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Completion Report for Regional Aquifer Well R-53

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EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, aquifer testing, and dedicated sampling system installation for regional aquifer groundwater monitoring well R-53, located in the south fork of Cañada del Buey within Los Alamos National Laboratory (the Laboratory) Technical Area 54 (TA-54) in Los Alamos County, New Mexico. The well satisfies a requirement by the New Mexico Environment Department (NMED) to install a regional aquifer monitoring well downgradient of Material Disposal Area L at TA-54.

The R-53 monitoring well borehole was drilled using dual-rotary air-drilling methods with casing advance. 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; only small amounts of potable water were added to the air within the regional aquifer.

The R-53 borehole was drilled through canyon-bottom alluvium, Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed, Cerros del Rio volcanic rocks, and into the Puye Formation sediments. The total depth of the borehole was 1015 ft below ground surface (bgs).

Well R-53 was completed as a dual-screen well to evaluate water quality and measure water levels at two discrete depth intervals within the regional aquifer: one near the top of the aquifer and one approximately 100 ft deeper. A packer separates the well screens to ensure isolation of each groundwater-bearing zone. The upper 10-ft-long screened interval is set between 849.2 and 859.2 ft bgs within the top of the Puye Formation, and the lower 20-ft-long screened interval is set between 959.7 and 980.2 ft bgs within Puye Formation sediments. The composite depth to water after well installation and well development was 831.8 ft bgs.

The well was completed in accordance with an NMED-approved well design. The well was developed and target water-quality parameters were achieved at both screened intervals. Hydrogeologic testing indicated that monitoring well R-53 is productive and will perform effectively to meet the planned objectives. A sampling system and transducers were installed in the upper and lower well screens in the R-53 well, and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

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Acronyms and Abbreviations

amsl	above mean sea level
APV	actuated access port valve
ASTM	American Society for Testing and Materials
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
DTW	depth to water
EES-14	Earth and Environmental Sciences Group 14
Eh	oxidation-reduction potential
EP	Environmental Programs (Directorate)
gpd	gallons per day
gpm	gallons per minute
hp	horse power
I.D.	inside diameter
LANL	Los Alamos National Laboratory
LH3	low-level tritium

MDA	material disposal area
µS/cm	microsiemens per centimeter
mV	millivolt
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
pH	potential of hydrogen
PVC	polyvinyl chloride
Qal	alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member of the Bandelier Tuff
Qct	Cerro Toledo interval
RPF	Records Processing Facility
SOP	standard operating procedure
TA	technical area
Tb 4	Cerros del Rio volcanic rocks
TD	total depth
TOC	total organic carbon
Tpf	Puye Formation
VOC	volatile organic compound
WES-EDA	Waste and Environmental Services Division–Environmental Data and Analysis
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for regional aquifer groundwater monitoring well R-53. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the Compliance Order on Consent (the Consent Order). The R-53 monitoring-well borehole was drilled from January 13 to March 7, 2010, and completed from March 12 to March 29, 2010, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

Well R-53 is located in the south fork of Cañada del Buey within the Laboratory's Technical Area 54 (TA-54) in Los Alamos County, New Mexico (Figure 1.0-1). The purpose of the R-53 well is to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the Laboratory's Groundwater Protection Program, the Consent Order, and the NMED-approved drilling work plan. Specifically, regional aquifer well R-53 satisfies a requirement by NMED to install a regional aquifer monitoring well downgradient of Material Disposal Area (MDA) L at TA-54.

The primary objective of the drilling activities at R-53 was to drill and install a dual-screen regional aquifer monitoring well in the uppermost part of the regional groundwater system to monitor groundwater quality near MDA L. Secondary objectives were to establish water levels and flow characteristics in the regional aquifer in this area, collect drill-cutting samples, and conduct borehole geophysical logging.

The R-53 borehole was drilled to a total depth (TD) of 1015.0 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. A monitoring well was installed with two screens. The upper 10-ft-long screened interval is between 849.2 and 859.2 ft bgs, and the lower 20-ft-long screened interval is between 959.7 and 980.2 ft bgs. The composite depth to water (DTW) after well installation and well development was recorded on April 11 at 831.8 ft bgs. A dedicated sampling system has been installed with an inflatable packer isolating the two well screens. The dedicated sampling system allows discrete sampling and water-level monitoring of both screen intervals. Water-level transducers have been placed in upper and lower well-screen intervals to evaluate hydraulic relationships between this well and other nearby wells.

Postinstallation activities included well development, aquifer testing, surface completion, sampling system installation, and geodetic surveying. Future activities will include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendices completed to date associated with the R-53 project. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the NMED in accordance with U.S. Department of Energy policy.

2.0 PRELIMINARY ACTIVITIES

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

2.1 Administrative Preparation

The following documents helped guide the implementation of the scope of work for the R-53 project:

- “Drilling Work Plan for Regional Aquifer Well R-53” (LANL 2009, 107687);
- “Drilling Plan for Regional Aquifer Well R-53” (TerranearPMC 2010, 108561);
- “Integrated Work Document for Regional and Intermediate Aquifer Well Drilling” (LANL 2007, 100972);
- “Storm Water Pollution Prevention Plan Addendum” (LANL 2006, 092600); and
- “Waste Characterization Strategy Form for TA-54 Wells R-53 and R-54 (Area L) Regional Well Installation and Corehole Drilling”(LANL 2009, 108526).

2.2 Site Preparation

The drill pad had been prepared by Laboratory personnel several weeks before the drill rig, air compressors, trailers, and support vehicles were mobilized to the drill site from January 10 to 12, 2010. This included staging of alternative drilling tools and construction materials at the Pajarito Road lay-down yard. Access road construction was performed by Laboratory personnel before rig mobilization and was continually problematic due to winter weather conditions.

Potable water was obtained from a fire hydrant on East Jemez Road. Safety barriers and signs were installed around the borehole cuttings containment pit and along the perimeter of the work area.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and approach and provides a chronological summary of field activities conducted at monitoring well R-53.

3.1 Drilling Approach

The drilling methodology and selection of equipment and drill-casing sizes for the R-53 monitoring well were designed to retain the ability to investigate and case-off potential perched groundwater above the regional aquifer. Further, the drilling approach ensured that a sufficiently-sized drill casing was used to meet the required 2-in.-minimum annular thickness of the filter pack around a 5.56-in.-outside-diameter (O.D.) well casing.

Dual-rotary air-drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-53 borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. The Foremost DR-24HD drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, a deck-mounted 900 ft^3/min air compressor, and general drilling equipment. Auxiliary equipment included two 1150 ft^3/min trailer-mounted air compressors. Three sizes of A53 grade B flush-welded mild carbon-steel casing (16-in., 12-in., and 10-in.-inside-diameter [I.D.]) were used for the R-53 project.

The dual-rotary technique at R-53 used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all within the vadose zone) included potable water and a mixture of potable water with Baroid AQF-2 foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of foaming agents was terminated at 745.0 ft bgs, roughly 100 ft above the anticipated top of the regional aquifer. No additives other than potable water were used for drilling below 745.0 ft bgs. The total amounts of drilling fluids introduced into the borehole and those recovered are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-53 Well

Drilling equipment and supplies to the R-53 drill site were mobilized from January 10 to 12, 2010. Decontamination of the equipment and tooling was performed before mobilization to the site. On January 13, following on-site equipment inspections, the monitoring-well borehole was initiated at 0920 hours using dual-rotary methods with 16-in. drill casing and a 15.75-in. tricone bit.

Drilling and advancing 16-in. casing proceeded rapidly through canyon-bottom alluvium, the Tshirege Member of the Bandelier Tuff, the Cerro Toledo interval, the Otowi Member of the Bandelier Tuff, and the Guaje Pumice Bed. Drilling continued through the top of the Cerros del Rio volcanic rocks to 262.0 ft bgs where the 16-in. drill casing was landed on January 18. No indications of groundwater were observed while advancing the 16-in. casing.

From January 19 to February 3, drilling activities were suspended while the crew supported 24-h operations at regional well R-50. On February 3, drilling activities resumed with open-hole drilling using a 15-in. hammer bit. Drilling proceeded through basaltic breccias, basaltic lavas and cinders, andesitic sediments, and scoria of the Cerros del Rio volcanic rocks. On February 7, unstable borehole conditions were encountered at approximately 745.0 ft bgs at the base of a scoria deposit. The bit and drill rods became stuck in the borehole, and from February 7 to 8, borehole cleanout was performed with water and a minimal amount of foam. On February 9, the scoria was measured at 683.0 ft bgs, indicating approximately 62 ft of slough surrounded the drill tools. From February 10 to 11, a second string of drill rods was run into the hole, and water, air, and foam were used to circulate the cuttings to the surface. On February 11, both strings of drill rods were removed from the borehole. Use of AQF-2 drilling foam was stopped at 745 ft bgs.

On February 12, video, natural gamma, and induction logs were run from ground surface to 726.0 ft bgs to document conditions in the open portion of the borehole (262.0 to 726.0 ft bgs). From February 15 to 19, the 16-in. casing shoe was cut off at 255.0 ft bgs, and the 12-in. drill casing was installed to 722.0 ft bgs. The borehole was cleaned out with an underreaming bit, and the 12-in. casing was advanced to a depth of 769.0 ft bgs.

From February 24 to 26, a 12-in. open borehole was advanced with a downhole hammer bit through the bottom of the Cerros del Rio volcanic rocks and into the Puye Formation sediments to a depth of 861.0 ft bgs. Water production of 15–30 gallons per minute (gpm) was noted on February 26 at 840.0 ft bgs while the open hole was advanced, and a water sample was collected. On February 27, the 12-in. casing shoe was cut off at 765.7 ft bgs. After the shoe was cut, the drilling subcontractor ran a video log to verify the cut. The video log also recorded a water level of 828.0 ft bgs (approximately 33 ft of standing water in the borehole). The drill crew began installing 10-in. drill casing into the borehole on February 27 and 28.

On March 1, before the 10-in. casing was landed, a manual water-level measurement was recorded at 829.9 ft bgs. The 10-in. casing was then landed at 861.0 ft bgs on March 2. The 10-in. casing was advanced with a 9 7/8-in. tricone bit through Puye Formation sediments to a depth of 1012.4 ft bgs. Water production of 70 gpm was noted on March 7 at 979.0 ft bgs while the 10-in. casing was advanced, and a second water sample was collected. On March 7, the 9 7/8-in. tricone bit reached the TD of 1015.0 ft bgs. A natural gamma ray log was run the same afternoon to provide stratigraphic information. On March 8, the 10-in. casing shoe was cut off at 1007.0 ft bgs. A video log was run on March 9 to verify the cut. The video log also recorded a water level of 838.2 ft bgs in the borehole.

During drilling, field crews worked 12-h shifts 7 d/wk. Weather and access road conditions resulted in several site closures and delays.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-53. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-53 monitoring well borehole at 5-ft intervals from ground surface to the TD of 1015.0 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. 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 for R-53 is summarized in section 5.1, and the borehole lithology is detailed in Appendix A.

