–5% quartz grains.	Tpf	

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GROUND ELEVATION: 7227.92 ft amsl			**Total Depth:** 1418 ft bgs
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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
1385–1393	Volcaniclastic sediments—Light gray to reddish-gray, partially altered dacite clasts with traces of perlite and quartz clasts. Clay to rounded gravels. 1385'–1395' WR/+10F: 98% dacite clasts; 2% perlite clasts. +35F: 90–95% dacite clasts; 5–10% quartz clasts; trace pumice and perlite.	Tpf	The Tpf-Tjfp boundary is interpreted to be at 1393 ft bgs based on increase in siliciclastic sediments below that depth.
1393–1418	**MIOCENE PUMICEOUS SEDIMENTS:** Siliciclastic and volcaniclastic sediments—Subrounded to rounded granules and gravels (up to 20 mm) of mixed volcanic clasts and quartz grains. 1395'–1400' WR: Clay and gravel size grains, 40% perlite; 50% dacite; 10% quartz. 1400'–1418' WR: Fine sand to gravel with minor clay composition as for 1395–1400 ft bgs. 1395'–1418' +10F: 40% perlite clasts; 40–50% dacite clasts; 10–20% ash flow tuff and rhyolite clasts. +35F: 50% quartz grains, 30% dacitic clasts, 20% perlite clasts; trace biotite and pyroxene grains.	Tjfp	Bottom of borehole is at 1418 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.

% = estimated percent by volume of a given sample constituent

bgs = below ground surface

ft = feet

Qal = Quaternary alluvium

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff

Qbt = Bandelier Tuff

Qct = Cerro Toledo interval

Tjfp = Miocene pumiceous sediments

Tpf = Puye Formation

Tt2= Tschicoma Formation dacitic lavas

+10F = plus No.10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

Appendix B

Groundwater Analytical Results

B-1.0 SCREENING GROUNDWATER ANALYSES AT R-60

The R-60 regional aquifer monitoring well is screened from 1330 to 1350 ft below ground surface (bgs) in the Puye Formation. This appendix presents screening analytical results for samples collected during well development and aquifer testing at R-60.

Sample GW60-10-24557 was collected after initial well development and aquifer testing and analyzed for anions and metals. Additionally, 12 samples were collected for analysis of total organic carbon (TOC) during development and aquifer testing. Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14) conducted the anion, metals, and TOC analyses. Table B-1.0-1 presents a summary of samples collected for laboratory analysis at R-60.

Additionally, field water-quality parameters, including pH, conductivity, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity, were measured at regular intervals during well development and aquifer testing.

B-2.0 SCREENING ANALYTICAL RESULTS

This section presents the anion and metal analytical results, TOC concentrations, and field parameters measured during well development and aquifer testing

B-2.1 Anions and Metals

EES-14 laboratory screening analytical results for anions and metals from sample GW60-10-24557 are presented in Table B-2.1-1. The analytical results for this well development sample are compared with maximum background concentrations from completed regional wells (LANL 2007, 095817). It should be noted that these values were obtained for the Laboratory as a whole, and background concentrations for the area immediately upgradient of well R-60 may differ because of local variations in geochemistry.

Dissolved concentrations of the following anions or metals in the screening sample slightly exceed Laboratory background concentrations.

- Chloride was detected at 11.0 mg/L compared with the maximum background concentration of 5.95 mg/L for regional aquifer groundwater.
- Nitrite-N was reported at 0.058 mg/L. Nitrite-N was not detected in the regional wells sampled for the Laboratory background study. However, the concentration reported in the R-60 screening sample is below the New Mexico Quality Control Commission standard for groundwater (20.6.2.3103 New Mexico Administrative Code) of 10 mg/L for nitrite-N in drinking water.
- Nitrate-N was detected at 0.57 mg/L, slightly above the maximum background value in the regional aquifer of 0.53 mg/L.
- Sulfate was reported at 13.1 mg/L and the maximum background concentration for the Laboratory is 8.63 mg/L.
- Boron was measured at 59 µg/L, slightly above the regional aquifer maximum background concentration of 52.6 µg/L.
- Barium was measured at 471 µg/L, in comparison to the regional aquifer maximum background concentration of 115 µg/L.
- Zinc was detected at 0.082 mg/L, slightly above the maximum background concentration of 0.032 mg/L.

B-2.2 Total Organic Carbon

Concentrations of TOC varied from 0.2 to 1.01 mgC/L in 12 groundwater samples collected during development and aquifer testing at well R-60 (Table B-2.2-1). These concentrations are below the target concentration for TOC at the end of well development, 2.0 mgC/L.

B-2.3 Field Parameters

Field parameters (pH, conductivity, temperature, DO, ORP, and turbidity) were measured during well development and aquifer testing and are summarized in Table B-2.3-1. Well development was initially conducted for 4 d. Aquifer testing was then conducted for 3 d, followed by the final period of well development that lasted for 24 d. Because these three activities were conducted consecutively, the field parameters for all three are summarized below.

During well development and aquifer testing, pH varied from 6.50 to 8.15, and temperature ranged from 17.4°C to 25.4°C. Concentrations of DO varied from 2.3 to 8.0. Specific conductance ranged from 160 to 134 μS/cm, and turbidity values varied from 43.9 to 0.0 nephelometric turbidity units (NTU). Corrected oxidation-reduction potential (Eh) values, determined from field ORP measurements, varied from 136.0 to 412.7 mV. Three temperature-dependent correction factors were used to calculate Eh values from field ORP measurements: 208.9, 203.9, and 198.5 mV at 15ºC, 20ºC, and 25ºC, respectively. Figure B-2.3-1 figure the field parameters measured over the course of well development and aquifer testing.

The parameters measured at the end of the final period of well development were: pH of 7.6, temperature of 24.05ºC, DO of 6.26 mg/L, specific conductance of 136 μS/cm and turbidity of 0.8 NTU.

B-3.0 SUMMARY

Concentrations of chloride, nitrate-N, sulfate, boron, barium, and zinc slightly exceeded Laboratory maximum background concentrations in one sample collected after initial well development and aquifer testing. Nitrite-N was reported in the sample and will continue to be evaluated in future monitoring at R-60. Concentrations of TOC were below the target level of 2.0 mgC/L, and turbidity was below the target concentration of 5 NTU at the end of development. R-60 will be sampled quarterly for 1 yr. The data will be assessed and the well will be incorporated into the Interim Facility-Wide Groundwater Monitoring Plan. Data from ongoing sampling at R-60 will be analyzed and presented in the appropriate Laboratory periodic monitoring report.

B-4.0 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 New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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)

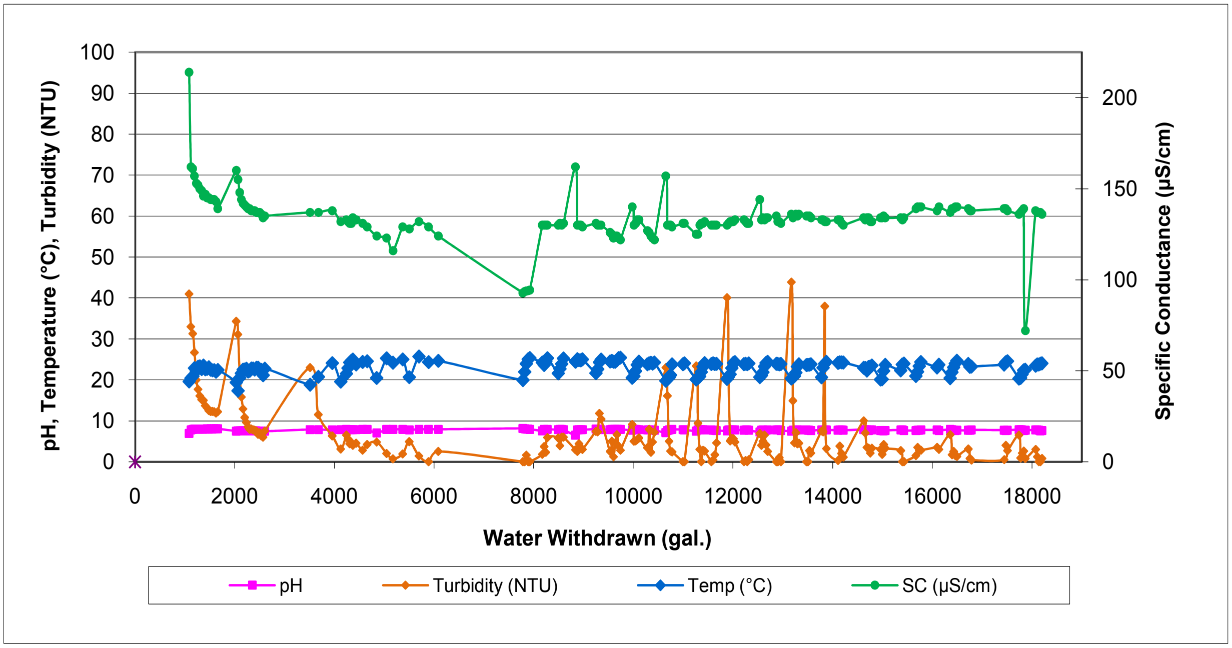

Figure B-2.3-1 Water-quality parameters measured during well development and aquifer testing at R-60

Table B-1.0-1
Groundwater Screening Samples Collected during Well Development and Aquifer Testing at Well R-60

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analyses
Development					
R-60	GW60-10-24563	10/22/2010	1352.00	Groundwater, pumped	TOC
R-60	GW60-10-24557	11/1/2010	1353.72	Groundwater, pumped	Anions, metals
R-60	GW60-10-24569	11/1/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24570	11/2/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24571	11/3/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24572	11/4/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24573	11/6/2010	1353.72	Groundwater, pumped	TOC
R-60	GW60-10-24574	11/7/2010	1353.72	Groundwater, pumped	TOC
Aquifer Testing					
R-60	GW60-10-24564	10/26/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24565	10/26/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24566	10/27/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24567	10/27/2010	1338.46	Groundwater, pumped	TOC
R-60	GW60-10-24568	10/27/2010	1338.46	Groundwater, pumped	TOC

Table B-2.1-1
EES-14 Screening Analytical Results

	Analyte	EPA[a] Method	Result	Unit	Qualifier	Maximum Background Value[b]	Unit
Anions	Alk-CO3$^{(-2)}$	300, rev. 2.1	0.8	mg/L	U[c]	None	mg/L
	Alk-CO3+HCO3	310.1	81.2	mg/L	None	152	mg/L
	Br$^{(-)}$	300, rev. 2.1	0.01	mg/L	U	0.098	mg/L
	C2O4$^{(-2)}$	300, rev. 2.1	0.01	mg/L	U	None	mg/L
	Cl$^{(-)}$	300, rev. 2.1	11.00	mg/L	None	5.95	mg/L
	ClO4$^{(-)}$	314, rev. 1	0.005	mg/L	U	0.41	mg/L
	F$^{(-)}$	300, rev. 2.1	0.33	mg/L	None	0.57	mg/L
	NO2$^{(-)}$	300, rev. 2.1	0.190	mg/L	None	None	mg/L
	NO2-N	300, rev. 2.1	0.058	mg/L	None	0.0	mg/L
	NO3$^{(-)}$	300, rev. 2.1	2.53	mg/L	None	None	mg/L
	NO3-N	300, rev. 2.1	0.57	mg/L	None	0.53	mg/L
	PO4$^{(-3)}$	300, rev. 2.1	0.45	mg/L	None	None	mg/L
	SO4$^{(-2)}$	300, rev. 2.1	13.1	mg/L	None	8.63	mg/L

Table B-2.1-1 (continued)

	Analyte	EPA[a] Method	Result	Unit	Qualifier	Maximum Background Value[b]	Unit
General	Total dissolved solids	n/a[d]	221	mg/L	None	225.0	mg/L
	SiO2	360.2	81	mg/L	None	87.2	mg/L
	Cations	n/a	1.52	n/a	None	n/a	n/a
	Anions	n/a	2.01	n/a	None	n/a	n/a
	Balance	n/a	-0.14	n/a	None	n/a	n/a
	Lab pH	150.1	7.51	n/a	None	8.96	n/a
Metals	Ag	200.8, rev. 5.4	1.00	µg/L	U	2.50	µg/L
	Al	200.8, rev. 5.4	18.00	µg/L	None	73.50	µg/L
	As	200.8, rev. 5.4	0.80	µg/L	None	12.00	µg/L
	B	200.7, rev. 4.4	59.00	µg/L	None	51.60	µg/L
	Ba	200.7, rev. 4.4	471.00	µg/L	None	115.00	µg/L
	Be	200.8, rev. 5.4	1.00	µg/L	None	0.50	µg/L
	Ca	200.7, rev. 4.4	9.73	mg/L	None	41.70	mg/L
	Cd	200.8, rev. 5.4	1.00	µg/L	U	0.50	µg/L
	Co	200.8, rev. 5.4	1.00	µg/L	U	7.00	µg/L
	Cr	200.8, rev. 5.4	2.00	µg/L	None	7.20	µg/L
	Cs	200.8, rev. 5.4	1.00	µg/L	U	4.45	µg/L
	Cu	200.8, rev. 5.4	1.00	µg/L	U	5.00	µg/L
	Fe	200.7, rev. 4.4	143.00	µg/L	None	147.00	µg/L
	Hg	200.8, rev. 5.4	0.05	µg/L	U	0.26	µg/L
	K	200.7, rev. 4.4	1.79	mg/L	None	3.11	mg/L
	Li	200.8, rev. 5.4	20.00	µg/L	None	25.00	µg/L
	Mg	200.7, rev. 4.4	3.64	µg/L	None	4.40	µg/L
	Mn	200.8, rev. 5.4	15.00	µg/L	None	124.00	µg/L
	Mo	200.8, rev. 5.4	3.00	µg/L	None	4.40	µg/L
	Na	200.7, rev. 4.4	15.52	mg/L	None	32.90	mg/L
	Ni	200.8, rev. 5.4	2.00	µg/L	None	50.00	µg/L
	Pb	200.8, rev. 5.4	0.20	µg/L	U	2.90	µg/L
	Rb	200.8, rev. 5.4	2.00	µg/L	None	None	µg/L
	Sb	200.8, rev. 5.4	1.00	µg/L	U	1.00	µg/L
	Se	200.8, rev. 5.4	1.00	µg/L	U	3.93	µg/L
	Si	200.7, rev. 4.4	37.73	mg/L	None	None	mg/L
	Sn	200.8, rev. 5.4	1.00	µg/L	U	3.60	µg/L
	Sr-90	200.7, rev. 4.4	47.00	pCi/L	None	477.00	pCi/L
	Th	200.8, rev. 5.4	1.00	µg/L	U	None	µg/L
	Ti	200.7, rev. 4.4	2.00	µg/L	U	1.00	µg/L
	Tl	200.8, rev. 5.4	1.00	µg/L	U	0.83	µg/L
	U	200.8, rev. 5.4	0.60	µg/L	None	2.50	µg/L
	V	200.8, rev. 5.4	7.00	µg/L	None	29.70	µg/L
	Zn	200.8, rev. 5.4	82.00	µg/L	None	32.00	µg/L

Note: Results are for screening sample GW60-10-24557, collected after the initial phase of well development and aquifer testing.

[a] EPA = U.S. Environmental Protection Agency.

[b] Values are derived from LANL 2007, 095817.

[c] U = The analyte was not detected.

[d] n/a = Not applicable.

Table B-2.2-1
TOC Results

Sample ID	EPA* Method	TOC Concentration (mgC/L)
GW60-10-24569	415.1	0.40
GW60-10-24570	415.1	0.31
GW60-10-24563	415.1	0.30
GW60-10-24564	415.1	1.01
GW60-10-24565	415.1	0.52
GW60-10-24566	415.1	0.49
GW60-10-24567	415.1	0.48
GW60-10-24568	415.1	0.51
GW60-10-24571	415.1	0.55
GW60-10-24572	415.1	0.25
GW60-10-24573	415.1	0.29
GW60-10-24574	415.1	0.20

*EPA = U.S. Environmental Protection Agency.