4.2 Water Sampling

Two groundwater-screening samples were collected from the drilling discharge at 840.0 and 979.0 ft bgs. These borehole samples were analyzed for anions (including perchlorate), cations, metals, volatile organic compounds (VOCs), and low-level tritium (LH3). The samples were collected after the bottom of 20-ft runs of casing, where the driller stopped water circulation and circulated air. As the discharge cleared, the water samples were collected directly from the discharge cyclone. Table 4.2-1 summarizes the screening samples collected during the R-53 monitoring well installation project. Groundwater chemistry and field water-quality parameters are discussed in Appendix B.

Five groundwater screening samples were collected during well development from the development pump's discharge line. Development samples were analyzed by Earth and Environmental Sciences Group 14 (EES-14) for total organic carbon (TOC) only.

Additionally, 12 groundwater-screening samples were collected during aquifer testing from the pump's discharge line. These samples were also analyzed by EES-14 for TOC only.

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

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-53 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 encountered at R-53.

5.1 Stratigraphy

Stratigraphic units for the R-53 borehole, drilled to a depth of 1015.0 ft bgs, are presented below in order of occurrence from youngest to oldest units. Lithologic descriptions are based on microscopic examination and analysis of drill cuttings samples collected from the discharge hose. Cuttings and borehole geophysical logs were used to identify unit contacts. Figure 5.1-1 shows the stratigraphy at R-53. A detailed lithologic log is presented in Appendix A.

Quaternary Alluvium, Qal (0–6 ft bgs)

Quaternary alluvium, consisting of unconsolidated, poorly sorted sand and gravelly sand composed of tuffaceous and volcanic detritus and also containing rounded volcanic and quartzite pebbles typical of introduced base-course gravels used in drill pad construction, was encountered from 0 to approximately 6 ft bgs. No evidence of alluvial groundwater was observed.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (6–18 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff occurs from 6 to 18 ft bgs and is locally a minimum of 12 ft thick. Unit 1v is a poorly to moderately welded rhyolitic ash-flow tuff that is pumiceous, crystal-bearing to locally crystal-rich and generally liithic-poor. Locally preserved fragments of ash-flow tuff indicate that Unit 1v contains up to 20% flattened strongly devitrified pumice lapilli, up to 20% quartz and sanidine crystals, and as much as 2% of volcanic lithic fragments set in a matrix of weathered volcanic ash. Abundant ash is locally preserved in cuttings. 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 (18–130 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was intersected in the R-53 borehole from 18 to 130 ft bgs and has an estimated thickness of 112 ft. Unit 1g is a poorly welded rhyolitic ash-flow tuff that is strongly pumiceous, crystal-bearing, and lithic-poor. Unit 1g cuttings locally exhibit abundant ash matrix and infrequent fragments of indurated tuff, suggesting generally poor welding. Pumice lapilli are generally glassy with a lusterous appearance and are quartz- and sanidine-phyric. Volcanic lithic fragments, predominantly dacites, occur in minor abundances.

Cerro Toledo Interval, Qct (130–150 ft bgs)

The Cerro Toledo interval, a layer of poorly consolidated volcaniclastic sediments that occurs stratigrahically between the Tshirege and Otowi Members of the Bandelier Tuff, is present from 130 to 150 ft bgs. Cerro Toledo deposits are estimated to be 20 ft thick. 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 hornblende- and/or biotite-phyric dacites, flow-banded rhyodacite, andesite, abundant vitric pumices, and quartz and sanidine crystals.

Otowi Member of the Bandelier Tuff, Qbo (150–242 ft bgs)

The Otowi Member of the Bandelier Tuff is present in the R-53 section from 150 to 242 ft bgs and is estimated to be 92 ft thick. The Otowi Member is a poorly welded rhyolite ash-flow tuff (i.e., ignimbrite) 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, or xenoliths, 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 (242–258 ft bgs)

The Guaje Pumice Bed occurs from 242 to 258 ft bgs and has an estimated local thickness of 16 ft. This air-fall tephra deposit forms the base of the Otowi Member. The unit contains abundant (up to 100% by volume) rounded, lustrous, vitric, phenocryst-poor pumice lapilli with minor occurrences of small volcanic lithic fragments and quartz and sanidine crystals.

Cerros del Rio Volcanic Rocks, Tb 4 (258–830 ft bgs)

The Cerros del Rio volcanic rocks (formerly Cerros del Rio basalt), encountered in R-53 from 258 to 830 ft bgs, locally forms a varied complex sequence of lavas, tephras, and volcanic sedimentary deposits of basaltic to intermediate volcanic composition. The cumulative thickness of the Tb 4 volcanic rocks is approximately 572 ft. The upper part of the volcanic rocks, from 258 to 366 ft bgs, includes an 81-ft-thick phenocryst-poor, olivine-clinopyroxene basalt flow and overlying layer of rubbly, volcanic breccia. The middle Tb 4 section, from 366 to 652 ft bgs, forms a complex sequence of thin basaltic lavas and interflow scoriaceous cinder deposits. A 93-ft-thick section of volcanic sediments, intersected from 652 to 745 ft bgs, is made up of detritus derived from sources of basaltic to intermediate (tentatively andesitic) composition. The base of the Cerros del Rio volcanic rocks, from 745 to 830 ft bgs, was formed of massive phenocryst-poor lava of intermediate (tentatively dacitic) composition.

Puye Formation, Tpf (830–1015 ft bgs)

Puye Formation volcaniclastic sediments (Tpf), intersected from 830 ft bgs to the bottom of the R-53 borehole at 1015 ft bgs, are locally a minimum of 185 ft thick. These sediments vary considerably in texture, ranging from fine to coarse gravels with silty sand to moderately well-sorted sands with minor gravel content. Typically they are poorly to moderately cemented. The majority of the Puye section consists of volcanic detritus, predominantly of gray biotite- and/or hornblende-phyric dacites with less abundant lithologies ranging from andesite to rhyolite. Puye sediments exhibit minor to locally significant percentages of Precambrian quartzo-feldspathic rocks. Precambrian detritus (quartzite, granitic rocks, microcline, etc.) makes up at least 25% by volume of select sampling intervals and indicates the occurrence of Totavi Lentil-type axial river gravel deposits interfingered with Puye volcaniclastic sediments.

5.2 Groundwater

Drilling proceeded without any indications of groundwater until approximately 840.0 ft bgs at the top of the Puye Formation. The groundwater production rate was estimated to be between 15 and 30 gpm and the DTW was 829.9 ft bgs. The borehole was advanced to 979.0 ft bgs, where the groundwater production rate increased to approximately 70 gpm. The 10-in. casing was advanced to 1012.4 ft bgs, and the tricone bit was advanced to 1015.0 ft bgs to allow water flow into the cased borehole. The DTW stabilized at 840.3 ft bgs on March 9 before well installation.

6.0 BOREHOLE LOGGING

A video log, induction log, and two natural gamma ray logs were collected during the R-53 drilling project using Laboratory-owned equipment. Two video logs were collected using subcontractor-owned equipment. A summary of video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

A video run was made in the R-53 borehole on February 12, 2010, to document conditions in the open portion of the borehole from 262 to 726.0 ft bgs. The video log is presented in Appendix D (on a DVD included with this report).

Two additional videos were run on February 27 and March 9 to verify the 12-in. and 10-in. casing shoes had been cut. The video from February 27 recorded a water level at 828.0 ft bgs (bottom of borehole at 861.0 ft bgs), and the video from March 9 recorded a water level at 838.2 ft bgs (bottom of borehole at 1015.0 ft bgs). These video logs were observational and were not recorded to storage media.

6.2 Geophysical Logging

A natural gamma ray survey and an induction log were run in the borehole on February 12 to document conditions in the open portion of the borehole.

A natural gamma ray survey to TD was taken in the cased borehole on March 7, before well construction commenced. Logging data are presented in Appendix E (on CD included with this report).

7.0 WELL INSTALLATION

The R-53 well was installed between March 12 and 29, 2010. The following sections describe the final well design and well-construction details.

7.1 Well Design

The R-53 well was designed in accordance with the approved drilling work plan; the final well design was prepared after borehole TD was reached. NMED approved the final design before the well was installed. The well was designed with dual screens to monitor groundwater quality near the top of the regional aquifer and deeper in the aquifer within Puye Formation sediments; the upper screen was set from approximately 850 to 860 ft bgs, and the lower screen was installed from approximately 960 to 980 ft bgs.

7.2 Well Construction

The R-53 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. Screened sections utilized three 10-ft lengths of 5.0-in.-I.D. rod-based 0.020-in. wire-wrapped screens to make up the 10-ft-long upper and 20-ft-long lower well-screen intervals. Compatible external stainless-steel threaded 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 they were installed. A 2.2-in.-O.D. steel flush threaded tremie pipe, also decontaminated before use, delivered the annular fill materials down-hole during well construction. Short lengths of 10-in. drill casing (5.4-ft casing and shoe, at a depth of 1007.0 to 1012.4 ft bgs); 12-in. drill casing (3.3-ft casing and shoe, at a depth of 765.7 to 769.0 ft bgs); and 16-in. drill casing (7.0-ft casing and shoe, at a depth of 255.0 to 262.0 ft bgs) remain in the borehole. The 10-in. casing stub was encased in the lowermost bentonite seal/slough, while the 12-in. and 16-in. casing stubs were encased in the upper bentonite seal.

Decontamination of the stainless-steel well casing and screen took place on March 11 along with mobilization of initial well-construction materials to the site. A 21.7-ft stainless-steel sump was placed below the bottom of the lower well screen. Stainless-steel centralizers (four sets of four) were welded to the well casing approximately 2.0 ft above and below each screen.

On March 12, at 0930 h, the 5-in. stainless-steel well casing was started into the wellbore. The drill rig was demobilized from the site on March 13 after 551.8 ft of well casing was installed. A Pulstar work-over rig was mobilized on the same day and was used for all remaining well-construction activities.

After the well casing was landed at 1001.9 ft bgs, the annular materials began to be installed on March 17. A lower seal composed of 3/8-in. bentonite chips and 1/4-in. bentonite pellets (14.7 ft^3) was placed from 985.2 to 1009.4 ft bgs above slough from 1009.4 to 1015.0 ft bgs. A 10/20 silica sand filter pack was installed from 953.9 to 985.2 ft bgs and surged to promote compaction (total 10/20 sand: 18.8 ft^3). A short 20/40 silica sand transition collar on top the filter pack was placed from 951.8 to 953.9 ft bgs (total 20/40 sand: 1.6 ft^3).

A bentonite seal separating the two screened intervals was added from 864.1 to 951.8 ft bgs consisting of 3/8-in. bentonite chips and 1/4-in. bentonite pellets (65.0 ft^3). The upper screen filter pack of 10/20 silica sand was then installed at 843.8 to 864.1 ft bgs and surged (total 10/20 sand: 15.0 ft^3). The upper filter pack was then capped with a short 20/40 silica sand transition collar from 841.8 to 843.8 ft bgs (total 20/40 sand: 2.0 ft^3).

The upper bentonite seal was installed from 199.1 to 841.8 ft bgs using 3/8-in. bentonite chips (787.4 ft^3). The final surface seal of neat Portland cement (441.2 ft^3) was placed above the upper bentonite seal from 3.0 to 199.1 ft bgs. The actual volume of cement exceeded the calculated volume by approximately 33% and was likely caused by cement loss to the surrounding formation. Well construction was completed on March 29. Figure 7.2-1 shows the well schematic for R-53, and Table 7.2-1 summarizes volumes of materials used during well construction.