Table B-2.3-1
Purge Volumes and Field Parameters during Well Development and Aquifer Testing at R-60

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (μS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
10/19/10	n/r[b]; swabbing/bailing						400.0	400.0
10/20/10	n/r, swabbing/bailing						164.0	594.0
10/21/10	n/r, pumping while swabbing screen						288.6	882.6
10/22/10	6.95	19.61	6.58	106.8, 310.7	214	41.0	202.3	1084.9
	7.78	20.41	6.58	66.5, 270.4	162	33.0	36.0	1120.9
	7.94	20.90	6.58	61.2, 265.1	161	31.3	36.0	1159.9
	7.96	22.88	6.44	62.5, 261.0	157	26.7	36.0	1192.9
	7.98	22.20	6.59	62.7, 266.6	153	20.0	36.0	1228.9
	7.98	23.22	6.43	59.2, 257.7	152	17.7	36.0	1264.9
	7.98	23.32	6.56	50.6, 249.1	150	16.1	36.0	1300.9
	8.00	22.64	6.52	53.6, 252.1	149	15.2	36.0	1336.9
	8.00	23.52	6.57	48.5, 247.0	146	15.0	36.0	1372.9
	8.00	22.60	6.64	51.4, 249.9	147	13.7	36.0	1408.9
	8.03	22.69	6.71	50.6, 249.1	145	13.2	36.0	1444.9
	8.01	23.10	6.59	43.8, 243.5	145	12.5	36.0	1480.9
	8.03	22.48	6.72	49.8, 253.7	144	12.3	36.0	1516.9
	8.01	22.34	6.58	44.8, 248.7	144	12.3	36.0	1552.9
	8.03	22.37	6.75	34.5, 238.4	144	12.2	36.0	1588.9
	8.03	22.00	6.64	35.8, 239.7	143	11.9	36.0	1624.9
	8.03	22.44	6.74	30.7, 234.6	139	12.2	36.0	1660.9

Table B-2.3-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (μS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pumping Test								
10/23/10	n/r, pumping, aquifer test preparation						32.8	1693.7
10/24/10	n/r, pumping, aquifer test preparation						100.5	1794.2
10/26/10	7.51	19.38	3.33	142.5, 346.4	160	34.3	237.4	2031.6
	7.53	17.35	3.15	124.7, 333.6	155	31.1	34.2	2065.8
	7.57	20.52	3.51	94.8, 298.7	148	20.9	34.8	2100.6
	7.56	21.62	3.57	69.7, 273.6	144	15.8	34.2	2134.8
	7.56	22.49	3.42	68.8, 272.7	142	12.9	33.6	2168.4
	7.56	22.52	3.45	52.5, 251.0	141	10.8	33.6	2202.0
	7.58	22.73	3.47	65.2, 263.7	140	9.6	33.0	2235.0
	7.59	22.04	3.53	69.4, 273.3	139	8.5	33.6	2268.6
	7.59	22.20	3.53	68.7, 272.6	139	7.9	32.4	2301.0
	7.58	22.79	3.42	34.9, 233.4	138	8.0	33.6	2334.6
	7.57	22.79	3.28	33.4, 232.9	138	7.8	33.6	2368.2
	7.55	22.50	3.13	30.8, 234.7	138	7.7	32.4	2400.6
	7.53	22.97	2.93	19.1, 217.6	137	7.5	34.8	2435.4
	7.51	22.96	2.73	11.5, 210.0	137	6.7	33.6	2469.0
	7.48	22.52	2.32	-3.7, 194.8	137	7.1	33.0	2502.0
	7.47	22.45	2.41	-7.2, 196.7	136	6.3	33.6	2535.6
	7.48	21.15	2.47	-22.8, 181.1	134	6.0	34.2	2569.8
	7.46	22.75	2.39	-41.2, 157.7	135	7.5	34.2	2604.0
Well Development								
10/29/10	n/r, pumping, swabbing/bailing						651.0	3255.0
10/30/10	n/r, pumping						184.5	3439.5
10/31/10	7.88	18.82	7.08	183.0, 386.9	137	23.0	74.6	3514.1
	7.86	20.76	7.29	106.0, 309.9	137	11.5	165.0	3679.1
	7.81	24.10	7.33	97.5, 296.0	138	6.3	279.0	3958.1
11/1/10	7.83	19.58	7.55	208.8, 412.7	132	3.1	169.7	4127.8
	7.89	21.52	7.41	194.5, 398.4	133	6.5	115.0	4242.8
	7.88	22.88	7.15	200.3, 398.8	132	5.6	31.0	4273.8
	7.87	24.27	7.00	182.7, 381.2	131	4.4	35.0	4308.8
	7.86	24.70	7.21	173.6, 372.1	131	4.7	31.8	4340.6
	7.87	24.96	7.29	155.6, 354.1	134	4.0	30.6	4371.2
	7.87	23.78	7.32	139.0, 337.5	133	4.5	65.4	4436.6
	7.90	24.39	7.45	124.5, 323.0	131	2.8	130.8	4567.4
	7.89	24.56	7.62	108.6, 307.1	129	4.2	91.1	4658.5

Table B-2.3-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/2/10	7.09	20.47	7.35	80.9, 284.8	124	4.8	190.3	4848.8
	7.91	25.27	7.37	64.6, 263.1	123	2.0	199.8	5048.6
	7.91	24.20	7.53	42.0, 240.5	116	0.7	127.2	5175.8
	7.92	25.01	8.03	41.2, 239.7	129	1.9	196.2	5372.0
11/3/10	7.79	20.67	6.42	23.2, 227.1	128	4.9	131.4	5503.4
	7.93	25.70	7.74	45.0, 243.5	132	1.4	194.4	5697.8
	7.93	24.35	7.93	12.7, 211.2	129	0.0	194.4	5892.2
	7.93	24.66	7.94	25.0, 223.5	124	2.5	194.4	6086.6
11/4/10	n/r, pumping						744.4	6831.0
11/5/10	n/r, pumping						699.4	7530.4
11/6/10	8.15	19.95	4.92	149.5, 353.4	92.8	0.0	253.7	7784.1
	8.08	21.95	5.62	147.3, 351.2	93.6	0.0	36.0	7820.1
	8.00	23.96	5.04	138.6, 337.1	93.9	1.6	33.0	7853.1
	7.97	25.03	5.05	124.0, 322.9	94.1	0.0	36.0	7889.1
	7.95	25.35	5.02	122.8, 321.3	94.3	0.0	33.0	7922.1
	7.57	24.25	7.37	148.7, 347.2	130	1.8	252.0	8174.1
	7.90	23.64	7.47	210.8, 409.3	130	3.7	36.0	8210.1
	7.88	24.56	7.49	191.8, 390.8	130	2.3	33.0	8243.1
	7.94	25.32	7.42	171.0, 369.5	130	5.9	33.0	8276.1
11/7/10	7.83	21.60	6.54	192.8, 391.3	130	5.8	217.2	8493.3
	7.95	22.71	7.28	175.9, 374.4	131	3.9	33.0	8526.3
	7.90	23.92	6.60	165.6, 364.1	130	6.0	36.0	8562.3
	7.88	25.25	6.64	153.0, 351.5	131	6.0	36.0	8598.3
	6.50	24.42	6.35	180.0, 378.5	162	2.9	242.0	8840.3
	7.80	25.06	7.32	159.0, 357.5	130	2.5	36.0	8876.3
	7.82	24.82	7.11	152.7, 351.2	130	4.4	33.0	8909.3
	7.85	24.79	6.39	143.2, 341.7	130	3.5	36.0	8945.3
	7.83	25.02	6.74	124.7, 323.2	129	3.0	33.0	8978.3
11/8/10	7.98	21.65	7.20	148.8, 352.7	131	7.4	271.4	9249.7
	7.96	22.62	7.34	125.8, 324.3	130	7.3	35.1	9284.8
	7.90	24.30	6.98	123.7, 322.2	130	11.8	34.5	9319.3
	7.87	24.96	6.88	113.2, 311.7	130	10.4	34.8	9354.1
	7.86	24.50	7.27	46.4, 244.9	126	2.5	180.0	9534.1
	7.90	24.63	7.03	44.6, 243.1	125	5.0	34.5	9568.6
	7.93	24.43	7.92	50.8, 249.3	123	1.2	34.2	9602.8
	7.93	24.44	7.96	52.8, 251.3	124	4.6	33.6	9636.4
	7.93	24.78	7.79	53.2, 251.7	124	6.6	33.9	9670.3
	7.91	25.33	7.62	50.4, 248.9	123	3.8	34.2	9704.5

Table B-2.3-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (μS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/8/10	7.90	25.44	7.56	48.4, 246.9	122	2.8	35.7	9740.2
11/9/10	7.72	20.51	5.94	142.5, 346.4	140	9.1	237.30	9977.50
	7.91	20.91	7.00	77.1, 281.0	130	5.0	32.70	10,010.20
	7.89	22.14	7.29	57.0, 260.9	131	5.1	34.20	10,044.40
	7.86	23.68	7.05	50.8, 249.3	133	5.4	34.50	10,078.90
	7.85	24.46	7.00	44.3, 242.8	133	5.8	33.60	10,112.50
	7.80	23.82	7.05	-13.0, 185.5	127	3.4	170.20	10,282.70
	7.76	24.05	6.49	-27.4, 171.1	126	7.9	34.50	10,317.20
	7.76	24.19	6.82	-28.1, 170.4	124	2.3	35.10	10,352.30
	7.74	23.97	7.04	-29.0, 169.5	123	4.8	35.10	10,387.40
	7.73	24.26	6.81	-32.7, 176.2	122	7.2	35.10	10,422.50
11/10/10	7.10	19.77	3.85	100.0, 303.9	157	23	231.00	10,653.50
	7.62	20.15	3.71	-55.9, 148.0	130	16.1	30.60	10,684.10
	7.81	20.57	5.79	-35.4, 168.5	130	5.0	32.40	10,716.50
	7.87	21.19	6.35	-40.4, 168.5	130	2.6	30.30	10,746.80
	7.91	23.8	6.71	-10.5, 188.0	129	2.4	30.90	10,777.70
	7.87	23.83	6.09	-20.8, 177.7	131	0.0	217.50	10,995.20
	7.79	24.06	6.03	-42.2, 156.3	131	0.0	31.20	11,026.40
11/11/10	7.50	20.1	4.25	-31.7, 177.2	125	23.4	235.20	11,261.60
	7.75	20.42	5.19	-57.0, 146.9	125	9.4	35.10	11,296.70
	7.80	20.85	6.01	-45.2, 158.7	130	3.0	35.10	11,331.80
	7.82	21.92	6.42	-22.3, 181.6	131	2..9	31.80	11,363.60
	7.82	23.21	6.56	-9.4, 189.1	131	2.8	34.20	11,397.80
	7.81	24.12	6.65	1.1, 199.6	132	2.6	33.00	11,430.80
	7.78	23.88	6.46	-31.1, 167.4	130	0.0	135.30	11,566.10
	7.74	24.05	6.47	-34.3, 164.2	130	0.4	34.80	11,600.90
	7.71	23.89	5.86	-39.0, 159.5	130	1.7	34.20	11,635.10
	7.66	23.92	6.11	-40.4, 159.0	130	4.6	34.50	11,669.60
11/12/10	7.54	20.23	3.68	-39.2, 164.7	130	40.1	210.00	11,879.60
	7.80	20.75	5.93	-45.9, 158.0	131	20.3	31.50	11,911.10
	7.80	21.38	6.38	-36.3, 167.6	132	5.1	32.10	11,943.20
	7.77	22.9	6.24	-35.8, 162.7	132	5.7	33.30	11,976.50
	7.77	24.16	6.49	-25.5, 173.0	132	5.6	32.10	12,008.60
	7.77	24.35	6.62	-17.2, 181.3	133	4.8	31.20	12,039.80
	7.74	23.85	6.62	-41.6, 156.9	133	0.0	179.90	12,219.70
	7.75	23.95	6.7	-39.1, 159.4	132	0.3	33.60	12,253.30
	7.77	23.84	6.39	-33.4, 165.1	131	0.0	32.10	12,285.40
	7.69	24.04	6.74	-36.0, 162.5	131	0.5	32.70	12,318.10

Table B-2.3-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (μS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/13/10	7.26	20.66	5.87	93.0, 296.9	144	6.9	220.50	12,538.60
	7.74	21.08	6.2	58.6, 262.5	133	4.0	31.50	12,570.10
	7.75	21.87	6.54	29.7, 233.6	134	5.0	30.30	12,600.40
	7.74	23.27	6.58	27.7, 226.6	133	6.5	30.60	12,631.00
	7.74	24.15	6.74	21.8, 225.7	134	4.1	32.10	12,663.10
	7.76	24.41	6.85	20.3, 219.2	134	2.5	32.10	12,695.20
	7.75	23.93	7.04	-22.5, 176.0	135	0.0	173.90	12,869.10
	7.76	23.92	6.91	-25.0, 173.5	132	0.0	30.00	12,899.10
	7.76	23.79	6.49	-26.2, 172.3	132	1.0	30.00	12,929.10
	7.66	23.89	6.32	-36.2, 162.3	131	0.0	32.10	12,961.20
11/14/10	7.47	20.31	4.19	78.0, 281.9	136	43.9	210.00	13,171.20
	7.69	20.6	5.48	-39.7, 164.2	134	14.9	30.60	13,201.80
	7.73	20.93	6.17	-51.5, 155.4	135	4.6	30.60	13,232.40
	7.73	21.78	6.61	-35.3, 168.6	136	7.1	30.00	13,262.40
	7.76	23.26	6.22	-22.1, 176.4	135	4.4	29.70	13,292.10
	7.77	23.81	6.39	-14.0, 184.5	136	4.5	30.90	13,323.00
	7.75	23.63	6.72	-27.1, 171.4	135	0.0	150.70	13,473.70
	7.73	23.67	6.82	-34.0, 164.5	135	0.0	29.70	13,503.40
	7.71	23.72	6.2	-40.3, 158.2	135	2.7	30.00	13,533.40
	7.63	23.82	5.95	-51.6, 146.9	134	2.1	30.00	13,563.40
11/15/10	7.77	20.64	6.02	-20.8, 183.1	133	7.5	214.20	13,777.60
	7.74	22.97	6.27	39.8, 238.3	133	7.3	31.50	13,809.10
	7.76	23.95	6.41	-34.1, 164.4	132	38	31.80	13,840.90
	7.75	24.4	6.47	-31.5, 167.0	132	3.2	32.70	13,873.60
	7.74	24.17	6.64	-23.6, 174.9	133	0.3	234.30	14,107.90
	7.75	24.31	6.64	-18.1, 180.4	133	3.8	34.80	14,142.70
	7.78	24.29	7.04	-9.9, 188.6	131	2.0	35.10	14,177.80
	7.69	24.24	6.69	-27.1, 171.4	130	1.1	36.90	14,214.70
11/16/10	7.88	22.95	6.72	62.7, 261.2	134	10	408.60	14,623.30
	7.87	22.94	7	53.5, 252.0	133	7.0	32.40	14,655.70
	7.75	22.26	7.34	27.0, 225.9	134	3.5	31.80	14,687.50
	7.66	23.15	5.66	-19.3, 179.2	134	3.3	33.30	14,720.80
	7.75	23.26	5.66	-14.5, 184.0	132	2.1	33.00	14,753.80
	7.80	23.51	6.4	-2.2, 196.3	132	3.3	33.30	14,787.10
11/17/10	7.66	20.09	6.63	86.4, 290.3	134	3.0	174.20	14,961.30
	7.66	20.15	6.52	49.2, 253.1	134	1.8	32.70	14,994.00
	7.58	22.19	5.99	-21.2, 177.4	135	4.2	30.30	15,024.30
	7.67	23.69	6.78	0.6, 199.1	134	3.3	31.80	15,056.10
	7.79	22.32	6.73	69.2, 273.1	134	2.7	310.00	15,366.10

Table B-2.3-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (μS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/17/10	7.75	23.77	6.74	40.6, 239.1	133	0.0	32.70	15,398.80
	7.65	23.97	7.56	11.0, 209.9	134	0.0	32.40	15,431.20
11/18/10	7.63	20.93	6.64	113.5, 317.4	139	1.5	239.40	15,670.60
	7.72	21.99	6.4	120.4, 324.3	140	3.5	34.50	15,705.10
	7.70	23.35	6.63	113.6, 312.1	140	2.8	33.00	15,738.10
	7.76	24.38	6.29	20.5, 219.0	140	2.8	33.00	15,771.10
	7.77	23.03	7.41	81.6, 280.1	138	3.5	325.00	16,096.10
	7.64	23.7	6.71	92.6, 291.1	140	3.0	36.00	16,132.10
11/19/10	7.93	20.42	6.09	100.1, 304.0	137	6.6	226.80	16,358.90
	7.83	21.87	6.66	88.1, 292.0	139	1.7	36.00	16,394.90
	7.70	23.04	6.13	85.2, 283.7	139	2.5	33.00	16,427.90
	7.66	23.98	5.83	82.1, 280.6	140	1.5	33.00	16,460.90
	7.68	24.70	6.36	76.0, 274.5	140	1.3	33.00	16,493.90
	7.68	23.92	6.67	90.3, 288.8	139	3.1	228.40	16,722.30
	7.73	23.19	7.14	89.9, 288.4	138	0.8	31.50	16,753.80
	7.79	23.24	6.71	76.2, 274.3	138	0.4	31.50	16,785.30
11/20/10	7.73	23.74	6.39	93.0, 291.5	139	0.5	656.60	17,441.90
	7.64	24.33	6.17	92.1, 290.6	139	4.0	33.00	17,474.90
	7.71	24.58	6.53	86.3, 284.8	138	2.7	33.00	17,507.90
11/21/10	7.86	20.34	5.34	94.7, 298.6	136	6.5	231.00	17,738.90
	7.86	20.47	6.53	80.3, 284.2	137	0.9	32.40	17,771.30
	7.78	21.38	6.66	92.6, 296.5	138	2.1	31.20	17,802.50
	7.61	22.36	6.4	49.5, 248.0	139	2.6	31.50	17,834.00
	7.68	22.48	6.81	68.1, 272.0	72	0.8	31.80	17,865.80
	7.80	23.46	6.44	64.6, 263.1	138	3.0	207.90	18,073.70
	7.79	23.77	6.79	65.6, 264.1	137	1.2	31.80	18,105.50
	7.72	23.76	6.67	72.1, 270.6	137	0.0	31.80	18,137.30
	7.58	23.96	5.67	53.4, 251.9	137	0.0	31.50	18,168.80
	7.60	24.05	6.26	64.4, 261.9	136	0.8	31.50	18,200.30

[a] Eh (mV) is calculated from an Ag/AgCl-saturated KCl electrode filling solution at 15ºC, 20ºC, and 25ºC by adding temperature-sensitive correction factors of 208.9 mV, 203.9 mV, and 198.5 mV, respectively.

[b] n/r = Not recorded.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the analysis of hydraulic pumping tests conducted during October 2010 at R-60, a regional aquifer well located on an unnamed mesa at the head of Ten Site Canyon, immediately downgradient (east) of Material Disposal Area C, at Los Alamos National Laboratory (the Laboratory). The tests on R-60 were conducted to quantify the hydraulic properties of the screened aquifer and to check for interference effects at nearby well R-46. Testing consisted of brief trial pumping, background water-level data collection, and a 24-h constant-rate pumping test.

As in most of the R-well pumping tests conducted on the Pajarito Plateau, an inflatable packer system was used in R-60 to try to eliminate casing storage effects on the test data. Unfortunately, as described below, the low yield of R-60, along with the limited available drawdown, resulted in complete dewatering of the well screen and filter pack during routine development procedures. Drainage of the filter pack behind the blank casing above the screen allowed entry of air, which apparently was trapped when water levels recovered at the conclusion of development pumping. The trapped air induced a storage-like effect because of expansion and contraction of the air during test pumping and recovery. Thus, it was not possible to eliminate storage effects from the test data.

Conceptual Hydrogeology

R-60 lies within sands and gravels of the Puye Formation, screened from 1330 to 1350.9 ft below ground surface (bgs). The static water level measured on October 23, 2010, before testing was 1318.87 ft bgs. The ground surface elevation at the well was estimated at 7225 ft above mean sea level (amsl), making the approximate water-level elevation 5906.13 ft amsl. Because of the proximity of the water table to the well screen (just 11 ft above it), unconfined conditions were assumed for R-60.

Drill cuttings obtained from R-60 suggested clean sand and gravel were present from 1320 to 1335 ft bgs and from 1345 to 1355 ft bgs, with intervals of silty material immediately above, between, and below these zones. Thus, the hydraulically contiguous interval penetrated by the well screen extended essentially from 1320 to 1355 ft bgs.

Low Well Yield

As mentioned previously, the low production capacity of the well resulted in substantial drawdown during pump development at just 1.2 gallons per minute (gpm). At this discharge rate, the water level drew down to near the bottom of the screen, dewatering the screen and filter pack, including the portion of the filter pack above the screen behind the blank casing. It was hoped that the formation porosity and permeability would be sufficient to allow trapped air above the screen to be expelled from the filter pack during water level recovery, thereby resaturating the filter pack before testing.

In setting up for the pumping test, the pump intake was initially installed above the top of the well screen to avoid dewatering the screen and filter pack. (This was done to minimize storage effects in case the previously drained filter pack had refilled by expelling any entrained air during recovery.) This allowed the discharge rate to be adjusted to a level that would keep the pumping water level above the screen at all times during testing. At this installation depth, the packer remained above the static water level, so once the discharge valve was adjusted to the proper setting and preliminary purging was completed, the pump was shut off and the pump/packer assembly was lowered an additional 10 ft to ensure submergence of the packer before it was inflated.

These efforts were to no avail, however, as the data collected during testing exhibited significant storage effects. This implied that trapped air in the filter pack above the screen must not have been expelled readily during water-level recovery and down time between development and testing.

The low yield of the well also affected the operation of the 5-horsepower (hp) pump used in the testing. Keeping the pumping water level a few feet above the top of the screen dictated running the pump at rates approaching 0.5 gpm—less than optimal according to the pump and motor manufacturers. The pump manufacturer recommends a minimum rate of more than 3 gpm for this particular pump to avoid undue strain on the pump components caused by excessive back pressure. Similarly, the motor manufacturer's guideline called for a minimum flow rate of more than 1.5 gpm (based on the size of the shroud in which the pump was installed) to provide proper cooling of the motor. During testing, it was observed that the discharge rate varied erratically—ostensibly impossible when pumping under relatively uniform conditions. It was possible that the excessive backpressure applied to the pump and/or excessive heating of the motor may have interfered with proper pump operation and contributed to the unusual pump output characteristics.

R-60 Testing

R-60 was tested from October 23 to 28, 2010. After running the pump on October 23 and again early on October 24, testing began with brief trial pumping on October 24, background data collection, and a 24-h constant-rate pumping test that was started on October 26. Following shutdown of the 24-h test on October 27, recovery data were recorded for 24 h until October 28.

On October 23, when the pump was installed, potable water from a nearby hydrant was used to manually fill the drop pipe sections as they were installed. This was done to eliminate (1) the enormous time it would have taken to fill the drop pipe by pumping the well (at a low rate) following installation, and (2) the damaging/destructive cavitation that would have occurred while the pump was being used to fill the drop pipe.

Filling the drop pipe manually meant that each 20-ft section immediately beneath a check valve (at about 260-ft intervals) remained full of air following installation. It was likely that preliminary pumping on October 23 and 24 and trial testing on October 24 were not sufficient to purge all of the air out of the drop pipe. As a result, compression of the remaining trapped air within the drop pipe sections had a transient effect on startup discharge rates and drawdown during the trial tests, as described below.

Trial testing of R-60 began at 9:00 a.m. on October 24 at a discharge rate of 0.58 gpm and continued for 30 min. Following shut down, recovery data were recorded for 30 min until 10:00 a.m. when trial 2 pumping began at a discharge rate of 0.56 gpm. Following 60 min of pumping, the pump was shut down, and recovery/background data were collected for 2700 min until 8:00 a.m. on October 26.

At 8:00 a.m. on October 26, the 24-h pumping test was begun, with an average discharge rate during the test of 0.54 gpm. Pumping continued for 1440 min until 8:00 a.m. on October 27. Following shutdown, recovery data were recorded for 1440 min until 8:00 a.m. on October 28 when the pump was pulled from the well.

C-2.0 BACKGROUND DATA

The background water-level data collected in conjunction with running the pumping tests allow the analyst to observe the water-level fluctuations that occur naturally in the aquifer and help distinguish between water-level changes caused by conducting the pumping test and changes associated with other causes.

Background water-level fluctuations have several causes, among them barometric pressure changes, operation of other wells in the aquifer, Earth tides, and long-term trends related to weather patterns. The background data hydrographs from the monitored wells were compared with barometric pressure data from the area to determine if a correlation existed.

Previous pumping tests on the plateau have demonstrated a barometric efficiency for most wells of between 90% and 100%. Barometric efficiency is defined as the ratio of water-level change divided by barometric pressure change, expressed as a percentage. In the initial pumping tests conducted on the early R-wells, downhole pressure was monitored using a vented pressure transducer. This equipment measures the difference between the total pressure applied to the transducer and the barometric pressure, this difference being the true height of water above the transducer.

Subsequent pumping tests, including at R-60, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency, and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from Technical Area 54 (TA-54) tower site from the Waste and Environmental Services Division—Environmental Data and Analysis (WES-EDA). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is at approximately 7225 ft amsl. The static water level in R-60 was 1318.87 ft below land surface, making the approximate water-table elevation 5906.13 ft amsl. Therefore, the measured barometric pressure data from TA-54 had to be adjusted to reflect the pressure at the elevation of the water table within R-60.

The following formula was used to adjust the measured barometric pressure data:

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R-60} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-60}}{T_{WELL}}\right)\right] \qquad \textbf{Equation C-1}$$

where, P_{WT} = barometric pressure at the water table inside R-60

P_{TA54} = barometric pressure measured at TA-54

g = acceleration of gravity, in m/sec^2 (9.80665 m/sec^2)

R = gas constant, in J/kg/degree kelvin (287.04 J/kg/degree kelvin)

E_{R-60} = land surface elevation at R-60 site, in feet (approximately 7225 ft)

E_{TA54} = elevation of barometric pressure measuring point at TA-54, in feet (6548 ft)

E_{WT} = elevation of the water level in R-60, in feet (approximately 5906.13 ft)

T_{TA54} = air temperature near TA-54, in degrees kelvin (assigned a value of 43.2 degrees Fahrenheit, or 279.4 degrees kelvin)

T_{WELL} = air temperature inside R-60, in degrees kelvin (assigned a value of 71.1 degrees Fahrenheit, or 294.9 degrees kelvin)

This formula is an adaptation of an equation WES-EDA provided. It can be derived from the ideal gas law and standard physics principles. An inherent assumption in the derivation of the equation is that the air temperature between TA-54 and the well is temporally and spatially constant and that the temperature of the air column in the well is similarly constant.

The corrected barometric pressure data reflecting pressure conditions at the water table were compared with the water-level hydrograph to discern the correlation between the two and determine whether water level corrections would be needed prior to data analysis.

C-3.0 IMPORTANCE OF EARLY DATA

When pumping or recovery first begins, the vertical extent of the cone of depression is limited to approximately the well screen length, the filter pack length, or the aquifer thickness in relatively thin permeable strata. For many pumping tests on the plateau, the early pumping period is the only time the effective height of the cone of depression is known with certainty because, soon after startup, the cone of depression expands vertically through permeable materials above and/or below the screened interval. Thus, the early data often offer the best opportunity to obtain hydraulic conductivity information because conductivity would equal the earliest-time transmissivity divided by the well screen length.

Unfortunately, in many pumping tests, casing-storage effects dominate the early-time data, potentially hindering the effort to determine the transmissivity of the screened interval. The duration of casing-storage effects can be estimated using the following equation (Schafer 1978, 098240).

$$t_c = \frac{0.6\left(D^2 - d^2\right)}{\frac{Q}{s}}$$

Equation C-2

where, t_c = duration of casing storage effect, in minutes

D = inside diameter of well casing, in inches

d = outside diameter of column pipe, in inches

Q = discharge rate, in gallons per minute

s = drawdown observed in pumped well at time t_c, in feet

The calculated casing storage time is quite conservative. Often, the data show that significant effects of casing storage have dissipated after about half the computed time.

For wells screened across the water table or wells in which the filter pack can drain during pumping, there can be an additional storage contribution from the filter pack. The following equation provides an estimate of the storage duration accounting for both casing and filter pack storage.

$$t_c = \frac{0.6\left[\left(D^2 - d^2\right) + S_y\left(D_B^2 - D_C^2\right)\right]}{\frac{Q}{s}}$$

Equation C-3

where, S_y = short term specific yield of filter media (typically 0.2)

D_B = diameter of borehole, in inches

D_C = outside diameter of well casing, in inches

This equation was derived from Equation C-2 on a proportional basis by increasing the computed time in direct proportion to the additional volume of water expected to drain from the filter pack. (To prove this, note that the left hand term within the brackets is directly proportional to the annular area [and volume] between the casing and drop pipe while the right hand term is proportional to the area [and volume] between the borehole and the casing, corrected for the drainable porosity of the filter pack. Thus, the summed term within the brackets accounts for all of the volume [casing water and drained filter pack water] appropriately.)

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. Unfortunately, in R-60, air was trapped in the filter pack above the screen because of previous dewatering of the well screen during development. As a result, the data set showed substantial storage effects.

C-4.0 TIME-DRAWDOWN METHODS

Time-drawdown data can be analyzed using a variety of methods. Among them is the Theis method (1934-1935, 098241). The Theis equation describes drawdown around a well as follows:

$$s = \frac{114.6Q}{T} W(u)$$ **Equation C-4**

where,

$$W(u) = \int_u^\infty \frac{e^{-x}}{x} dx$$ **Equation C-5**

and

$$u = \frac{1.87r^2S}{Tt}$$ **Equation C-6**

and where, s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

To use the Theis method of analysis, the time-drawdown data are plotted on log-log graph paper. Then, Theis curve matching is performed using the Theis type curve—a plot of the Theis well function $W(u)$ versus $1/u$. Curve matching is accomplished by overlaying the type curve on the data plot and, while keeping the coordinate axes of the two plots parallel, shifting the data plot to align with the type curve, effecting a match position. An arbitrary point, referred to as the match point, is selected from the overlapping parts of the plots. Match-point coordinates are recorded from the two graphs, yielding four values: $W(u)$: $1/u$, s, and t. These match-point values are used to compute transmissivity and storage coefficient as follows:

$$T = \frac{114.6Q}{s} W(u)$$

Equation C-7

$$S = \frac{Tut}{2693r^2}$$

Equation C-8

where, T = transmissivity, in gallons per day per foot

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

An alternative solution method applicable to time-drawdown data is the Cooper-Jacob method (1946, 098236), a simplification of the Theis equation that is mathematically equivalent to the Theis equation for most pumped well data. The Cooper-Jacob equation describes drawdown around a pumping well as follows:

$$s = \frac{264Q}{T} \log \frac{0.3Tt}{r^2 S}$$

Equation C-9

The Cooper-Jacob equation is a simplified approximation of the Theis equation and is valid whenever the u value is less than about 0.05. For small radius values (e.g., corresponding to borehole radii), u is less than 0.05 at very early pumping times and therefore is less than 0.05 for most or all measured drawdown values. Thus, for the pumped well, the Cooper-Jacob equation usually can be considered a valid approximation of the Theis equation. An exception occurs when the transmissivity of the aquifer is very low. In that case, some of the early pumped well drawdown data may not be well approximated by the Cooper-Jacob equation.