During well construction, field crews worked one 12-h shift, 7 d/wk from March 12 to 23, and two 12-h shifts, 7 d/wk from March 24 to March 29. As with the drilling operations, weather and access road conditions resulted in several site closures and delays.

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 was 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 March 30 and April 6, 2010. Initially, both screened intervals were swabbed and composite water was bailed to remove formation fines in the filter packs and well sump. Bailing continued until water clarity visibly improved. Final development was then performed with a submersible pump at each screen.

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 drawn repeatedly across each screened interval causing a surging action across the screen/filter pack. The bailing tool employed was a 4.0-in.-O.D. by 21.0-ft-long carbon steel bailer with a total capacity of 12 gal. The tool was lowered by wireline and repeatedly filled, withdrawn from hole, and dumped into the cuttings pit.

After bailing, a 5-horse power (hp), 4-in.-Grundfos submersible pump and an inflatable packer located above or below the pump were installed in the well for the final stage of well development. Approximately 11,945 gal. of groundwater was purged at R-53 during well development activities.

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

Upper Screen

On April 2, an inflatable packer was installed below the upper screened interval and the pumping assembly was lowered into the well. The upper screen was purged from bottom to top in 2-ft increments from 858 to 849 ft bgs on April 3. Additional pumping was conducted on April 4. Because the water level was slightly below the top of the upper screen and to prevent the pump from breaking suction and cavitating, the pump intake was relocated to the bottom of the upper screen at 859 ft bgs. Pumping rates at the upper screen ranged between 11.0 and 11.3 gpm. Approximately 5200 gal. of groundwater was purged during development at the upper well screen.

Lower Screen

On April 4 and 5, the same pump used for the upper screen development was reconfigured without a pump shroud and with a packer above the pump to purge the lower screen. The lower screen was purged from top to bottom in 2-ft increments from 960 ft bgs to 980 ft bgs. After pumping throughout the lower screened interval, the pump was set at the top of the screen at 959 ft bgs, and the packer was inflated to ensure discrete water quality parameter samples. Pumping rates at the lower screen ranged between 10.7 and 10.9 gpm. Approximately 6100 gal. of groundwater was purged during lower well screen development.

Approximately 11,945 gal. of groundwater was purged at R-53 during well-development activities, 5200 gal. from the upper screen, 6100 gal. from the lower screen and 645 gal. during bailing. Another 48,228 gal. was purged during aquifer testing. Total groundwater purged during postinstallation activities was 60,173 gal.

8.1.1 Well Development Field Parameters

Field parameters were measured at well R-53 by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. These conditions resulted in a variation of field parameters during well development and during the pumping test, most notably in temperature, pH, ORP, and DO.

Upper Screen

During development of the upper screen, measurements of pH and temperature varied from 7.04 to 8.18 and from 20.07 to 21.11°C, respectively. Concentrations of DO ranged from 6.60 to 7.02 mg/L. Eh values varied from 376.2 to 438.4 millivolts (mV). Specific conductance varied from 358 to 380 microsiemens per centimeter (µS/cm) and turbidity varied slightly from 0.2 to 0.8 NTU. The final parameter measurements for the upper screen at the end of development were: pH 8.05, temperature 20.14°C, specific conductance 360 µS/cm, and turbidity 0.7 NTU.

Lower Screen

During development of the lower screen, measurements of pH and temperature varied from 6.88 to 8.07 and from 19.14 to 20.45°C, respectively. Concentrations of DO ranged from 6.23 to 7.46 mg/L. Eh values varied from 372.9 to 391.7 mV. Specific conductance varied from 158 to 175 µS/cm and turbidity values were 0.0 NTU. The final parameter measurements for the lower screen at the end of development were pH 8.01, temperature 20.45°C, specific conductance 161, and turbidity 0.0 NTU. As discussed in Appendix B, the turbidity readings of 0.0 NTU measured at the lower screen are likely not accurate.

A further discussion of well-development field parameters is presented in Appendix B. Table B-1.2-1 lists field parameters measured during development and aquifer testing.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-53 between April 10 and 21. Several short-duration tests with short-duration recovery periods were performed on the first day of testing of each screened interval.

A 10-hp pump was used for the aquifer test on the lower screened interval. Initially, the pump’s flow rate was set to approximately 20 gpm. Approximately 31,762 gal. of groundwater was purged from the lower screen interval. A 24-h recovery period completed the 24-h testing of the lower screen interval.

The 10-hp pump used for the aquifer test on the lower screened interval was swapped for a 5-hp pump for the aquifer test on the upper screened interval. A 24-h test followed by a 24-h recovery period completed the testing of the upper screen interval. Approximately 16,466 gal. of groundwater was purged from the upper screen interval at a flow rate of approximately 10 gpm.

Turbidity, temperature, pH, DO, ORP, and specific conductance parameters were measured during the 24-h tests. In addition, water samples were collected and submitted to EES-14 for TOC analysis.

Approximately 60,173 gal. of groundwater was purged during aquifer-testing activities. Field water-quality parameters and TOC results are summarized in Appendix B. The results and analysis of the R-53 aquifer test are presented in Appendix C.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-53 was installed between July 3 and 7, 2010. The Baski, Inc., system has a single 3-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump capable of purging each screened interval discretely via pneumatically actuated access port valves (APVs). The system includes a viton-wrapped isolation packer between the screened intervals. The pump riser pipe consists of threaded and coupled nonannealed 1-in.-I.D. stainless steel. Two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) tubes are banded to the pump riser for dedicated transducers. The upper PVC transducer tube is equipped with a 6-in. section of 0.010-in. slotted screen with a threaded end cap at the bottom of the tube. The lower PVC transducer tube is equipped with a flexible nylon tube that extends from a threaded end cap at the bottom of the PVC tube through the isolation packer and measures water levels in the lower screen interval. Two In-Situ Level Troll 500 transducers were installed in the PVC tubes to monitor water levels in each screened interval.

Postinstallation construction and sampling system component installation details for R-53 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-53 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. All of the four bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on May 17, 2010 (Table 8.5-1). The survey data collected conforms 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 New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevation is 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 pin in the concrete pad, the top of the well casing, and the top of the protective casing for the R-53 monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-53 project includes 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-53 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with Waste Characterization Strategy Form for TA-54 Wells R-53 and R-54 (Area L) Regional Well Installation and Corehole Drilling”(LANL 2009, 108526).

Fluids produced during drilling and well development are expected to be land-applied after a review of associated analytical results per the waste characterization strategy form (WCSF) and the ENV-RCRA-Standard Operating Procedure (SOP) 010.1, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criteria for land application, the drilling fluids will be managed and disposed of based upon the regulatory classification of the waste. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, they will be left in a pit or container pending a “contained-in” approval from the NMED. If the hazardous wastes are containerized, they are subject to the 90-d accumulation limit and the “contained-in” approval must be obtained from NMED before the accumulation period is exceeded.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA SOP-011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criterion for land application, they will be excavated, containerized and placed in an accumulation area appropriate for the regulatory classification of the waste. Decontamination fluid used for cleaning the drill rig and equipment is containerized at point of generation. The fluid waste was sampled and will be disposed of at an authorized facility. Characterization of contact waste will be based on acceptable knowledge pending analyses of the waste samples collected from the drill cuttings, drilling fluids, 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 and the WCSF, 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-53 were performed as specified in “Drilling Plan for Regional Aquifer Well R-53” (TerranearPMC 2010, 108561).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-53 monitoring well.

David Schafer designed and implemented the aquifer test and wrote Appendix C.

LANL personnel ran natural gamma, induction and video logging equipment.

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

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

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

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

LANL (Los Alamos National Laboratory), March 2006. "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan," Los Alamos National Laboratory document LA-UR-06-1840, Los Alamos, New Mexico. (LANL 2006, 092600)

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

LANL (Los Alamos National Laboratory), November 5, 2009. "Waste Characterization Strategy Form for TA-54 Wells R-53 and R-54 (Area L) Regional Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2009, 108526)

LANL (Los Alamos National Laboratory), December 2009. "Drilling Work Plan for Regional Aquifer Well R-53," Los Alamos National Laboratory document LA-UR-09-7477, Los Alamos, New Mexico. (LANL 2009, 107687)

TerranearPMC, January 2010. "Drilling Plan for Regional Aquifer Well R-53," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2010, 108561)

11.2 Map Data Sources for R-53 Completion Report Location Map

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

Hypsography, 100 and 20 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; 19 September 2007.