According to the Cooper-Jacob method, the time-drawdown data are plotted on a semilog graph, with time plotted on the logarithmic scale. Then a straight line of best fit is constructed through the data points and transmissivity is calculated using:

$$T = \frac{264Q}{\Delta s}$$

Equation C-10

where, T = transmissivity, in gallons per day per foot

Q = discharge rate, in gallons per minute

Δs = change in head over one log cycle of the graph, in feet

Because many of the test wells completed on the plateau are severely partially penetrating, an alternate solution considered for assessing aquifer conditions is the Hantush equation for partially penetrating wells (Hantush 1961, 098237; Hantush 1961, 106003). The Hantush equation is as follows:

Equation C-11

$$s = \frac{Q}{4\pi T}\left[W(u) + \frac{2b^2}{\pi^2 (l-d)(l'-d')}\sum_{n=1}^{\infty}\frac{1}{n^2}\left(\sin\frac{n\pi l}{b} - \sin\frac{n\pi d}{b}\right)\left(\sin\frac{n\pi l'}{b} - \sin\frac{n\pi d'}{b}\right)W\left(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}\right)\right]$$

where, in consistent units, s, Q, T, t, r, S, and u are as previously defined and

b = aquifer thickness

d = distance from top of aquifer to top of well screen in pumped well

l = distance from top of aquifer to bottom of well screen in pumped well

d' = distance from top of aquifer to top of well screen in observation well

l' = distance from top of aquifer to bottom of well screen in observation well

K_z = vertical hydraulic conductivity

K_r = horizontal hydraulic conductivity

In this equation, $W(u)$ is the Theis well function and $W(u,\beta)$ is the Hantush well function for leaky aquifers where:

$$\beta = \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}$$

Equation C-12

Note that for single-well tests, $d = d'$ and $l = l'$.

C-5.0 RECOVERY METHODS

Recovery data were analyzed using the Theis recovery method. This is a semilog analysis method similar to the Cooper-Jacob procedure.

In this method, residual drawdown is plotted on a semilog graph versus the ratio t/t', where t is the time since pumping began and t' is the time since pumping stopped. A straight line of best fit is constructed through the data points and T is calculated from the slope of the line as follows:

$$T = \frac{264Q}{\Delta s}$$ **Equation C-13**

The recovery data are particularly useful compared with time-drawdown data. Because the pump is not running, spurious data responses associated with dynamic discharge rate fluctuations are eliminated. The result is that the data set is generally “smoother” and easier to analyze.

Recovery data also can be analyzed using the Hantush equation for partial penetration. This approach is generally applied to the early data in a plot of recovery versus recovery time.

C-6.0 SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is unknown, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

For fully penetrating wells, the Cooper-Jacob equation can be iterated to solve for the lower-bound hydraulic conductivity. However, the Cooper-Jacob equation (assuming full penetration) ignores the contribution to well yield from permeable sediments above and below the screened interval. To account for this contribution, it is necessary to use a computation algorithm that includes the effects of partial penetration. One such approach was introduced by Brons and Marting (1961, 098235) and augmented by Bradbury and Rothchild (1985, 098234).

Brons and Marting introduced a dimensionless drawdown correction factor, s_P, approximated by Bradbury and Rothschild as follows:

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right]$$ **Equation C-14**

In this equation, L is the well screen length in feet. When the dimensionless drawdown parameter is incorporated, the conductivity is obtained by iterating the following formula:

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right) \qquad \textbf{Equation C-15}$$

The Brons and Marting procedure can be applied to both partially penetrating and fully penetrating wells.

To apply this procedure, a storage coefficient value must be assigned. Storage coefficient values generally range from 10^{-5} to 10^{-3} for confined aquifers and 0.01 to 0.25 for unconfined aquifers (Driscoll 1986, 104226). Unconfined conditions were assumed for R-60, and a storage coefficient of 0.10 was arbitrarily assigned. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. For R-60, an arbitrary thickness of 100 ft was used in the calculations. For partially penetrating conditions, the calculations are not particularly sensitive to the choice of aquifer thickness because sediments far above or below the screen typically contribute little flow.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-60 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure C-7.0-1 shows aquifer pressure data from R-60 during the test period along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-60 data are referred to in the figure as the “apparent hydrograph” because the measurements reflect the sum of water pressure and barometric pressure, having been recorded using a nonvented pressure transducer. The times of the pumping periods for the R-60 pumping tests are included on the figure for reference.

R-60 showed no significant pressure change in response to barometric pressure fluctuations, suggesting a barometric efficiency near 100%. The slight perturbations in the apparent hydrograph showed a diurnal pattern, likely an Earth-tide response. These variations are easier to see in the expanded-scale plot in Figure C-7.0-2.

A small overall rise in water levels was observed during the background monitoring period. This may have been recovery from previous pumping (purging on October 23 and 24 and trial testing on October 24) or may have been a reflection of seasonal aquifer rebound from changing municipal pumping patterns (reduced production compared with summertime water usage).

Hydrograph data from nearby regional well R-46 (about 700 ft away) were downloaded to check for a possible pumping response to the R-60 tests. Because the barometric pressure fluctuations in the hydrograph were large, it was necessary to correct the water-level data by removing the barometric effect. This was done using BETCO (barometric and Earth-tide correction) software—a mathematically complex correction algorithm that uses regression deconvolution (Toll et al., 2007) to modify the data. The BETCO correction not only removes barometric pressure effects, but can remove Earth tide effects as well.

Figure C-7.0-3 shows the hydrograph data obtained from R-46 along with the BETCO correction. It was apparent that pumping R-60 at a little over half a gallon per minute had no discernable effect on R-46 water levels.

C-8.0 WELL R-60 DATA ANALYSIS

This section presents the data obtained from the R-60 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery from trial 1, trial 2 and the 24-h constant-rate test.

C-8.1 Well R-60 Trial 1 Test

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from the trial 1 test on R-60. As shown in the figure, exaggerated drawdown occurred for the first 25 sec or so, indicating a brief period during which the discharge rate was elevated. The pump had been lowered 10 ft just before testing so the upper 10 ft of the drop pipe was empty on startup. It took about 25 sec for water to fill the added drop pipe and reach the discharge valve. Once water reached the valve, the backpressure increased and reduced the flow rate.

An estimate was made of the effective storage time associated with expansion (and subsequent compression) of trapped air in the filter pack above the well screen. Applying Equation C-3 to the full drawdown observed in the various R-60 tests suggested storage durations approaching 4 h. The actual movement of the phreatic surface in the filter pack would have been only about 25% of this because of compression of the overlying air column that would have occurred when water levels recovered following the initial dewatering of the screen and filter pack. Thus, it was concluded that typical storage times would be on the order of 1 h (60 min). Because the trial 1 test was only 30 min long, the data were assumed to be storage affected and were not analyzed for transmissivity.

Figure C-8.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. The data showed classic storage-like response. Because of the limited recovery time of 30 min, no analysis was performed.

For illustrative purposes, the recovery data were plotted on the log-log graph shown in Figure C-8.1-3. The early straight-line response was consistent with storage response. Normally, the observed slope would be expected to have unit slope. However, progressive compression of the trapped air column would be expected to cause the measured response to vary from this theoretical prediction.

C-8.2 Well R-60 Trial 2 Test

Figure C-8.2-1 shows a semilog plot of the drawdown data collected from the trial 2 test on R-60 at a discharge rate of 0.56 gpm. The first few seconds of data showed slight exaggerated drawdown temporarily, probably an effect of slight residual air in the drop pipe beneath the uppermost check valves. Upon startup, the trapped air would have compressed as the check valves opened, because of being subjected to greater hydraulic pressure from the overlying water column in the drop pipe. Apparently a few seconds of pumping was needed to replenish this lost volume and begin producing water at full pressure at the surface discharge valve.

The bulk of the plot showed classic storage response. The approximate storage times are shown on the graph for reference.

The transmissivity estimated from the latest part of the data plot was 100 gallons per day (gpd) per foot. This was interpreted as the transmissivity of the hydraulically contiguous interval from 1320 to 1355 ft. This effective thickness of 35 ft made the computed average hydraulic conductivity 2.9 gpd/ft^2, or 0.38 ft/day. It was possible that enough time had elapsed that the cone of depression may have penetrated a greater effective sediment thickness. A greater assumed effective sediment thickness would reduce the calculated hydraulic conductivity estimates accordingly.

Figure C-8.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. The data again showed typical storage response. Figure C-8.2-3 shows a log-log plot of the recovery data, indicating that the early data exhibited a nearly straight line with close to unit slope, confirming the likelihood that the data were storage affected.

Figure C-8.2-4 shows an expanded-scale graph of the recovery data along with the approximate storage times for reference. The transmissivity computed from the data was 85 gpd/ft making the calculated hydraulic conductivity 2.4 gpd/ft^2, or 0.32 ft/d. Again, if this transmissivity value represents a sediment thickness greater than the assumed 35-ft interval, the corresponding hydraulic conductivity would be less.

The late data showed flattening, perhaps related to ongoing vertical growth of the cone of depression (partial penetration effects and/or leakage effects) or delayed yield of the unconfined aquifer.

C-8.3 Well R-60 24-h Constant-Rate Test

Figure C-8.3-1 shows a semilog plot of the drawdown data collected from the 24-h constant-rate pumping test conducted at an average discharge rate of 0.54 gpm. The early data on the graph showed exaggerated drawdown for the first quarter minute of pumping. Cold weather conditions had dictated draining the upper portion of the drop pipe overnight to prevent freezing and, as a result, initial pumping was against reduced head until the drop pipe refilled and water reached the surface discharge valve. Once water reached the valve, the backpressure increased and the flow rate decreased accordingly.

Over the first few hours of pumping, the discharge rate declined erratically. After about 200 min, the rate fell below 0.5 gpm. To avoid damaging the pump and motor, the flow rate was increased slightly as indicated on the graph. Subsequent erratic drawdown data showed that the discharge rate continued to vary slightly over the remaining pumping period.

Figure C-8.3-2 shows the recovery data collected following shutdown of the 24-h constant-rate pumping test. As indicated on the plot, the bulk of the data reflected storage effects. The estimated storage times are included on the graph for reference.

Figure C-8.3-3 shows a log-log plot of the recovery data. The early-time straight line trend was consistent with storage effects.

Figure C-8.3-4 shows an expanded-scale plot of the recovery data along with the estimated storage times for reference. The transmissivity computed from the line of fit shown on the graph was 99 gpd/ft, making the hydraulic conductivity 2.8 gpd/ft^2, or 0.38 ft/d.

The late recovery data showed continuous flattening over time, consistent with vertical expansion of the cone of depression and/or delayed yield effects.

C-8.4 Well R-60 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by R-60. This was done to provide a frame of reference for evaluating the foregoing analyses.

At the end of the 24-h pumping test, the discharge rate was 0.54 gpm with a resulting drawdown of 7.5 ft for a specific capacity of 0.072 gpm/ft. In addition to specific capacity and pumping time, other input values used in the calculations included a storage coefficient value of 0.10, a borehole radius of 0.61 ft (inferred from the volume of filter pack required to backfill the screen zone), a screen length of 20.9 ft, and an arbitrary saturated thickness of 100 ft.

Applying the Brons and Marting method to these inputs yielded a lower-bound hydraulic conductivity value of 2.7 gpd/ft^2, or 0.36 ft/d. The average hydraulic conductivity value from the foregoing pumping test analyses was also 2.7 gpd/ft^2, or 0.36 ft/d, consistent with the lower-bound value and suggesting a high well efficiency.

C-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-60. The tests were performed to gain an understanding of the hydraulic characteristics of the screen zone and possible effects at nearby regional well R-46.

A comparison of barometric pressure and R-60 water level data showed a high barometric efficiency and a small diurnal effect, probably a result of Earth tides.

Pumping R-60 at 0.54 gpm for 1440 min had no discernable effect on water levels in R-46.

Despite incorporating an inflatable packer in the pumping string, storage effects were observed in the test data. This was likely attributable to trapped air in the filter pack above the screen that entered the well during development pumping when the well screen was fully dewatered.

Analysis of the R-60 pumping tests showed an average hydraulic conductivity value of 2.7 gpd/ft^2, or 0.36 ft/d for the estimated 35-ft-thick contiguous permeable zone penetrated by the screen. Late test data showed continuous flattening of the data curves consistent with continuous vertical growth of the cone of depression (partial penetration or leakage effects) and/or delay yield.

R-60 produced 0.54 gpm for 1440 min with 7.5 ft of drawdown for a specific capacity of 0.072 gpm/ft. The lower-bound hydraulic conductivity computed from this information was 2.7 gpd/ft^2 or 0.36 ft/d, consistent with the pumping tests values.

C-10.0 REFERENCES

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

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

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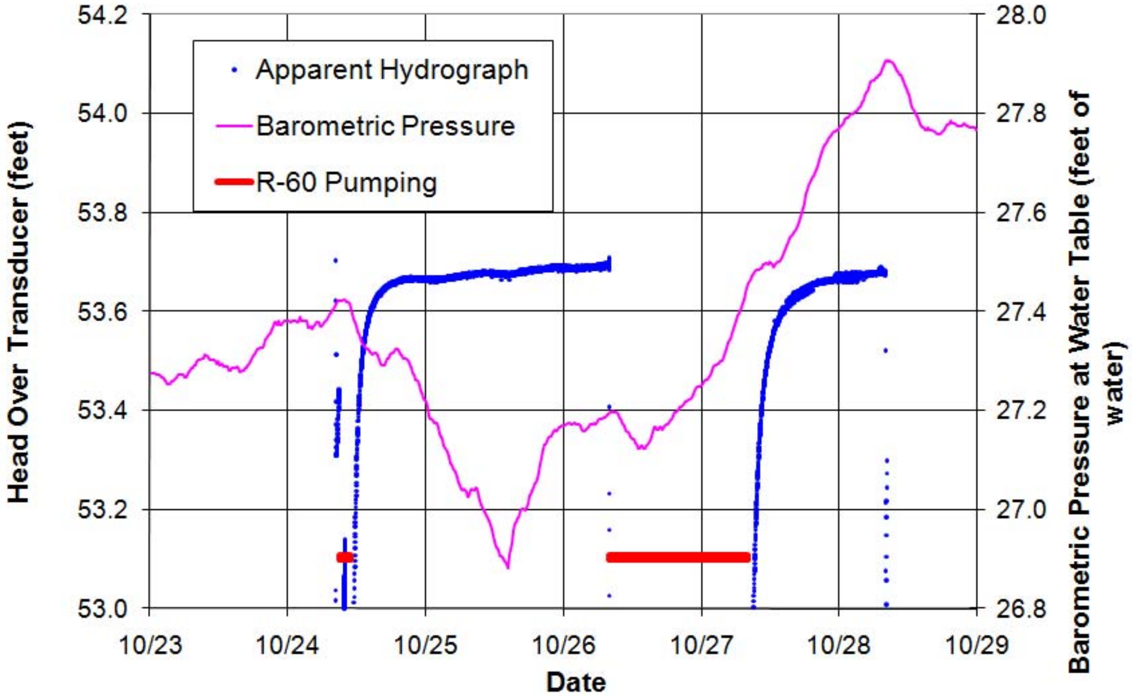


Figure C-7.0-1 Well R-60 apparent hydrograph

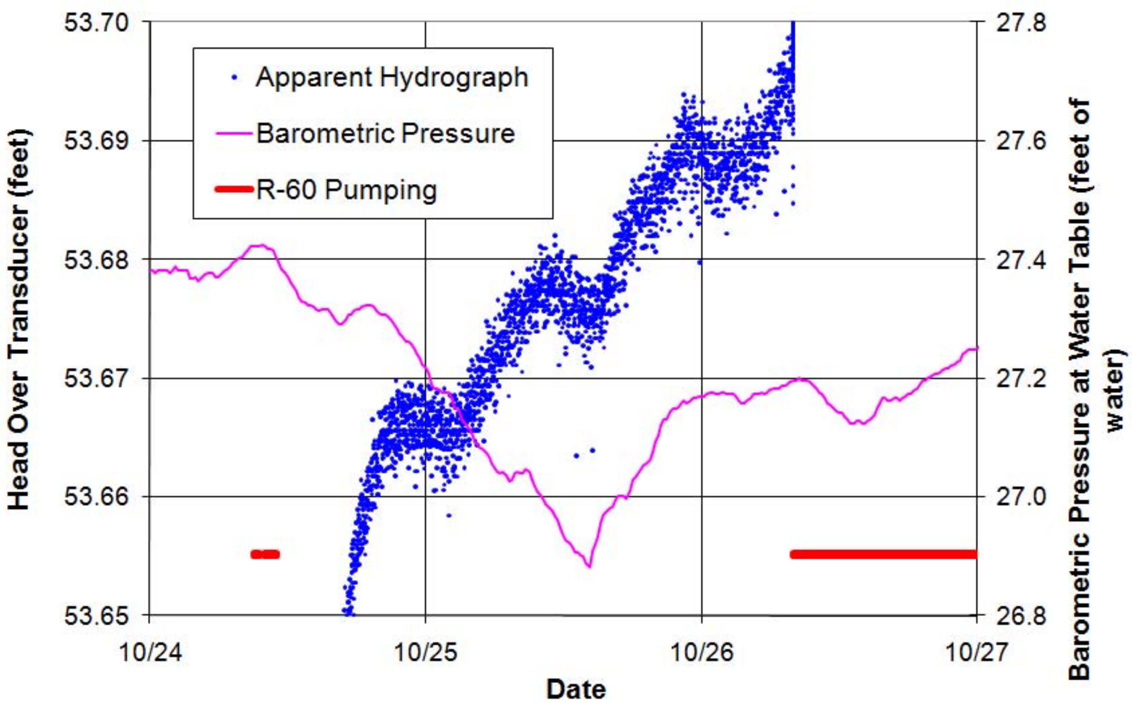


Figure C-7.0-2 Well R-60 apparent hydrograph—expanded scale

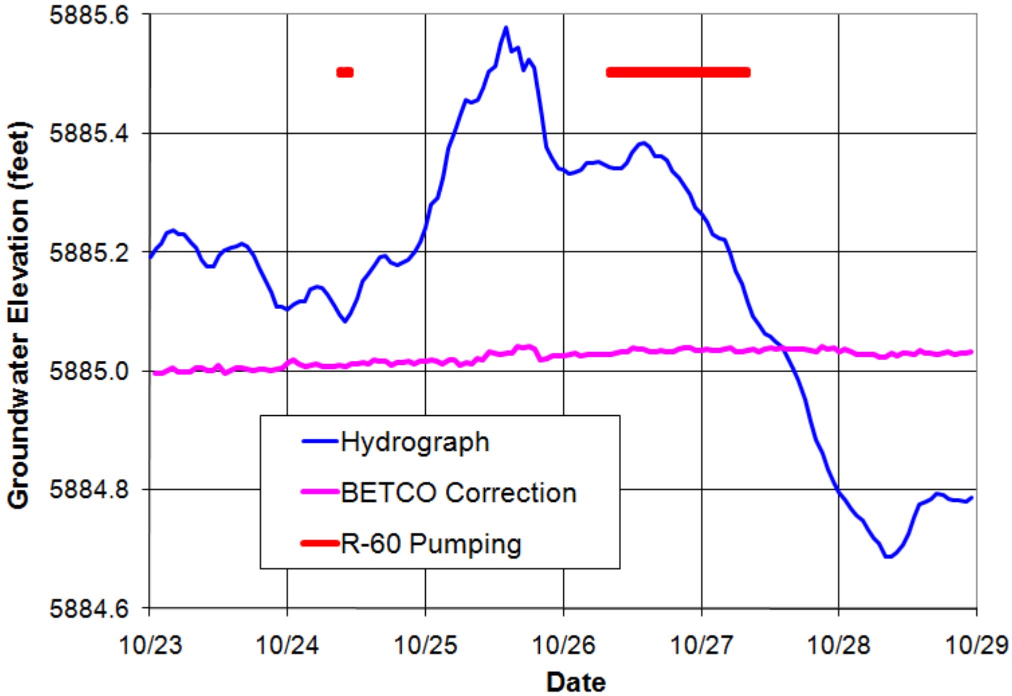


Figure C-7.0-3 Well R-46 hydrograph

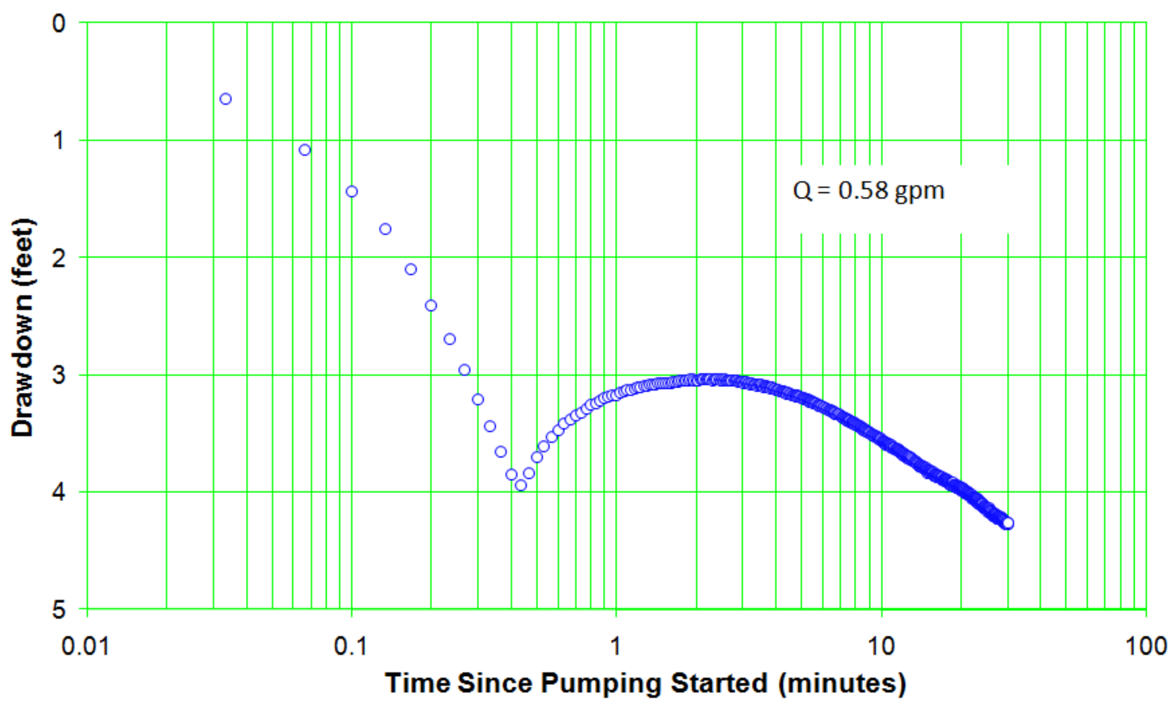


Figure C-8.1-1 Well R-60 trial 1 drawdown

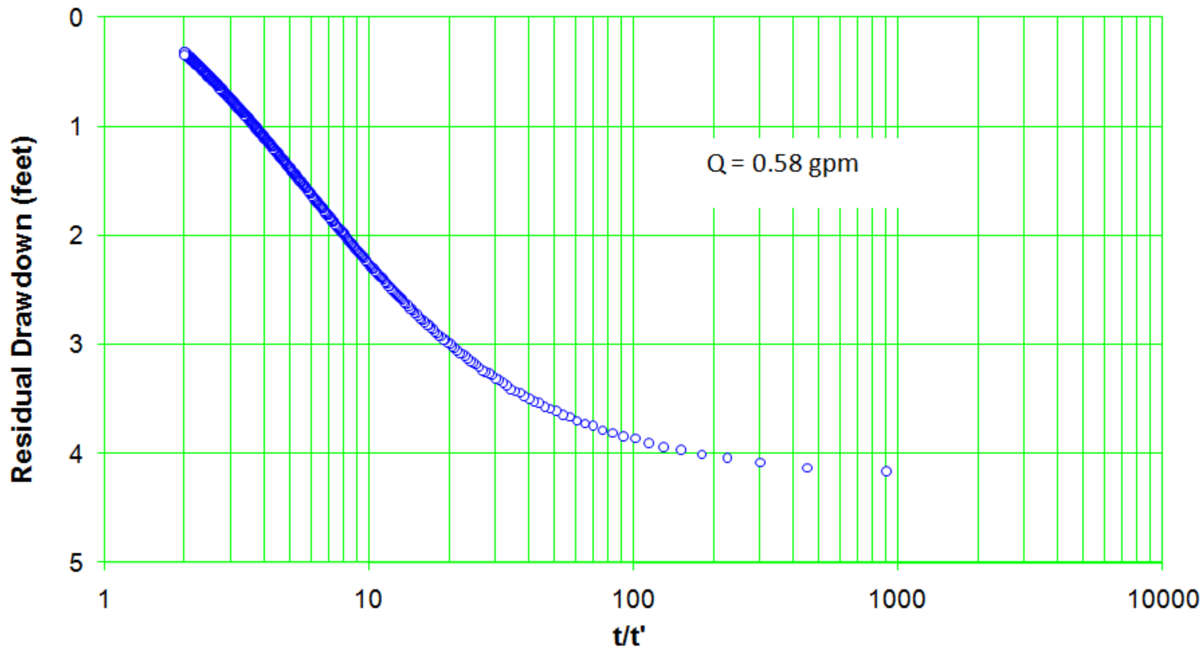


Figure C-8.1-2 Well R-60 trial 1 recovery

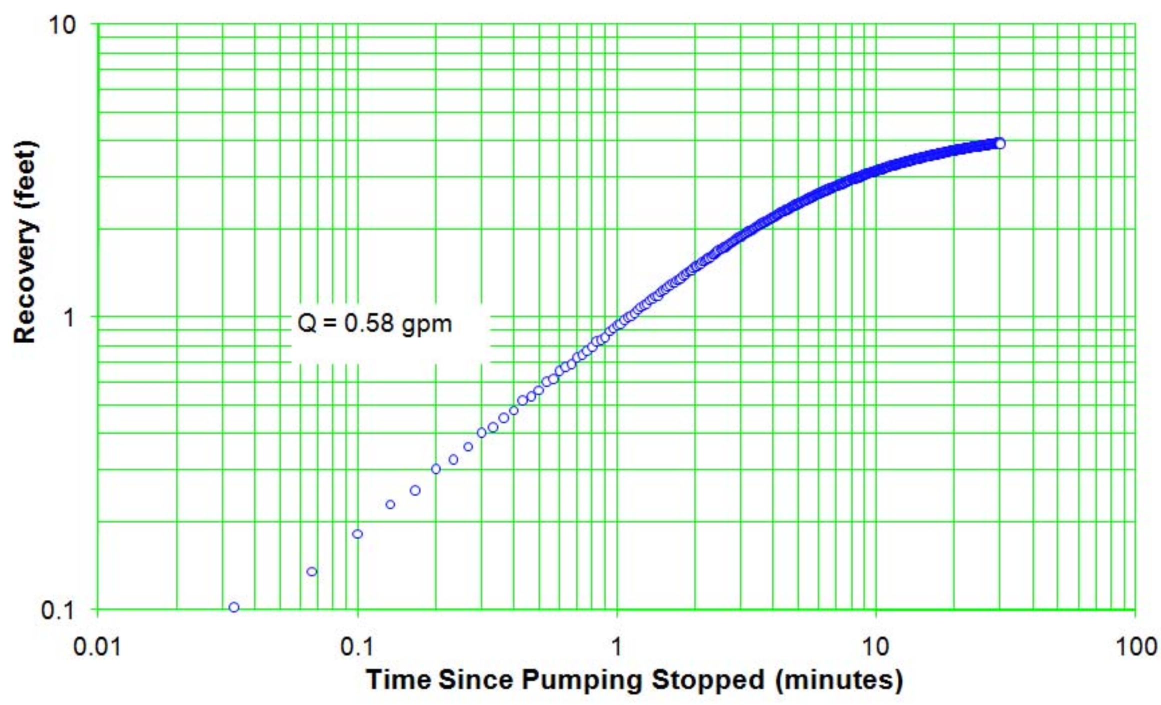


Figure C-8.1-3 Log-log plot of R-60 trial 1 recovery

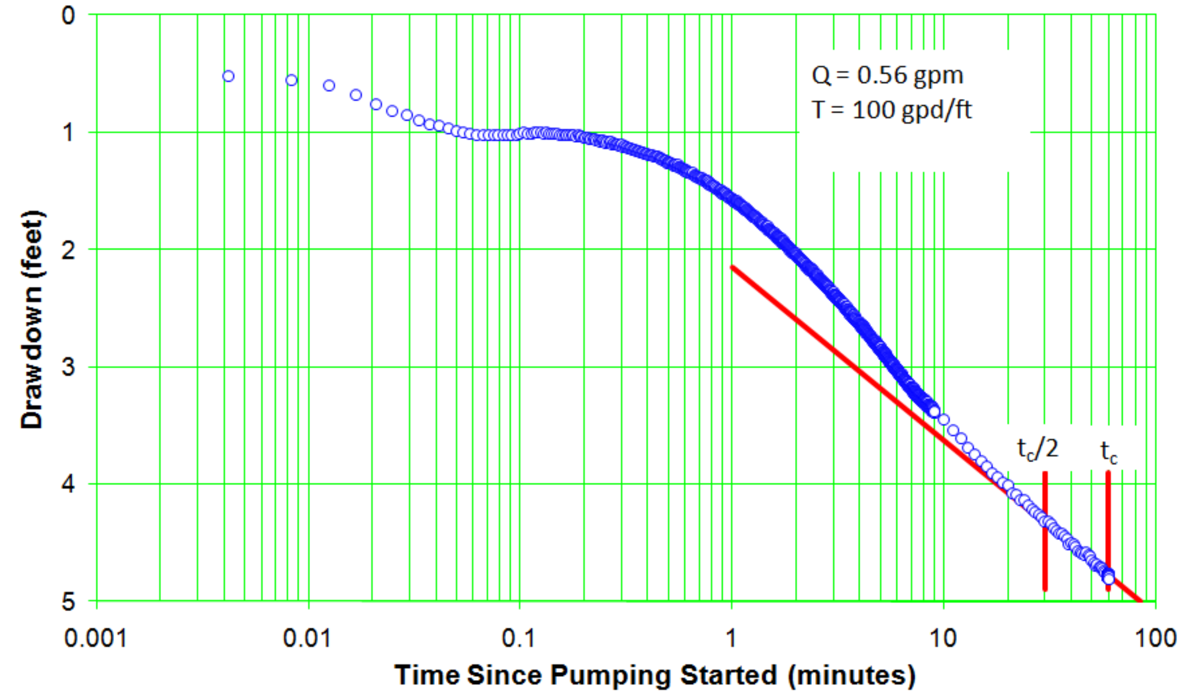


Figure C-8.2-1 Well R-60 trial 2 drawdown

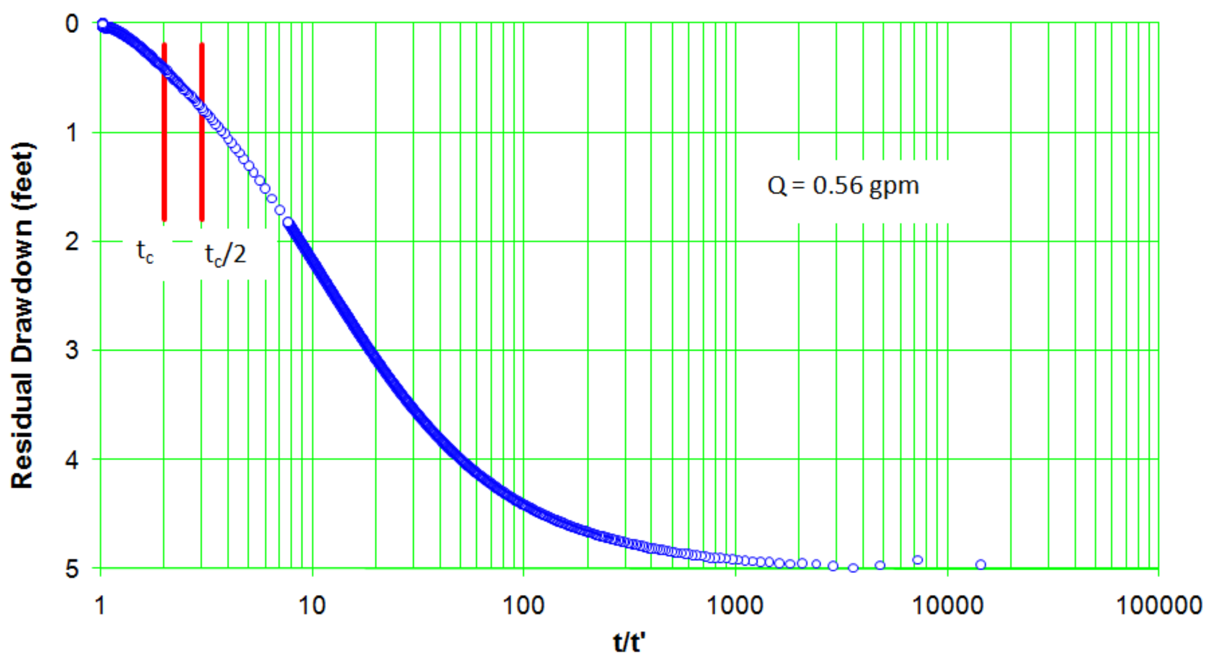


Figure C-8.2-2 Well R-60 trial 2 recovery