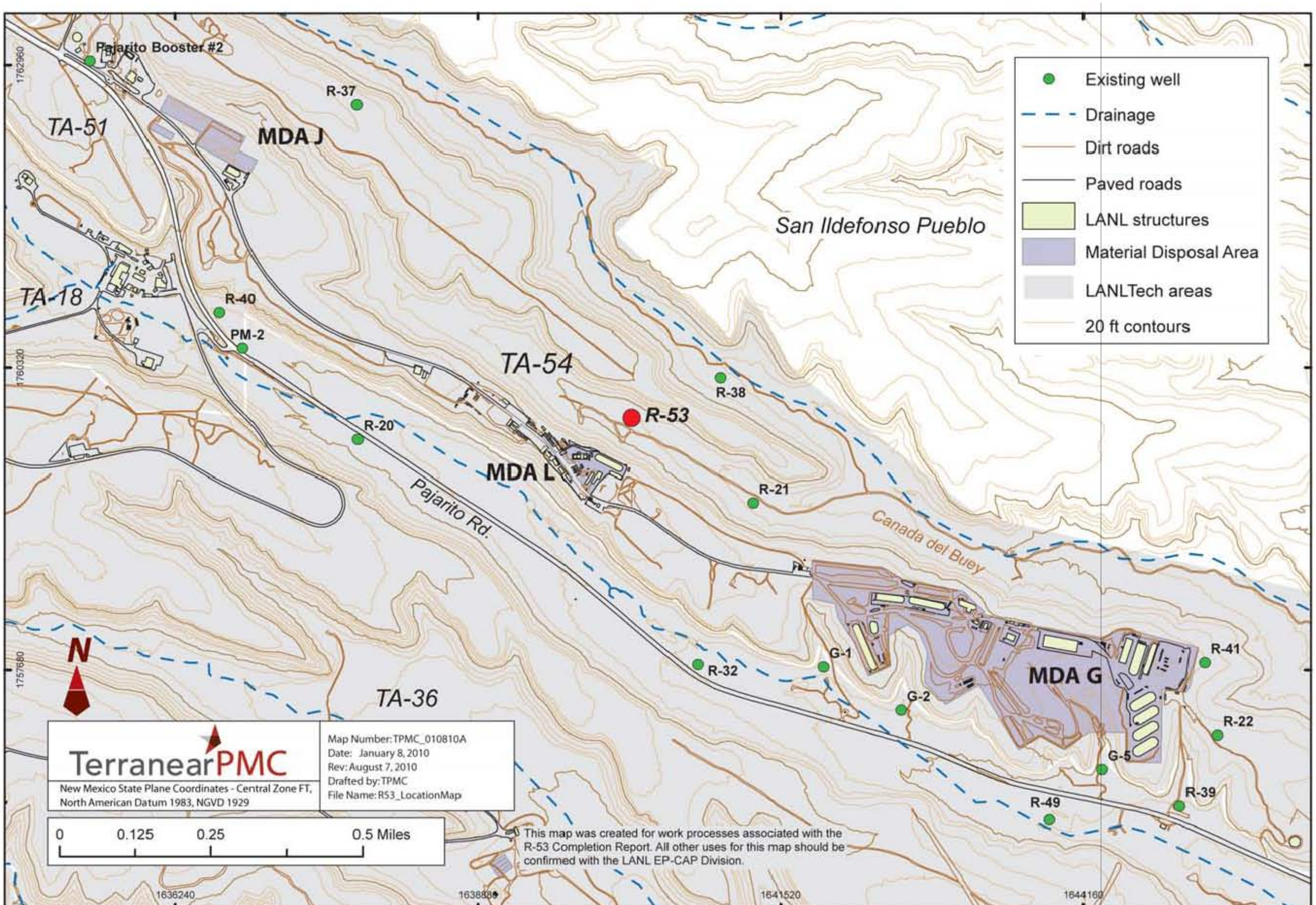

Figure 1.0-1 Location of monitoring well R-53

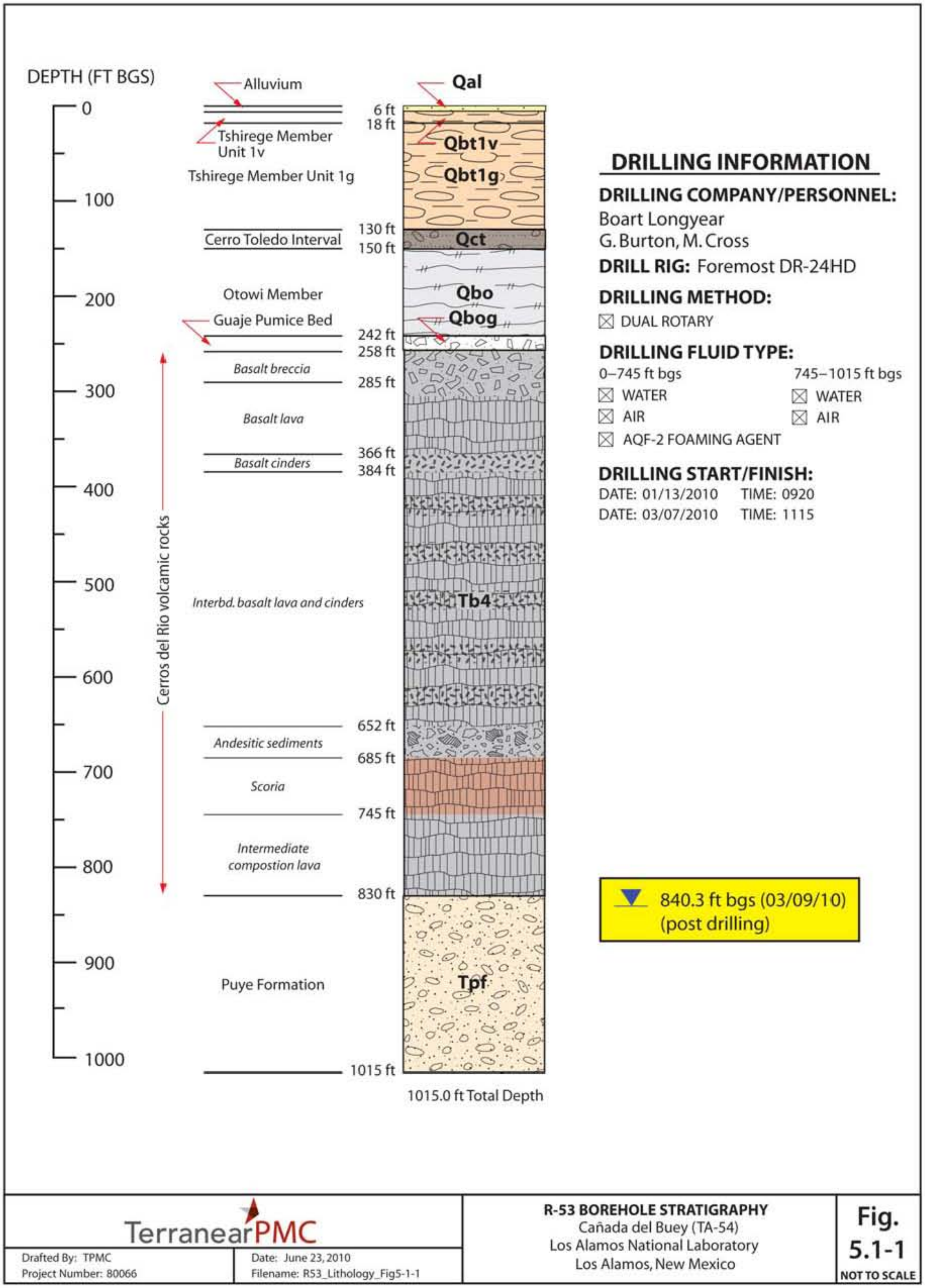

Figure 5.1-1 Monitoring well R-53 borehole stratigraphy

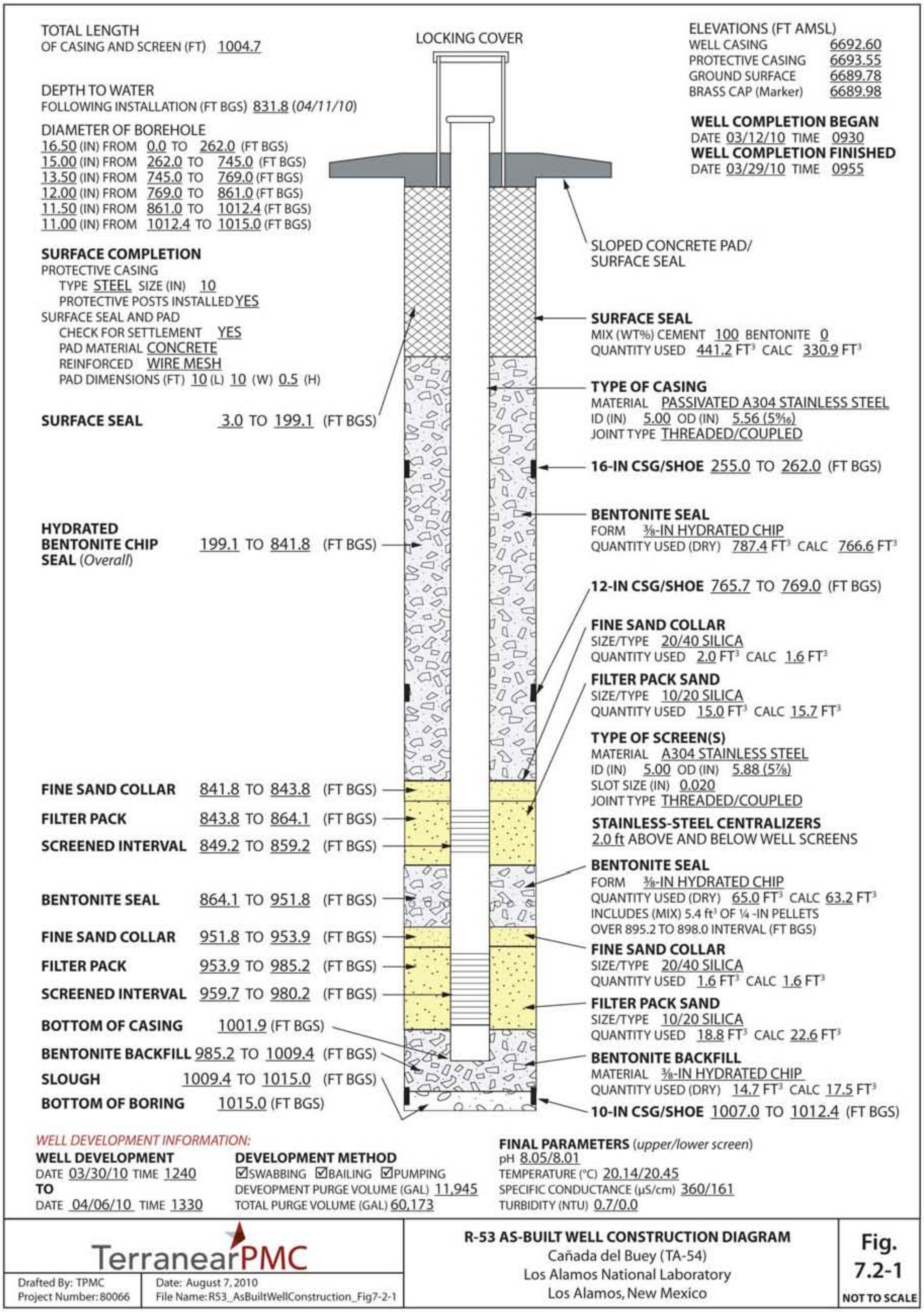

Figure 7.2-1 Monitoring well R-53 as-built well construction diagram

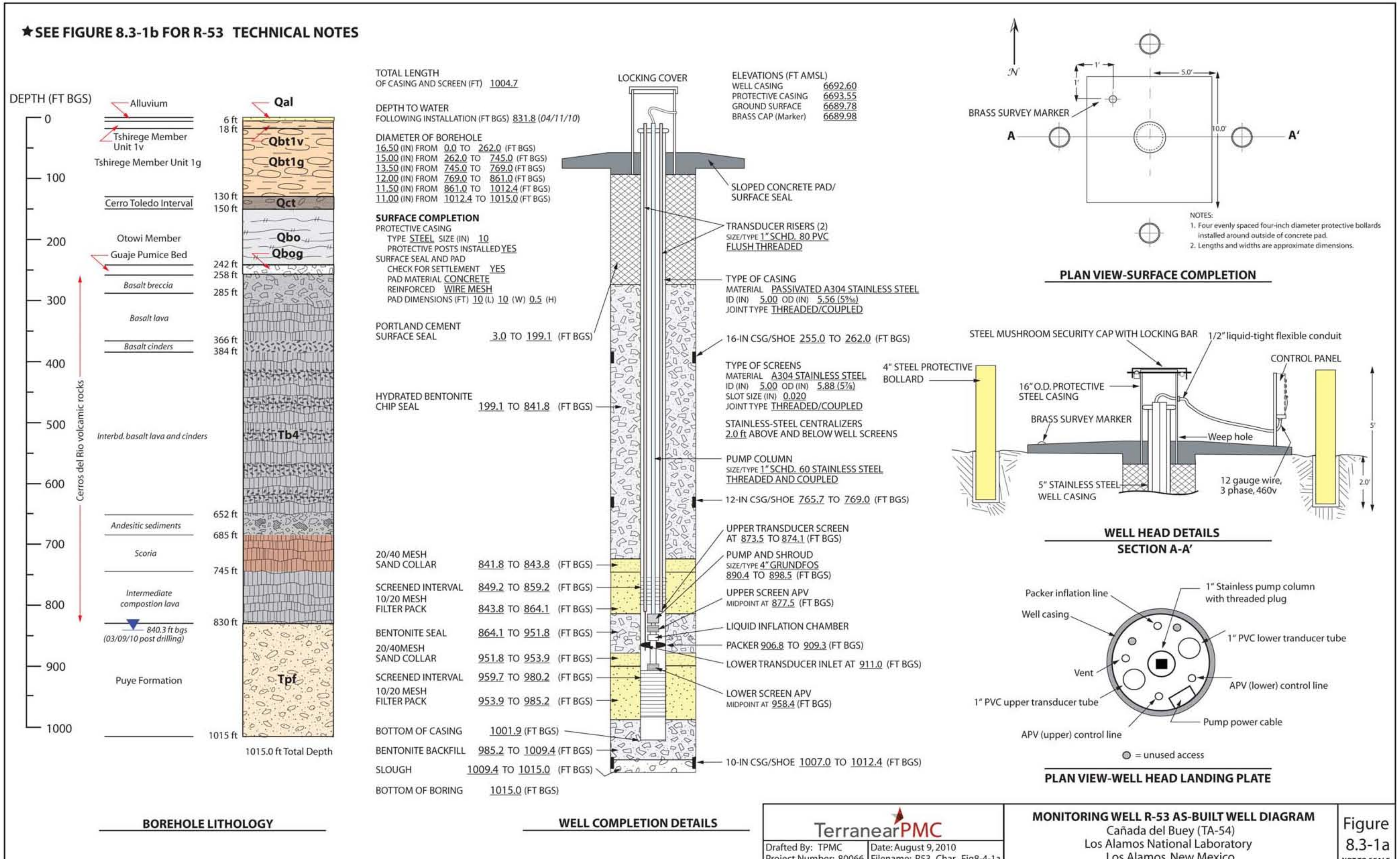

Figure 8.3-1a As-built schematic for regional monitoring well R-53

R-53 TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker

Northing:	1759860.57 ft
Easting:	1640109.61 ft
Elevation:	6689.98 ft AMSL

Well Casing (top of stainless steel)

Northing:	1759854.86 ft
Easting:	1640111.48 ft
Elevation:	6692.60 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

LANL: Video, natural gamma ray (×2), induction
Boart Longyear: Video (×2)

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam (to 745 ft bgs)

MILESTONE DATES

Drilling

Start:	01/13/2010
Finished:	03/07/2010

Well Completion

Start:	03/12/2010
Finished:	03/29/2010

Well Development

Start:	03/30/2010
Finished:	04/06/2010

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 11,945 gal. (5200/6100 gal. upper/lower screen, 645 gal. both screens)

Parameter Measurments (Final, upper screen/lower screen)

pH:	8.05/8.01
Temperature:	20.14/20.45°C
Specific Conductance:	360/161 µS/cm
Turbidity:	0.7/0.0 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Upper Screen

Water Produced:	16,466 gal.
Average Flow Rate:	10 gpm
Performed on:	04/16–19/2010

Lower Screen

Water Produced:	31,762 gal.
Average Flow Rate:	20 gpm
Performed on:	04/10–14/2010

DEDICATED SAMPLING SYSTEM

Pump
Make: Grundfos
Model: 5S30-820 CBM
4 U.S. gpm, APVs (Acccess Port Valves) midpoints at 877.5 (upper) and 958.4 (lower) ft bgs
Environmental retrofit

Motor
Make: Franklin Electric
Model: 2343262604
3 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
Upper 0.01-in. slot screen at 873.5–874.1 ft bgs,
Lower flexible tube from transducer set at 911.0 ft bgs

Transducers
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/Ns: 164422, 164614

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

TerranearPMC

Drafted By: TPMC
Project Number: 80066
Date: August 9, 2010
Filename: R53_TechnicalNotes_Fig8-3-1b

R-53 TECHNICAL NOTES
Cañada del Buey (TA-54)
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-53

Table 3.1-1
Fluid Quantities Used during R-53 Drilling and Well Construction

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling				
01/13/10	200	200	0	0
01/15/10	800	1000	5	5
01/16/10	700	1700	4	9
01/17/10	600	2300	5	14
01/18/10	400	2700	2	16
02/03/10	1500	4200	20	36
02/05/10	800	5000	10	46
02/06/10	2500	7500	25	71
02/07/10	500	8000	5	76
02/08/10	300	8300	0	76
02/10/10	1200	9500	25	101
02/11/10	1000	10,500	20	121
02/14/10	150	10,650	n/a*	121
02/20/10	1500	12,150	n/a	121
02/22/10	1500	13,650	n/a	121
02/23/10	500	14,150	n/a	121
02/24/10	500	14,650	n/a	121
02/25/10	2700	17,350	n/a	121
02/26/10	900	18,250	n/a	121
03/05/10	500	18,750	n/a	121
03/06/10	500	19,250	n/a	121
03/07/10	500	19,750	n/a	121
Well Construction				
03/17/10	150	19,900	n/a	n/a
03/18/10	1500	21,400	n/a	n/a
03/19/10	1800	23,200	n/a	n/a
03/20/10	200	23,400	n/a	n/a
03/21/10	1500	24,900	n/a	n/a
03/22/10	2500	27,400	n/a	n/a
03/23/10	2000	29,400	n/a	n/a
03/24/10	15,000	44,400	n/a	n/a
03/25/10	5500	49,900	n/a	n/a
03/26/10	250	50,150	n/a	n/a
03/27/10	4800	54,950	n/a	n/a

Table 3.1-1 (continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
03/28/10	2035	56,985	n/a	n/a
03/29/10	300	57,285	n/a	n/a
Total Water Volume (gal.)				
R-53	57,285			

* n/a = Not applicable. Foam use terminated at 745 ft bgs during drilling; none used during well construction.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-53

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-53	GW53-10-11670	02/26/10	840.0	Groundwater	Anions, cations, metals, VOCs, LH3