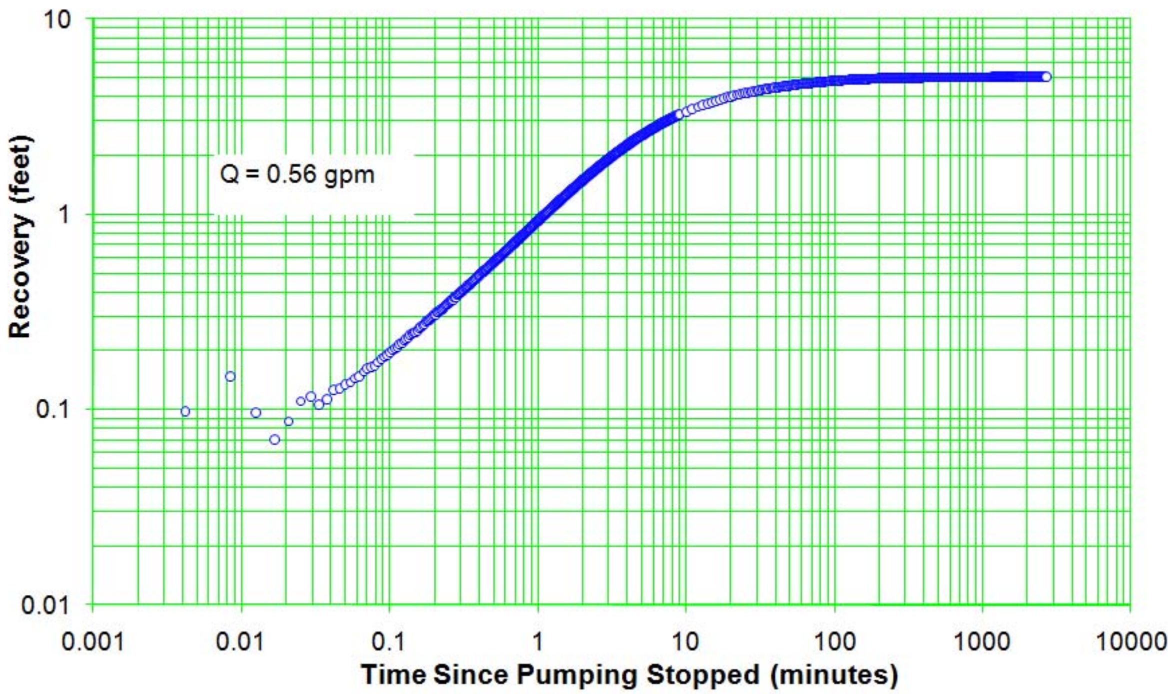


Figure C-8.2-3 Log-log plot of R-60 trial 2 recovery

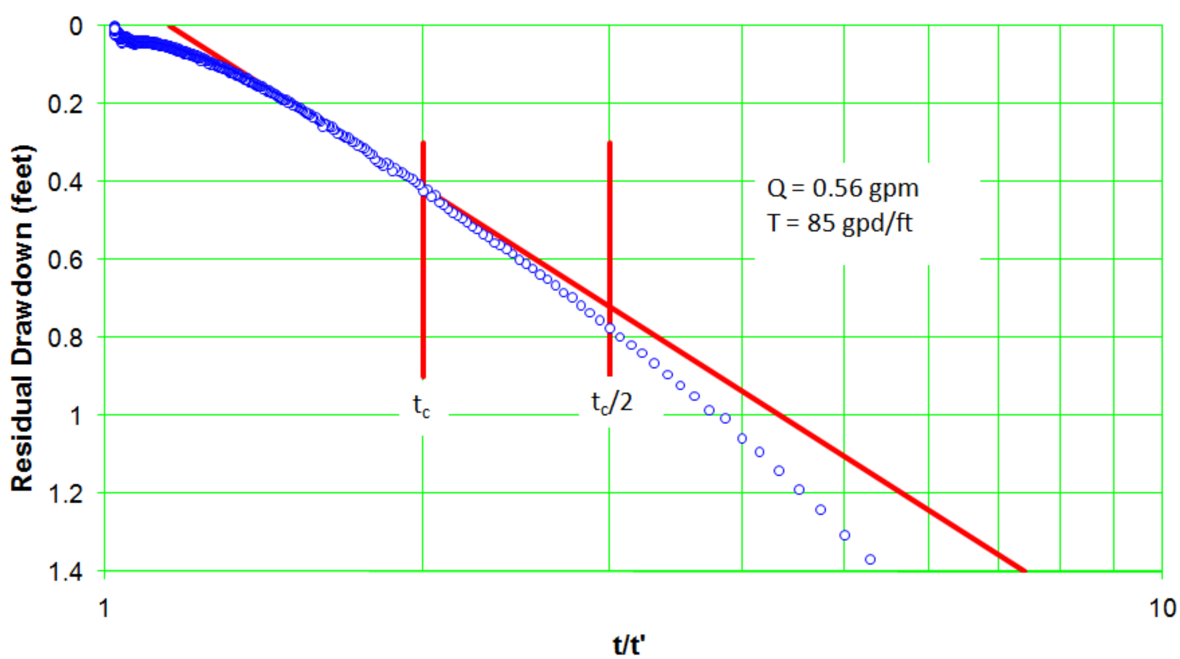


Figure C-8.2-4 Well R-60 trial 2 recovery—expanded scale

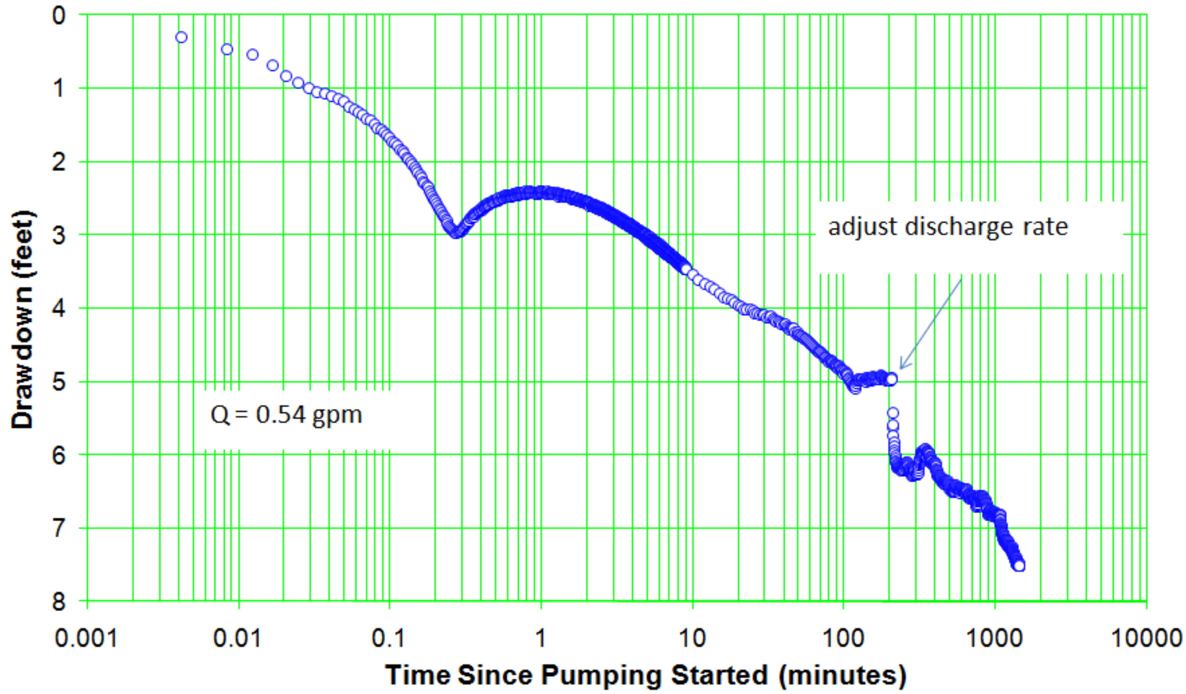


Figure C-8.3-1 Well R-60 drawdown

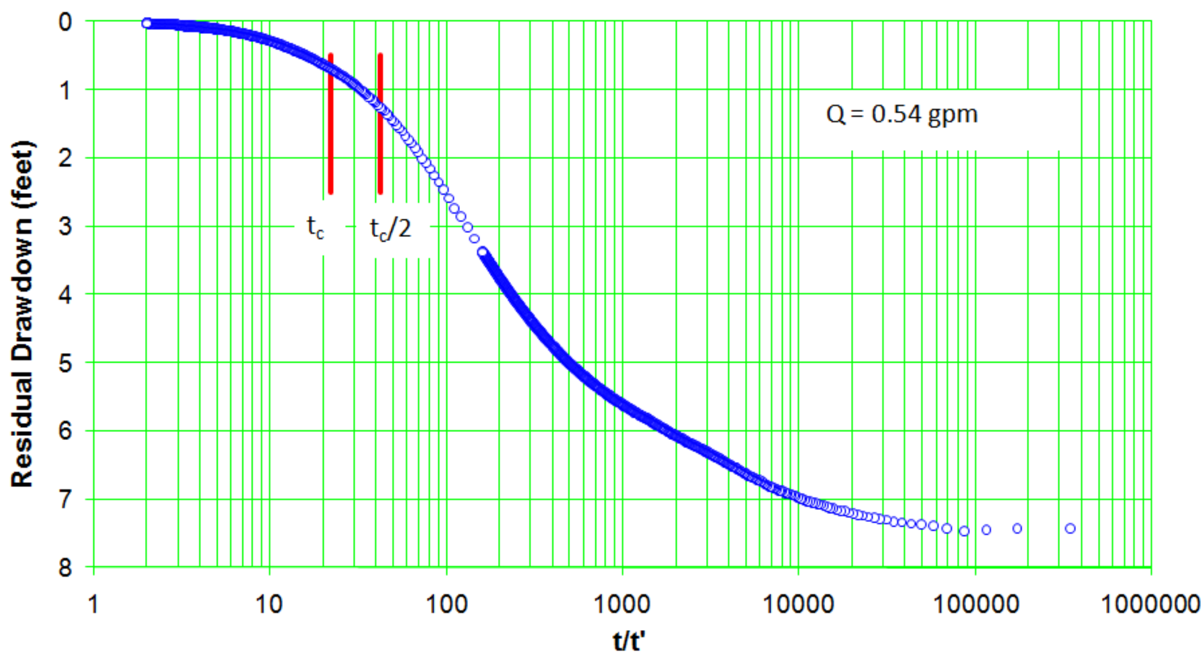


Figure C-8.3-2 Well R-60 recovery

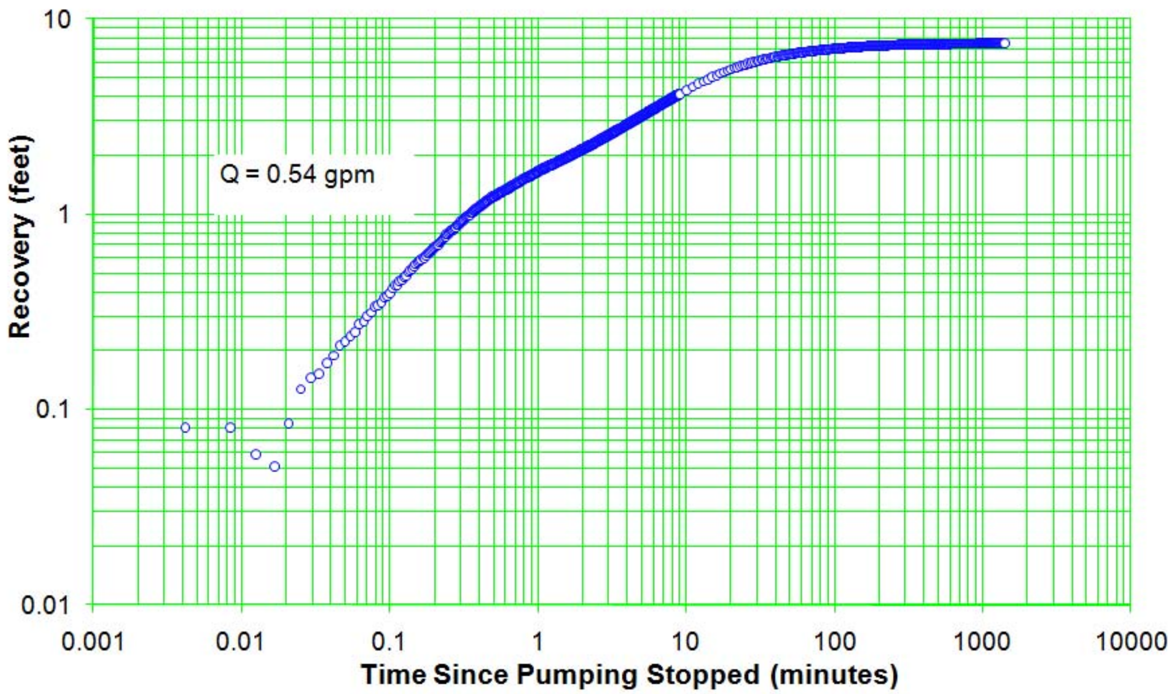


Figure C-8.3-3 Log-log plot of R-60 recovery

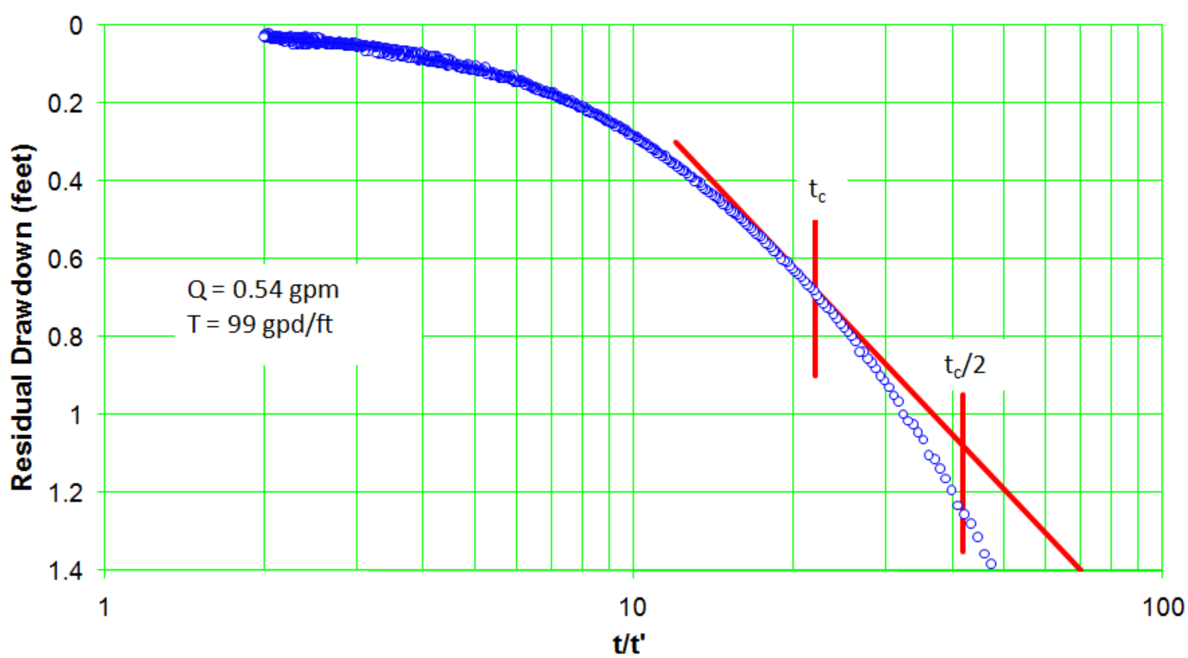


Figure C-8.3-4 Well R-60 recovery—expanded scale

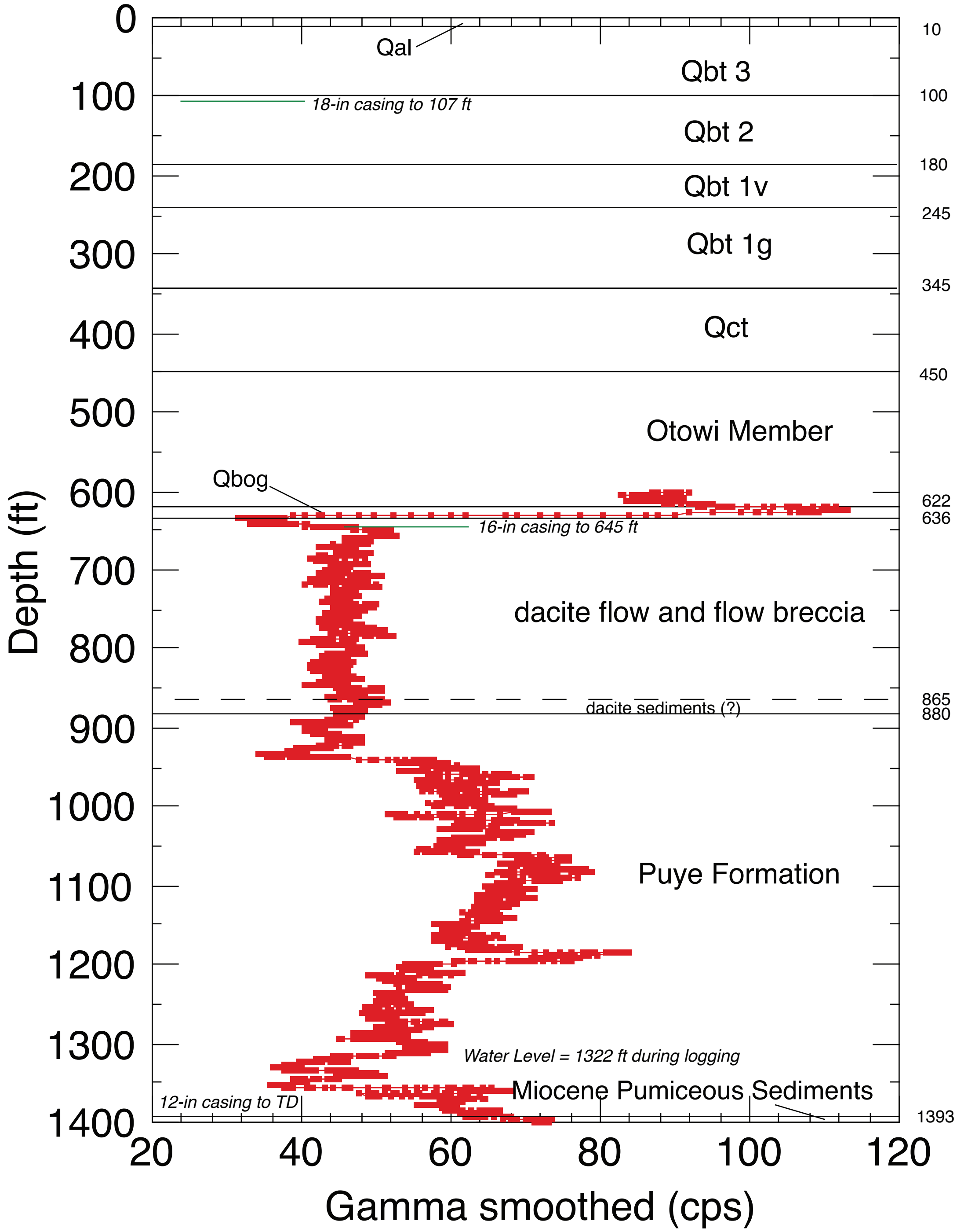
Appendix D

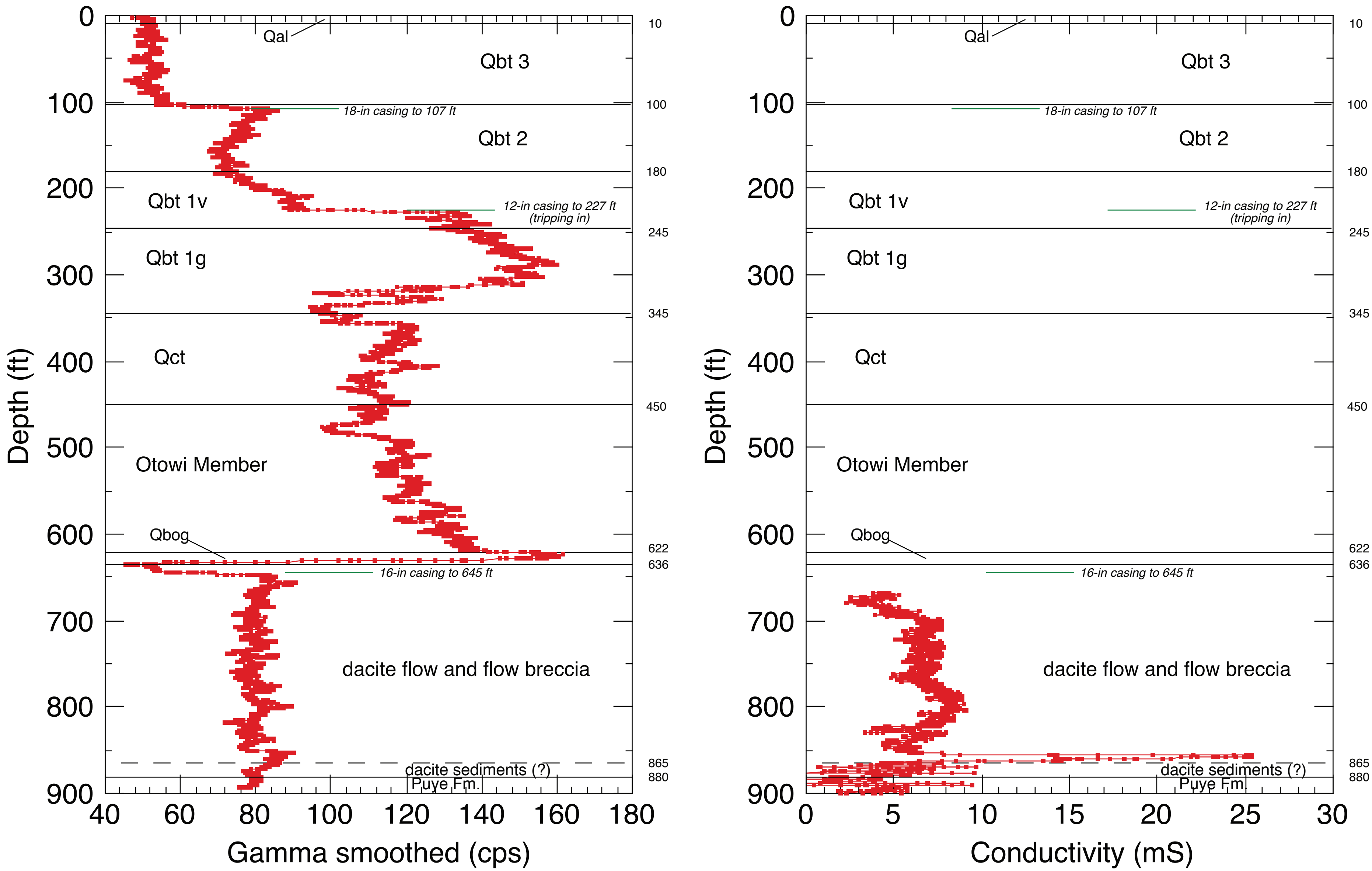
Borehole Video Logging
(on DVDs included with this document:
July 30, 2010, 0 to 660 ft [DVD 1]
September 24, 2010, 0 to 901 ft [DVD 2])

TO VIEW THE VIDEO THAT ACCOMPANIES THIS DOCUMENT, PLEASE CALL THE HAZARDOUS WASTE BUREAU AT 505-476-6000 TO MAKE AN APPOINTMENT

Appendix E

Geophysical Logging
(on CD included with this document)


Qal
Qbt 3
18-in casing to 107 ft
Qbt 2
Qbt 1v
Qbt 1g
Qct
Otowi Member
Qbog
16-in casing to 645 ft
dacite flow and flow breccia
dacite sediments (?)
Puye Formation
Water Level = 1322 ft during logging
Miocene Pumiceous Sediments
12-in casing to TD
10
100
180
245
345
450
622
636
865
880
1393
Depth (ft)
Gamma smoothed (cps)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
20
40
60
80
100
120