R-53	GW53-10-11671	03/07/10	979.0	Groundwater	Anions, cations, metals, VOCs, LH3
Well Development					
R-53	GW53-10-11680	04/03/10	859.0	Groundwater	TOC
R-53	GW53-10-11681	04/04/10	859.0	Groundwater	TOC
R-53	GW53-10-11682	04/04/10	859.0	Groundwater	TOC
R-53	GW53-10-11683	04/06/10	961.45	Groundwater	TOC
R-53	GW53-10-11684	04/06/10	961.45	Groundwater	TOC
Aquifer Testing					
R-53	GW53-10-11685	04/13/10	911.86	Groundwater	TOC
R-53	GW53-10-11686	04/13/10	911.86	Groundwater	TOC
R-53	GW53-10-11687	04/13/10	911.86	Groundwater	TOC
R-53	GW53-10-11688	04/13/10	911.86	Groundwater	TOC
R-53	GW53-10-11689	04/14/10	911.86	Groundwater	TOC
R-53	GW53-10-11690	04/14/10	911.86	Groundwater	TOC
R-53	GW53-10-11691	04/18/10	846.65	Groundwater	TOC
R-53	GW53-10-11692	04/18/10	846.65	Groundwater	TOC
R-53	GW53-10-11693	04/18/10	846.65	Groundwater	TOC
R-53	GW53-10-11694	04/19/10	846.65	Groundwater	TOC
R-53	GW53-10-11695	04/19/10	846.65	Groundwater	TOC
R-53	GW53-10-11696	04/19/10	846.65	Groundwater	TOC

Table 6.0-1
R-53 Borehole Logging

Date	Depth (ft bgs)	Description
02/12/10	Surface to 726	LANL personnel ran video, natural gamma ray, and induction logs in the borehole. Openhole from 262 to 726 ft bgs.
02/27/10	Surface to 828	Drilling subcontractor ran a video log inside 12-in. casing to verify the12-in. casing cut and to observe standing water column. DTW was 828 ft bgs.
03/07/10	Surface to 1014	LANL personnel ran natural gamma ray log after reaching TD (1015 ft bgs).
03/09/10	Surface to 1007	Drilling subcontractor ran a video log inside 10-in. casing to verify the 10-in. casing cut and to observe standing water column. DTW was 838.2 ft bgs.

Table 7.2-1
R-53 Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: cement slurry	441.2 ft^3
Upper bentonite seal: bentonite chips	787.4 ft^3
Upper fine sand collar: 20/40 silica sand	2.0 ft^3
Upper filter pack: 10/20 silica sand	15.0 ft^3
Middle bentonite seal: bentonite chips/pellets	65.0 ft^3
Lower fine sand collar: 20/40 silica sand	1.6 ft^3
Lower filter pack: 10/20 silica sand	18.8 ft^3
Backfill: bentonite chips/pellets	14.7 ft^3

Table 8.5-1
R-53 Survey Coordinates

Identification	Northing	Easting	Elevation
R-53 Brass cap embedded in pad	1759860.57	1640109.61	6689.98
R-53 ground surface near pad	1759859.50	1640107.05	6689.78
R-53 top of 16-in. protective casing	1759855.47	1640111.86	6693.55
R-53 top of stainless-steel well casing	1759854.86	1640111.48	6692.60

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

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-53

Location ID	Sample ID	Date Collected	Description	Sample Type
R-53	WST53-10-13641 (UF[a])	3/16/10	Decon Fluid	Liquid
R-53	WST53-10-13637 (F[b])	3/16/10	Decon Fluid	Liquid
R-53	WST53-10-13645 (FD[c])	3/16/10	Decon Fluid	Liquid
R-53	WST53-10-13649 (FTB[d])	3/16/10	Decon Fluid	Liquid
R-53	WST53-10-13642 (UF)	3/19/10	Decon Fluid	Liquid
R-53	WST53-10-13638 (F)	3/19/10	Decon Fluid	Liquid
R-53	WST53-10-13646 (FD)	3/19/10	Decon Fluid	Liquid
R-53	WST53-10-13650 (FTB)	3/19/10	Decon Fluid	Liquid
R-53	WST53-10-13633 (UF)	4/14/10	Development Water	Liquid
R-53	WST53-10-13632 (F)	4/14/10	Development Water	Liquid
R-53	WST53-10-13634 (FD)	4/14/10	Development Water	Liquid
R-53	WST53-10-13635 (FTB)	4/14/10	Development Water	Liquid
R-53	WST53-10-13644 (UF)	4/15/10	Decon Fluid	Liquid
R-53	WST53-10-13640 (F)	4/15/10	Decon Fluid	Liquid
R-53	WST53-10-13648 (FD)	4/15/10	Decon Fluid	Liquid
R-53	WST53-10-13652 (FTB)	4/15/10	Decon Fluid	Liquid
R-53	WST53-10-13643 (UF)	4/20/10	Decon Fluid	Liquid
R-53	WST53-10-13639 (F)	4/20/10	Decon Fluid	Liquid
R-53	WST53-10-13647 (FD)	4/20/10	Decon Fluid	Liquid
R-53	WST53-10-13651 (FTB)	4/20/10	Decon Fluid	Liquid

[a] UF = Unfiltered.
[b] F = Filtered.
[c] FD = Field duplicate.
[d] FTB = Field trip blank.

Appendix A

Borehole R-53 Lithologic Log

Los Alamos National Laboratory
Borehole Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-53	**TECHNICAL AREA (TA):** 54	**PAGE:** 1 of 15
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 1/13/2010/ 0920	**END DATE/TIME:** 3/7/2010/1115
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6689.78 ft AMSL		**TOTAL DEPTH: 1015** ft
DRILLERS: G. Burton, M. Cross	**SITE GEOLOGISTS:** R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
0–6	**ALLUVIUM:** Construction fill and alluvial sediments—light brown (5YR 6/4) sand with pebble gravels made up of mixed native tuffaceous alluvial sediments and quartz pebble-bearing gravel used in drill pad construction; unsorted, unconsolidated.	**Qal**	Note: drill cuttings for microscopic and descriptive analysis were collected at 5-ft intervals from 0 ft to borehole TD at 1015 ft bgs. Alluvial sediments and construction fill, encountered from 0 to 6 ft bgs, are approximately 6 ft thick.
6–18	**UNIT 1v OF THE TSHIREGE MEMBER OF THE BANDELIERTUFF:** Tuff—very pale orange (10YR 8/2) poorly welded, moderately indurated, pumiceous, crystal-bearing to crystal-rich, lithic-poor. Pumices noted as predominantly devitrified. 6'–18' WR: samples locally contain abundant silty ash and chips of indurated, weathered crystal tuff. +10F: 70-80% fragments of weathered, indurated crystal-pumice rhyolite ash-flow tuff; 20–30% subrounded volcanic lithic fragments (dacites); 3–5% quartz and sanidine crystals. +35F: 70–85% quartz and sanidine crystals, 15–25% tuff fragments, 2–3% dacitic lithics. Note: first appearance of vitric pumice observed in 15–20-ft sampling interval.	**Qbt 1v**	Unit 1v of the Tshirege Member of the Bandelier Tuff (Qbt 1v), encountered from 6 ft to 18 ft bgs, is estimated to be a minimum of 12 ft thick. The lower Qbt 1v contact was determined on the basis of cuttings examination and natural gamma log interpretation.
18–30	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIERTUFF:** Tuff—very pale orange (10YR 8/2) poorly welded, weakly to moderately indurated, pumiceous, crystal-bearing, lithic-poor. Pumices noted as vitric. 18–30 ft WR: samples locally contain abundant silty ash and chips of rhyolitic ash-flow tuff. +10F: 50-70% angular/broken chips and subangular volcanic lithic fragments (up to 7 mm, predominantly hornblende dacites); 30–50% fragments of indurated tuff. Tuff is composed of 15–20% quartz and sanidine crystals; 15–20% small (up to 7 mm) locally flattened, devitrified and vitric pumices; 1-2% volcanic lithic fragments set in a matrix of weathered volcanic ash. +35F: 70–85% quartz and sanidine crystals, 15–25% tuff fragments, 2–3% dacitic lithics.	**Qbt 1g**	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), was encountered from 18 ft to 130 ft bgs, is estimated to be 112 ft thick.

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<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: 6689.78 ft AMSL</td><td>TOTAL DEPTH: 1015 ft</td></tr>
<tr><td colspan="2">DRILLERS: G. Burton, M. Cross</td><td colspan="3">SITE GEOLOGISTS: R. Lawrence</td></tr>
<tr><td>Depth (ft bgs)</td><td>Lithology</td><td colspan="2">Lithologic Symbol</td><td>Notes</td></tr>
<tr><td>30–65</td><td>Tuff—moderate orange pink (5YR 8/4) poorly welded, poorly to moderately indurated, pumice-rich, crystal-bearing, lithic-poor. Pumices noted as weathered to vitric.

30–65 ft WR: samples contain abundant fine ash and pumices that are vitric or weathered with relict vitric textures. +10F: 85–95% pale orange fibrous-textured, weathered to glassy pumices that are quartz- and sanidine-phyric;
3-5% lithic fragments (predominantly dacitic);
5-10% fragments of pumiceous rhyolitic crystal tuff. Note: pumices commonly exhibit black obsidian rinds surrounding select phenocrysts. +35F: 85–95% free crystals of quartz and sanidine commonly showing obsidian rims
(i.e., apparently fused around crystal boundaries);
10-20% granular fragments of weathered glassy pumice;
2-5% dacitic lithics.</td><td colspan="2">Qbt 1g</td><td></td></tr>
<tr><td>65–80</td><td>Tuff—very pale orange (10YR 8/2) to moderate orange pink (5YR 8/4) poorly welded, pumiceous, crystal-bearing, lithic-poor. Pumices vitric with weathered to lustrous appearance.

65–80 ft +10F: 80–90% lapilli/fragments of vitric pumice, weathered to glassy luster, fibrous, quartz- and sanidine-phyric; 10–20% angular to subangular hornblende-bearing volcanic lithics (up to 7 mm) of predominantly dacitic composition; rare fragments of indurated tuff. +35F:
80-90% free crystals of quartz and sanidine; 10–15% vitric pumice fragments; 2–4% volcanic lithics.</td><td colspan="2">Qbt 1g</td><td></td></tr>
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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
80–130	Tuff—pale yellowish gray (5Y 8/1) to white (N9) poorly welded, pumiceous, crystal-bearing, lithic-poor. Pumices are vitric with lustrous appearance. 80–100 ft +10F: 95–99% lapilli/fragments of white, fibrous, quartz- and sanidine-phyric pumice exhibiting abundant small Mn-oxide spots; 1–5% subangular to subrounded volcanics lithics (predominantly light gray dacites). +35F: free quartz and sanidine crystals; white vitric pumice fragments and volcanic lithics in varying proportions. 100–110 ft +10F: 70–80% white fragments of lustrous, quartz- and sanidine-phyric glassy pumice; 20–30% angular to subangular to subrounded volcanic lithics (up to 8 mm) of various lithologies (hornblende- and/or biotite-phyric dacites, andesite, mineralized rhyolite(?) with fine cubic pseudomorphs after pyrite). 110–115 ft +10F: 99% angular fragments of white lustrous, quartz- and sanidine-phyric glassy pumice; 1% dacitic lithic fragments. 115–130 ft +10F: 80–95% white fragments of lustrous, quartz- and sanidine-phyric glassy pumice speckled with Mn-oxide spots; 5–20% angular to subangular volcanic lithics (up to 10 mm), predominantly dacitic. +35F: free quartz and sanidine crystals; white vitric pumice fragments and volcanic lithics in varying proportions.	**Qbt 1g**	The lower Qbt 1g contact was determined on the basis of cuttings examination and natural gamma log interpretation.
130–150	**CERRO TOLEDO INTERVAL:** Volcaniclastic sediments—varicolored, very pale orange (10YR 8/2) to light brownish gray silty fine to coarse sands with pebble gravel; poorly to moderately sorted, moderately to strongly cemented. Detritus of pumice, dacite and other volcanic rocks, and minor quartz and sanidine crystals. 130–140 ft +10F: 85–95% fragments of lustrous, fibrous, quartz- and sanidine-phyric pumice; 5–15% indurated fragments of white, fine-grained tuffaceous sandstone with quartz and sanidine crystal grains and fragments of volcanic rocks in a white silty matrix; 1–3% subangular dacite fragments. 140–150 ft +10F: 70–90% broken to subangular clasts (up to 15 mm) comprised of various volcanic rocks (light gray and pink hornblende- and/or biotite-phyric dacites, gray fine-grained dacite, flow-banded rhyodacite); 10–30% fragments of rounded pebbles (up to 9 mm) of white to pale orange, vitric, quartz- and sanidine-phyric pumice. +35F: 40-50% volcanic grains; 30–40% pumice grains; 10-20% quartz and sanidine crystals.	**Qbt 1g**	The Cerro Toledo interval (Qct), encountered from 130 ft to 150 ft bgs, is estimated to be 20 ft thick. The lower Qct contact determined on the basis of cuttings examination and natural gamma log interpretation.

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DRILLERS: G. Burton, M. Cross	SITE GEOLOGISTS: R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
150–175	**OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—varicolored, very pale orange (10YR 8/2) to very light gray (N8) poorly welded, weakly indurated, pumiceous, crystal-bearing, lithic-rich. 150–160 ft WR/+10F: 60–70% pale orange tan glassy, quartz- and sanidine-phyric pumices; 30-40% angular to subangular volcanic fragments (predominantly gray hornblende-dacites). +35F: free quartz and sanidine crystals; white vitric pumice fragments and volcanic grains in varying proportions. 160–170 ft WR/+10F: 20–30% glassy, quartz- and sanidine-phyric pumices; 70–80% angular to subangular volcanic fragments. 170–175 ft WR/+10F: 60–70% glassy pumices, commonly well rounded; 30–40% granules (up to 5 mm) of dacite, some of which exhibit well rounded morphologies; minor fragments of anomalous white tuffaceous sandstone.	**Qbo**	The Otowi Member of the Bandelier Tuff (Qbo), intersected from 150 ft to 242 ft bgs, is estimated to be 92 ft thick.
175–210	Tuff—light gray (N7) to very pale orange (10YR 8/2), poorly welded, weakly indurated, pumiceous, crystal-bearing, lithic-bearing to lithic-rich. 175–210 ft +10F: 50–70% angular/ broken volcanic lithic fragments including gray to pink hornblende-phyric dacites, white quartz-phyric rhyodacite; 30–50% fragments of white to pale orange glassy, quartz- and sanidine-phyric pumice. +35F: grains/fragments composed of free quartz and sanidine crystals; white vitric pumice fragments and volcanic lithics in varying proportions.	**Qbo**	

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
210–242	Tuff—varicolored, very light gray (N7) to very pale orange (10YR 8/2), poorly welded, weakly indurated, pumiceous, crystal-bearing, lithic-bearing to lithic-rich. 210–220 ft +10F: 80–85% fragments of very pale orange to white vitric, quartz- and sanidine-phyric pumices; 15-20% angular volcanic lithic fragments (predominantly light gray porphyritic hornblende-phyric dacites +35F: 30-40% pumice fragments; 40–50% volcanic lithic grains; 20–30% free quartz and sanidine crystals. 220–235 ft +10F: 40–60% vitric pumice fragments; 20-40% angular volcanic lithic fragments (gray dacites, hornblende-dacites); 10–15% anomalous fragments of white silty fine-grained sandstone with abundant quartz and sanidine crystals and volcanic grains. +35F: 30-40% pumice fragments; 20–30% volcanic lithic grains; 30–50% free quartz and sanidine crystals. 235–242 ft +10F: 90–95% white vitric pumice lapilli (up to 15 mm) glassy luster, phenocryst-poor; 5–10% dacitic lithic fragments. +35F: 40% pumice fragments; 40% volcanic lithic grains; 20% free quartz and sanidine crystals.	**Qbo**	The lower Qbo contact determined on the basis of cuttings examination and natural gamma log interpretation.
242–258	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—white (N9), poorly welded to non-welded, pumice-rich, crystal-bearing to crystal-poor. 245–250 ft +10F: 80% white vitric pumice, glassy luster, phenocryst-poor; 20% small (up to 5 mm) dacitic lithic fragments. +35F: 40–50% white pumice grains; 20-30% quartz and sanidine crystals; 20–30% volcanic lithic grains. 250–258 ft +10F: 95–97% white vitric pumice fragments and subrounded lapilli (up to 14 mm) that are phenocryst-poor and exhibit glassy luster with pristine appearance; 3-5% angular fragments of volcanic (predominantly dacite) lithics. +35F: 98–99% white pumice grains; 1–2% volcanic lithics; virtually no free quartz and sanidine crystals present.	**Qbog**	The Guaje Pumice Bed (Qbog), intersected from 242 ft to 258 ft bgs, is estimated to be 16 ft thick. The lower Qbog contact was determined on the basis of cuttings examination and natural gamma log interpretation.