Depth (ft)
Gamma smoothed (cps)
Conductivity (mS)
Qal
Qbt 3
Qbt 2
Qbt 1v
Qbt 1g
Qct
Otowi Member
Qbog
dacite flow and flow breccia
dacite sediments (?)
Puye Fm.
18-in casing to 107 ft
12-in casing to 227 ft
(tripping in)
16-in casing to 645 ft
10
100
180
245
345
450
622
636
865
880

```
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WRAP    .NO                   :ONE LINE PER DEPTH STEP
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STRT    .FT           1406.3  :START DEPTH
STOP    .FT          600.033  :STOP DEPTH
STEP    .FT        -0.164042  :STEP
NULL    .            -999.25  :NULL VALUE
COMP    .                     :COMPANY
WELL    .                     :WELL
FLD     .                     :FIELD
LOC     .       R-60          :LOCATION
PROV    .       N/A           :PROVINCE
SRVC    .       N/A           :SERVICE COMPANY
DATE    .                     :DATE
UWI     .       N/A           :UNIQUE WELL ID
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DEPT    .FT                   :DEPTH
GAMM    .CPS                  :Gamma
~PARAMETER INFORMATION
ELEV    .                     :ELEVATION
STE     .                     :STE
DENS    .                     :DENSITY
CASI    .                     :CASING TO1
OPER    .                     :OPERATING RIG TIME
WGT1    .                     :WGT1
CASI    .                     :CASING SIZE1
CASI    .                     :CASING TO2
WGT2    .                     :WGT2
CASI    .                     :CASING SIZE2
WELL    .       R-60          :WELL ID
CASI    .                     :CASING TO3
K.B.    .                     :K.B.
WGT3    .                     :WGT3
TYPE    .       GR            :TYPE LOG
CASI    .                     :CASING SIZE3
CASI    .                     :CASING TO4
SALI    .                     :SALINITY
TITL    .                     :TITLE
WGT4    .                     :WGT4
TOP     .                     :TOP LOGGED INTERVAL
CASI    .                     :CASING SIZE4
WITN    .                     :WITNESSED BY
CASI    .                     :CASING TO5
DRIL    .                     :DRILLING MEAS. FROM
WGT5    .                     :WGT5
CASI    .                     :CASING SIZE5
CTY     .                     :CTY
WGT6    .                     :WGT6
CASI    .                     :CASING SIZE6
MAX.    .                     :MAX. REC. TEMP.
D.F.    .                     :D.F.
CASI    .                     :CASING TO6
OTHE    .                     :OTHER SERVICES
BIT1    .                     :BIT1
DEPT    .               1418  :DEPTH-DRILLER
BIT2    .                     :BIT2
RUN     .                     :RUN No
RUN1    .                     :RUN1
BIT3    .                     :BIT3
RUN2    .                     :RUN2
PERM    .                     :PERMANENT DATUM
TWP     .                     :TWP
BIT4    .                     :BIT4
LOG     .                     :LOG MEAS. FROM
BIT     .                     :BIT FROM1
RUN3    .                     :RUN3
BIT5    .                     :BIT5
CASI    .                     :CASING FROM1
TYPE    .                     :TYPE FLUID IN HOLE
RUN4    .                     :RUN4
FLD     .                     :FLD
BIT6    .                     :BIT6
BIT     .                     :BIT TO1
CASI    .                     :CASING FROM2
BIT     .                     :BIT FROM2
CO      .                     :CO
RGE     .                     :RGE
BIT     .                     :BIT TO2
DEPT    .                     :DEPTH-LOGGER
CASI    .                     :CASING FROM3
BIT     .                     :BIT FROM3
RUN5    .                     :RUN5
SEC     .                     :SEC
BIT     .                     :BIT TO3
G.L.    .                     :G.L.
CASI    .                     :CASING FROM4
BIT     .                     :BIT FROM4
RUN6    .                     :RUN6
BIT     .                     :BIT TO4
BTM     .                     :BTM LOGGED INTERVAL
CASI    .                     :CASING FROM5
BIT     .                     :BIT FROM5
STAT    .                     :STATE
BIT     .                     :BIT TO5
LEVE    .                     :LEVEL
CASI    .                     :CASING FROM6
BIT     .                     :BIT FROM6
COUN    .                     :COUNTRY
RECO    .                     :RECORDED BY
FILI    .                     :FILING No
BIT     .                     :BIT TO6
~OTHER
~A
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 1406.14   102.707
 1405.97   97.1406
 1405.81   94.2734
 1405.64   101.367
 1405.48   77.4961
 1405.32   126.539
 1405.15   60.5879
 1404.99   88.1094
 1404.82   80.3789
 1404.66   81.1211
 1404.49   80.4648
 1404.33   79.6094
 1404.17   96.4766
    1404   85.0352
 1403.84   83.5078
 1403.67   61.6348
 1403.51   68.1211
 1403.35   56.7344
 1403.18   49.1953
 1403.02   54.9492
 1402.85   53.3008
 1402.69   55.6621
 1402.53    41.209
 1402.36   64.7109
  1402.2   66.0195
 1402.03   64.4531
 1401.87    78.793
 1401.71   73.9375
 1401.54   61.9258
 1401.38   51.6387
 1401.21   77.5391
 1401.05   82.8555
 1400.89    61.834
 1400.72   66.3516
 1400.56   68.3984
 1400.39   73.4023
 1400.23   58.1152
 1400.07   73.7852
  1399.9    100.27
 1399.74   71.2852
 1399.57    69.832
 1399.41        75
 1399.25    73.125
 1399.08   67.6719
 1398.92   81.5234
 1398.75   74.3867
 1398.59   77.9531
 1398.43   88.5508
 1398.26   56.8984
  1398.1   51.3809
 1397.93   46.3711
 1397.77   77.7578
 1397.61   79.5938
 1397.44   77.4531
 1397.28   67.4453
 1397.11   77.0273
 1396.95   56.0645
 1396.78   85.5039
 1396.62   80.5938
 1396.46   82.4609
 1396.29   78.3906
 1396.13   57.8438
 1395.96   86.0469
  1395.8   55.6328
 1395.64   76.7539
 1395.47   86.4844
 1395.31        66
 1395.14   64.0469
 1394.98   60.0547
 1394.82   82.4961
 1394.65   71.1563
 1394.49   77.0195
 1394.32   58.5332
 1394.16   61.2051
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 1393.67    62.793
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 1393.34   62.5313
 1393.18   61.1348
 1393.01   62.7285
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 1392.52   68.9258
 1392.36   45.0645
 1392.19   51.7324
 1392.03   53.1602
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  1391.7   82.8125
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 1388.42   53.4844
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 1387.76   65.2539
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 1387.11   58.1563
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 1386.78   63.3457
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 1386.45   78.6133
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 1381.04   42.9648
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 1380.71   56.7598
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 1380.22   49.5098
 1380.05   54.7988
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 1378.08   56.1621
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 1374.64   54.7148
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 1372.83   78.5078
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 1371.52   67.9375
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 1370.37    87.293
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 1369.72   79.9609
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 1369.06   52.6504
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 1367.75   75.6641
 1367.59   56.5527
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 1367.09   59.6289
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 1365.12   61.4844
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 1362.34   51.3926
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 1361.68    48.127
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[illegible]
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642.52	54.4629
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639.075	37
638.911	27.5781
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634.154	31.1582
633.99	23.2539
633.825	27.0957
633.661	27.1816
633.497	27.2725
633.333	44.75
633.169	25.0801
633.005	28.6504
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626.28	142.93
626.116	115.82
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600.033	89.6563

Appendix F

R-60 Final Well Design and
New Mexico Environment Department Approval

Note: The information in the final well design package was developed at the completion of borehole drilling and before development of the final lithologic log. The preliminary information in the well design summary may differ slightly from the final lithologic interpretations or data presented in the well completion report.

R-60 Well Objectives

The principal objective of R-60 is to monitor groundwater at the top of the regional zone of saturation immediately down gradient of Material Disposal Area (MDA) C (Figure 1). R-60 is near the entry point for potential contaminants entering the regional aquifer from the vadose zone. Because the regional aquifer is made up of well-stratified sediments, hydraulic properties are expected to be highly anisotropic, favoring lateral flow within strata near the water table. Water table maps indicate that groundwater flow is towards the east-southeast. The R-60 well objectives are best met by installing a well screen in the uppermost part of the regional aquifer down gradient of MDA C.

R-60 Recommended Well Design

It is recommended that R-60 be installed as a single-screen well with a 20-ft stainless-steel, 20 slot, wire-wrapped well screen extending from 1335 to 1355 ft bgs. The most reliable estimate for the depth of the water table is 1319 feet (see discussion below). The primary filter pack will consist of 10/20 sand extending 5 ft above and 5 ft below the screen openings. A 3-ft secondary filter pack will be placed above the primary filter pack. The proposed well design is shown in Figure 2.

This well design is based on the objectives stated above and on the information summarized below.

R-60 Well Design Considerations

The top of the regional zone of saturation was predicted to occur at a depth of about 1339 ft based on water table maps of the area. Multiple water level measurements in the cased borehole indicated a depth-to-water of 1322 to 1323 ft, or about 16 to 17 ft higher than predicted. Because the presence of 12-in drill casing to the total depth of 1418 ft might have affected the measured water level, the drill casing was retracted about 32 ft, to 1385 ft bgs, and the water level was remeasured. The remeasured water level stabilized at a depth of 1319 ft. The water level of 1319 ft bgs was used to design the well.

Preliminary lithologic logs indicate that the geologic units encountered while drilling R-60 are, in descending stratigraphic order: Bandelier Tuff (0–636 ft), dacitic lavas and breccia (636–865 ft), Puye Formation (865–1394 ft), and Miocene pumiceous sediments (1394–1418 ft TD). The Puye Formation straddles the regional water table and is the primary target for the well screen.

The Puye Formation in the regional aquifer consists of stratified volcaniclastic deposits. Drill cuttings from R-60 and a borehole video from nearby well R-46 indicate that the Puye deposits are made up of dacitic boulders, cobbles, and pebbles in a poorly cemented silty and sandy matrix. Despite their coarse-grained nature, these rocks contain abundant silt in the rock matrix. Intervals of silt-free aquifer gravels and sands occur at depths of 1320–1335 ft, 1345–1355, and 1365–1375 ft.

Based on drill cuttings, the rocks in the 1345–1355 ft interval appear to have the best characteristics for water production in the vicinity of the water table. Rocks above 1335 ft also have good characteristics for water production, but are too close to the water table to ensure sufficient screen submergence during pumping associated with well development and sampling. The top of the proposed well screen (1335 ft) is approximately 16 ft below the water table. Submergence of the well screen will facilitate well development. The filter pack outside the screened interval extends approximately up to the water-table elevation and includes the saturated section of the upper silt-free interval (1320–1335 ft). The flow and transport through the filter pack will allow for detection of potential contaminants near the regional water table.

Other Zones Considered for the R-60 Well Screen

Rocks in the 1365–1375 ft interval are relatively silt free and probably have good hydrologic characteristics. However, these deposits are too deep (>42 ft below the water table) to address the goal defined for R-60 of monitoring for contamination near the top of the regional aquifer near MDA C.

The proposed well design incorporates a 20-ft well screen. A 10-ft well screen from 1335–1345 ft was evaluated as a means to monitor a more discrete zone of groundwater near the water table. However, the longer 20-ft screen was chosen because the rock matrix in the 1335–1345 ft interval is relatively silt rich and may not be very productive. The 20-ft screen design increases chances that the well screen will intersect productive (and faster) groundwater pathways in the upper part of the aquifer.

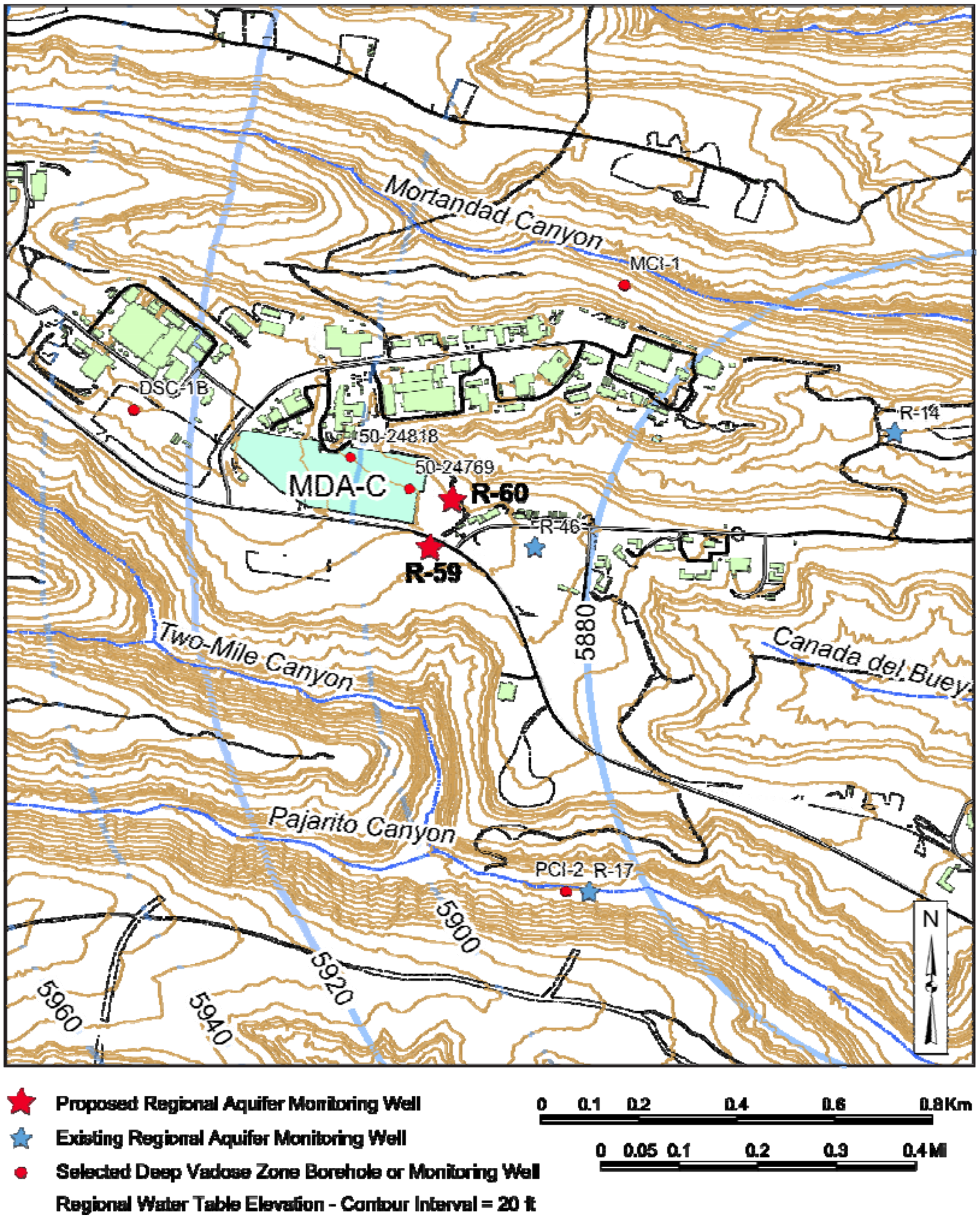

Figure 1 Map of well R-60 location. Preliminary location of planned monitoring well R-59 is also shown. The water table contours do not include the water level measured in the R-60 borehole.

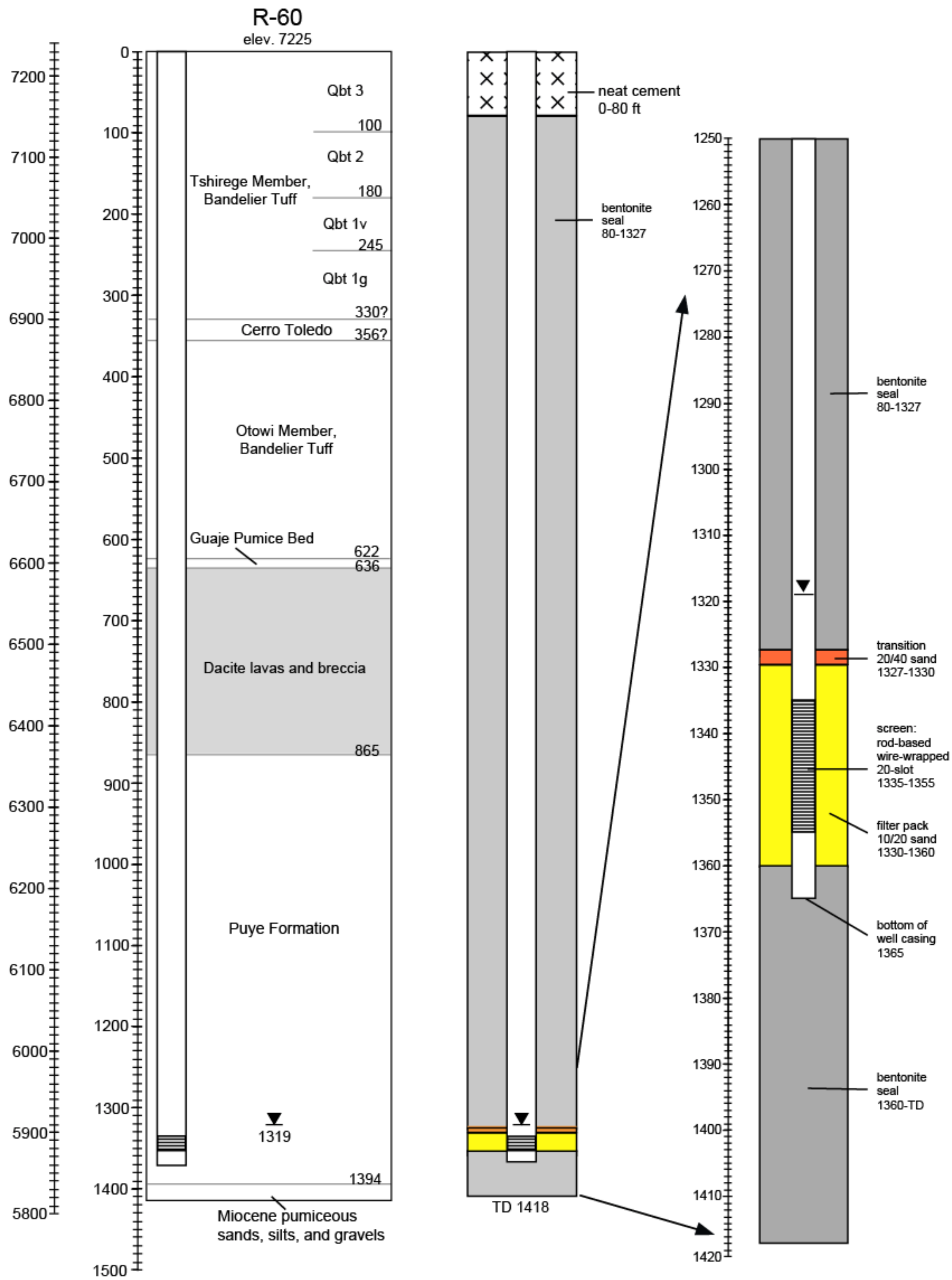

Figure 2 Proposed well design for R-60

From: "Dale, Michael, NMENV" <Michael.Dale@state.nm.us>
To: "Everett, Mark C" <meverett@lanl.gov>
Date: Wed, 6 Oct 2010 10:41:23 -0600
Subject: RE: R-60 proposed well design

Mark,

This e-mail serves as NMED approval, with direction, for installation of regional aquifer well R-60 as proposed in the document (the Document) attached to the original e-mail received by NMED yesterday, October 5, 2010 at 12:39 PM. LANL shall modify the construction of R-60 to reflect the movement of the filter packs and well screen five feet higher than proposed in the Document: 20/40 transition filter pack shall be installed from 1322' to 1325'; 10/20 primary filter pack shall be installed from 1325' to 1355'; and the well screen shall be installed from 1330' to 1350'. All other construction details as proposed in the Document are hereby approved, and is based on the information available to NMED at the time of the approval. NMED understands that LANL will provide the results of preliminary sampling, any modifications to the well design proposed in the Document and construction changes as directed by NMED, and any additional information related to the installation of well R-60 as soon as such information becomes available. In addition, LANL shall notify NMED within three days of water-quality sampling at the conclusion of the aquifer-testing period at R-60. LANL shall give notice of this installation to the New Mexico Office of the State Engineer as soon as possible. Thank you.

Michael Dale, NMED HWB

Hazardous Waste Bureau
New Mexico Environment Department
2905, Rodeo Park Drive East, Building 1
Santa Fe, NM 87505
Phone (505) 476-6052 / Fax (505) 476-6030
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Los Alamos Phone (505) 662-2673 / Cell 660-1679

-----Original Message-----
From: Everett, Mark C [mailto:meverett@lanl.gov]
Sent: Tue 10/5/2010 12:39 PM
To: Dale, Michael, NMENV; Cobrain, Dave, NMENV; Kulis, Jerzy, NMENV
Cc: Shen, Hai; Rich, Kent C; Rodriguez, Cheryl L; Fuller, Stephani; Ball, Theodore T
Subject: R-60 proposed well design

Michael,

Attached is LANL's proposed design for well R-60 east of MDA C. Please review and if you find it acceptable, respond to this e-mail with your concurrence. If you wish to discuss further, feel free to contact me.

Thanks,

Mark Everett, PG
Drilling Project Technical Lead
LANL
(505) 667-5931 (office)
(505) 231-6002 (mobile)