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
258–270	**CERROS DEL RIO VOLCANIC ROCKS:** Basalt breccia—medium gray to light tan (5Y 8/1) mixed angular chips of vesicular basalt and well rounded clasts of weathered basalt. 258–270 ft +10F: 30–40% rounded basalt detrital clasts; 60–70% angular/broken fragments of vesicular basalt; trace detrital pumice. +35F: mixed rounded grains and angular fragments of tan siltstone to very fine grained sandstone. This interval was determined to be a volcanic breccia from video log interpretation.	**Tb 4**	The Cerros del Rio volcanic rocks (Tb 4), including lavas, cinder deposits and reworked volcanic sediments, was intersected from 258 ft to 830 ft bgs and is estimated to be 572 ft thick.
270–285	Basalt breccia—medium gray (N5) to light orange tan (YR 7/4). Predominantly broken/angular basalt fragments with subordinate granules and small pebbles of rounded, silt-coated basalt. 270–285 ft +10F: 100% subangular to angular/broken fragments and clasts (up to 8 mm) of silt-coated vesicular basalt +35F: 85–90% basalt fragments; 10–15% fragments of tan siltstone.	**Tb 4**	
285–305	Basalt lava—medium gray (N5) massive basalt; broken/angular chips of phenocryst-poor, olivine-phyric basalt. 285–295 ft +10F: mixed angular/broken chips of vesicular basalt and minor fragments that exhibit some degree of rounding, possibly due to milling during drilling. +35F: 95% basalt fragments; 5% fragments of tan siltstone. 295–305 ft +10F: 100% angular chips of massive basalt, phenocryst-poor. Phenocrysts (less than 1% by volume) of small (up to 1 mm) olivine and rare plagioclase with aphanitic groundmass that is weakly altered.	**Tb 4**	

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
305–366	Basalt lava—medium light gray (N6) broken angular chips of massive basalt that is phenocryst-poor with fine olivine; groundmass fine grained/aphanitic and weakly altered. 305–330 ft +10F: 100% angular chips of vesicular basalt, weak limonite or hematite coating vesicles. Basalt is phenocryst-poor with less than 1% fine (up to 1 mm) green olivine, trace plagioclase and clinopyroxene; weakly altered aphanitic groundmass 330–355 ft +10F: predominantly angular chips of strongly vesicular basalt and less abundant massive basalt; vesicles commonly lined with reddish clay. Basalt composition similar to 305–330-ft interval. 355–366 ft WR: chips coated with light gray silt-sized particles. +10F: predominantly angular chips of massive (non-vesicular) phenocryst-poor, olivine-bearing basalt; groundmass aphanitic and weakly altered.	**Tb 4**	Note: upper and lower contacts of basalt lava, from 285 ft to 366 ft bgs, determined from downhole video log.
366–384	Basalt cinder deposits—medium gray (N5) to pale reddish gray (5R 6/2). Predominantly lapilli cinders of strongly vesicular to scoriaceous basalt with less abundant chips of massive olivine-phyric basalt. 366–384 ft +10F: mixed reddish gray scoriaceous cinders (lapilli, up to 14 mm) and less frequent angular chips of phenocryst-poor basalt with fine olivine. Olivine commonly in cumulophyric clusters with plagioclase. Vesicles commonly lined with reddish Fe-oxide (earthy hematite).	**Tb 4**	Note: upper and lower contacts of basalt cinder deposits, from 366 ft to 384 ft bgs, determined from downhole video log.
384–420	Basaltic lavas and interflow cinder deposits—medium gray (N5) to pale reddish gray (5R 6/2). Predominantly lapilli cinders of strongly vesicular to scoriaceous basalt with less abundant chips of massive olivine-phyric basalt. 384–400 ft +10F: mixed gray to reddish scoriaceous lapilli cinders (up to 20 mm) with hematite-lined vesicles and less abundant chips of olivine-phyric massive basalt. 400–420 ft +10F: predominantly chips of massive to vesicular olivine- and plagioclase-phyric basalt with less frequent strongly vesicular fragments that appear to be tephra particles. Basalt phenocrysts becoming more well developed with depth; olivine (up to 2 mm) intergrown with plagioclase.	**Tb 4**	Note: upper and lower contacts of interlayered thin basalt flows and cinder deposits, from 384 ft to 500 ft bgs, determined from downhole video log.

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<tr><td>420–460</td><td>Basaltic lavas and interflow cinder deposits—medium gray (N5) to pale reddish gray (5R 6/2). Samples in this interval contain mixed chips of massive basalt and lapilli cinders in varying proportions suggesting a sequence of interlayered lavas and tephra deposits.

420–430 ft WR/+10F: 90–95% angular chips of weakly vesicular basalt exhibiting phenocrysts (up to 1% by volume) of green olivine (up to 2 mm) and minor plagioclase set in an aphanitic groundmass that is weakly altered; 5-10% black to reddish (hematitic) cinders.

430–440 ft +10F: 50-60% basaltic cinders; 40–50% massive to weakly vesicular basalt chips.

440–445 ft +10F: predominantly chips of massive to weakly vesicular olivine-phyric and plagioclase-phyric basalt; minor cinders. Likely thin basalt flow.

445–460 ft +10F: roughly equal proportions of scoriaceous cinders and chips of massive basalt. Basalt lava exhibiting increasing presence of olivine as phenocrysts and intergrowths with black clinopyroxene (up to 2% by volume). Cinders commonly reddish gray (hematite-stained).</td><td>Tb 4</td><td colspan="2"></td></tr>
<tr><td>460–500</td><td>Basaltic lavas and interflow cinder deposits—medium gray (N5) to pale reddish gray (5R 6/2). Samples in this interval contain 50% or more of oxidized scoriaceous cinders and less than 50% chips of massive olivine- and clinopyroxene-phyric basalt, suggesting repeated interlayering of thin lavas and interflow tephras.

460–475 ft +10F: 70–80% reddish scoriaceous cinders; 20-30% chips of olivine- and clinopyroxene-phyric basalt.

475–500 ft +10F: Continued predominance of reddish (oxidized) vesicular to scoriaceous cinders and less frequent chips of olivine- and clinopyroxene-phyric basalt.</td><td>Tb 4</td><td colspan="2"></td></tr>
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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
500–545	Basaltic lavas and interflow cinder deposits—medium gray (N5) to light gray (N7). Samples in this interval contain more than 50% chips of massive to weakly vesicular, olivine- and clinopyroxene-phyric basalt and less than 50% basaltic cinders, suggesting repeated interlayering of lavas and thin interflow tephras. 500–520 ft +10F: 70–80% chips of massive basalt. Basalt is weakly porphyritic with phenocrysts (1–2% by volume) of olivine, clinopyroxenes (up to 2 mm) and trace plagioclase (olivine and Cpx commonly intergrown) with aphanitic groundmass that appears weakly altered; 20–30% reddish scoriaceous cinders. 520–535 ft +10F: Interval of increased cinder abundance; 60–70% angular chips of weakly vesicular olivine- and clinopyroxene-phyric basalt, 30–40% reddish scoriaceous cinders. 535–545 ft +10F: 90–95% angular chips of weakly vesicular basalt exhibiting slightly more well developed phenocrysts (2–3% by volume) of olivine (up to 3 mm), black clinopyroxene (commonly rimming, or intergrown with, olivine) and minor plagioclase; 5–10% reddish scoriaceous cinders.	**Tb 4**	Note: video log indicated a discrete lava flow in the 518 to 542-ft interval .
545–570	Basaltic lavas and interflow cinder deposits—medium gray (N5) to pale red (5Y 6/2). Samples in this interval contain more than 50% chips of reddish scoria and less than 50% chips of massive olivine- and clinopyroxene-phyric basalt. The persistent occurrence of mixed massive and scoriaceous basalt chips suggest s repeated interlayering of lavas and thin interflow tephras or reworked sediments. 545–550 ft +10F: 60–70% reddish (hematite-stained) strongly vesicular to scoriaceous cinder fragments and lapilli; 20–30% chips of massive basalt; 20–25% rounded detrital granules and small pebbles of basalt, suggesting a thin layer of reworked basaltic tephra. 550–570 ft +10F: 70–90% fragments of scoriaceous cinders, reddish (oxidized) to gray in color; 10–30% chips of weakly porphyritic basalt with phenocrysts (1–2% by volume) of olivine, clinopyroxene and plagioclase in a weakly altered aphanitic groundmass.	**Tb 4**	

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
570–652	Basaltic lavas and interflow cinder deposits—medium gray (N5) to pale red (5Y 6/2). Samples in this interval contain both chips of lava and cinders that vary considerably in proportion but persist as significant components suggesting a sequence of complexly interlayered basalt lavas and cinder deposits. 570–585 ft +10F: 80–90% chips of massive basalt lava; 10–20% red-orange (oxidized) scoriaceous cinders; 20–30% chips of massive basalt with phenocrysts (1–2% by volume) of clinopyroxene and minor olivine. 585–605 ft +10F: 50–60% chips of Cpx- and olivine-phyric basalt; 40–50% scoriaceous cinders. Trace detrital basalt in +35F: of interval 595–600 ft. 605–615 ft +10F: 20–30% chips of massive Cpx- and olivine-phyric basalt; 60–80% fragments and lapilli of gray vesicular and red scoriaceous cinders. 615–635 ft +10F: 60–80% chips of basalt lava; 20-40% reddish and gray vesicular to scoriaceous cinders. Trace rounded detrital basalt in +35F in the interval 625–630 ft. 635–652 ft +10F: 40–50% chips of massive Cpx- and olivine-phyric basalt lava; 50–60% strongly vesicular to scoriaceous basalt cinders.	**Tb 4**	Note: video log identified the 638 to 652-ft interval as breccia and clastic basaltic sediments. This interval forms the base of a thick sequence of interlayered Tb 4 lavas and cinder deposits from 366 ft to 652 ft bgs.
652–665	Andesitic sediments—light brownish gray (5YR 6/1) fine to medium gravels with silty fine to coarse sand, very poorly sorted, weak to moderately cemented. Samples in this interval contain angular chips of basalt and scoria, subrounded reworked volcanic granules/ pebbles and fragments of very fine grained volcanic sandstone. 652–665 ft WR: chips and detrital clasts are silt-coated. +10F: 80–90% angular/broken chips and subangular pebble clasts (up to 17 mm) of massive to vesicular dacite; 10-20% fragments of siltstone and very fine grained sandstone.	**Tb 4**	Note: the 652 to 745-ft interval was indentified in video log as clastic sedimentary deposits. Volcanic detritus throughout this section appears to be composed predominantly of phenocryst-poor, Cpx-phyric dacite or other “more magmatically evolved” (i.e., relative to basalt) intermediate volcanic lithology. The unidentified rock is tentatively referred to as andesite, pending geochemical analysis and identification.

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DRILLERS: G. Burton, M. Cross	**SITE GEOLOGISTS:** R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
665–685	Andesitic sediments— brownish gray (5YR 6/1) to medium dark gray (N4) fine to medium gravels with silty fine to coarse sand, poorly sorted, weak to moderately cemented. Samples contain abundant fragments/clasts of black scoria and fragments of silty very fine grained volcanic sandstone. 665–670 ft +10F: 85–90% subangular to subrounded clasts composed of black scoria; 10–15% fragments and rounded grains of black and red scoria and light tan fine-grained sandstone. +35F: 80% grains of black and minor red scoria; 20% siltstone fragments, trace grains of quartz, dacite and chert. 670–685 ft +10F: 99–100% subangular to subrounded clasts (up to 30 mm) of black scoria and vesicular andesite. Note that the degree of sedimentary reworking (rounding) increases downward in the interval; trace silty sandstone fragments.	**Tb 4**	
685–745	685–705 ft +10F: 99–100% subangular to well rounded (degree of rounding increases with depth) granules and pebbles (up to 17 mm) of black and reddish brown scoria and lesser massive to vesicular andesite; locally up to 1% fragments of light tan silty very fine grained sandstone. 705–720 ft +10F: 100% angular to subrounded clasts of reddish scoria. 720–730 ft+10F: 70–75% subangular to subrounded clasts of reddish scoria; 25–30% angular chips of altered (bleached) phenocryst-poor, Cpx-phyric andesite(?) suggesting a “more evolved” volcanic source for these clastic sediments 730–745 ft WR: samples contain abundant silty fine to coarse sand with the appearance of soil. +10F: predominantly subrounded to well rounded granules/pebbles of black and reddish cinders; less abundant chips of Cpx-phyric lava.	**Tb 4**	Note: the silt-rich interval 730 to 745 ft may represent a soil horizon.

BOREHOLE IDENTIFICATION (ID): R-53	**TECHNICAL AREA (TA):** 54		**PAGE:** 12 of 15
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 1/13/2010/ 0920		**END DATE/TIME:** 3/7/2010/1115
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD		**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6689.78 ft AMSL			**TOTAL DEPTH: 1015** ft
DRILLERS: G. Burton, M. Cross	**SITE GEOLOGISTS:** R. Lawrence		

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
745–830	Dacite lava—medium light gray (N6). Samples contain commonly well rounded fragments composed predominantly to exclusively of light gray fine grained (aphanitic) dacite(?) that is phenocryst-poor with rare phenocrystic clinopyroxene. Exceptionally well rounded dacite "pebbles" noted in many samples are interpreted as having been artificially milled during the drilling process. 745–755 ft +10F: monolithic sample; 100% angular/broken chips and well rounded granules/pebbles (up to 17 mm) composed of light gray dacite. 755–800 ft +10F: Nearly monolithologic samples of angular chips and well rounded granules/pebbles (up to 20 mm) of light gray, phenocryst-poor dacite. Select well rounded "clasts" possibly milled during drilling. Local trace abundances of reddish cinders. 800–830 ft +10F: Monolithologic interval. Samples contain mixed angular chips and rounded to well rounded granules/pebbles (up to 26 mm) composed of unique light gray, fine-grained phenocryst-poor dacite. Select well rounded "clasts" interpreted as milled during drilling.	**Tb 4**	Note: the 745 to 830-ft interval was indentified in video log as a discrete lava flow. Volcanic rocks in this section are of phenocryst-poor dacite or other intermediate volcanic lithology. The unidentified rock is tentatively referred to as dacite, pending geochemical analysis and identification. Note: The lower Tb 4 contact was determined on the basis of cuttings examination and natural gamma log interpretation.

BOREHOLE IDENTIFICATION (ID): R-53	**TECHNICAL AREA (TA):** 54	**PAGE:** 13 of 15
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 1/13/2010/ 0920	**END DATE/TIME:** 3/7/2010/1115
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6689.78 ft AMSL		**TOTAL DEPTH: 1015** ft
DRILLERS: G. Burton, M. Cross	**SITE GEOLOGISTS:** R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
830–870	**PUYE FORMATION:** Volcaniclastic sediments – varicolored light brownish gray (5YR 6/1) to pale pink (5YR 8/4) fine to medium gravels with fine to coarse sand and silt, poorly sorted, moderately indurated. Detritus composed of variable lithologies (black glassy dacite, abundant fine-grained dacite, gray porphyritic dacites, minor Precambrian quartzite). 830–835 ft +10F: 85–90% subangular to subrounded clasts (up to 27 mm) of massive to vesicular, fine-grained, phenocryst-poor dacite; 10–15% fragments of light pinkish claystone. +35F: 80–85% grains fine-grained dacite and vitrophyre; 5–7% fragments of pale tan claystone; 5–7% grains of various lithologies (volcanic rocks, trace quartzite). 835–855 ft WR/10F: Samples contain increasingly more varieties of volcanic rocks; 85–90% subangular to rounded clasts (up to 10 mm) composed of various volcanic rocks (fine-grained and porphyritic dacites, scoria, brown andesite, vitrophyre); 10–15% fragments of very fine grained sandstone and claystone. +35F: grains of varieties of volcanic rocks; minor quartzite and quartz crystals. 855–865 ft +10F: Interval of pebble gravels; 90–95% subangular to well rounded clasts composed of various volcanic rocks (as above); 5–10% claystone fragments. +35F: grains of various volcanic rocks as above (noted also obsidian, quartzite, pumice, granite). 865–870 ft +10F: Interval of silt-rich coarse sands with minor pebble gravel; 98% subangular to subrounded clasts compositionally similar to above plus pink microcline; 2% claystone fragments.	**Tpf**	Puye volcaniclastic sediments (Tpf), intersected from 830 ft to the bottom of the borehole at 1015 ft bgs, have a minimum thickness of 185 ft.
870–890	Volcaniclastic sediments – varicolored, light medium (N6) to pale pink (5YR 8/4) fine to medium gravels with fine to coarse sand, poorly sorted, weakly to moderately indurated. Detritus composed of light gray porphyritic dacites. 870–890 ft WR/+10F: 98–99% angular to subrounded clasts (up to 22 mm) predominantly of coarsely porphyritic hornblende- and/or biotite-phyric dacite, minor black scoria and weathered pumices; 1–2% clasts of quartzite and granite. +35F: 90% volcanic grains; 10% grains of quartzite, microcline and quartz crystals.	**Tpf**	

BOREHOLE IDENTIFICATION (ID): R-53	TECHNICAL AREA (TA): 54	PAGE: 14 of 15
DRILLING COMPANY: Boart Longyear Company	START DATE/TIME: 1/13/2010/ 0920	END DATE/TIME: 3/7/2010/1115
DRILLING METHOD: Dual Rotary	MACHINE: Foremost DR24 HD	SAMPLING METHOD: Grab
GROUND ELEVATION: 6689.78 ft AMSL		TOTAL DEPTH: 1015 ft
DRILLERS: G. Burton, M. Cross	SITE GEOLOGISTS: R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
890–905	Volcaniclastic sediments – varicolored, light medium (N6) to pale pink (5YR 8/4) fine to medium gravels with fine to coarse sand, poorly sorted, weakly to moderately indurated. Detritus of mixed volcanic and Precambrian quartzo-feldspathic lithologies. 890–905 ft WR/+10F: 60–70% subrounded to well rounded volcanic clasts (up to 25 mm) including fine-grained and porphyritic dacites, andesite; 30–40% subrounded granules and small pebbles (up to 20 mm) of quartzite, microcline, granite. +35F: 50–70% grains of quartzite, microcline and quartz crystals; 30–50% volcanic grains.	**Tpf**	Note: the occurrence of Precambrian lithologies (quartzite, etc.) making up at least 25% by volume of samples in the 890 to 905-ft interval suggests Totavi Lentil- type axial river gravel deposits interfingered with Puye Formation volcaniclastic sediments.
905–935	Volcaniclastic sediments –medium (N5) to medium light gray (N6) fine to medium gravels with fine to coarse sand, poorly sorted, weakly indurated. Detritus predominantly of light gray porphyritic dacites and minor (less than 5% by volume) quartzo-feldspathic rocks. 905–935 ft WR/+10F: 95–97% subrounded to well rounded clasts (up to 20 mm) predominantly of light gray hornblende-and/or biotite-phyric dacites; 3–5% detritus of quartzite and granite. +35F: 90–95% volcanic grains; 3–10% quartzo-feldspathic grains.	**Tpf**	
935–945	Volcaniclastic sediments–varicolored, light medium (N6) to pale pink (5YR 8/4) fine gravels with fine to coarse sand, poorly to moderately sorted, weakly to moderately indurated. Detritus predominantly of light gray porphyritic dacites and significant abundances (more than 15% by volume) of Precambrian quartzo-feldspathic lithologies. 935–945 ft WR/+10F: 75–85% detritus composed of various volcanic rocks, predominantly hornblende-dacites; 15-25% quartzite and granitic detrital clasts.	**Tpf**	Note: samples in the 835 to 945-ft interval contain Precambrian lithologies (quartzite, granite, etc.) making up at least 15% by volume, suggesting Totavi Lentil-type axial river gravel deposits interfingered with Puye Formation volcaniclastic sediments.
945–970	Volcaniclastic sediments–grayish orange pink (5YR 7/2) to pale yellowish gray (5Y 7/2) fine gravels with silty fine to coarse sand, poorly to moderately sorted, moderately cemented. Detritus predominantly of light gray porphyritic dacites and minor (less than 3% by volume) quartzo-feldspathic rocks. 945–950 ft interval of silty sandstone. WR/+10F: Samples contain 95–97% fragments of indurated silty fine-grained sandstone; 3–5% volcanic detritus. 950–955 ft +10F: 80% volcanic (predominantly hornblende-dacite) clasts; 20% fine-grained sandstone fragments. 955–970 ft +10F: 97–98% dacitic detritus; 2-3% Precambrian quartzo-feldspathic detritus.	**Tpf**	

BOREHOLE IDENTIFICATION (ID): R-53	**TECHNICAL AREA (TA):** 54		**PAGE:** 15 of 15
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 1/13/2010/ 0920		**END DATE/TIME:** 3/7/2010/1115
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD		**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6689.78 ft AMSL			**TOTAL DEPTH: 1015** ft
DRILLERS: G. Burton, M. Cross	**SITE GEOLOGISTS:** R. Lawrence		

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
970–980	Volcaniclastic sediments–light brownish gray (5YR 6/1) silty coarse to fine gravels with fine sand and minor pebble gravel, moderately sorted, moderately cemented. Detritus predominantly volcanic lithologies and minor (at least 5% by volume) quartzo-feldspathic rocks. 970–980 ft +10F: 80–90% granules and pebbles composed of volcanic (dacites, minor andesite) lithologies; 10-15% quartzo-feldspathic detritus; up to 5% fragments of indurated sandstone.	**Tpf**	
980–1000	Volcaniclastic sediments–light tan (10YR 8/2), predominantly silty fine to medium sands with minor pebble gravel, moderately sorted, moderately cemented. Detritus predominantly of light gray dacite. 980–1000 ft WR/+10F: 60–80% fragments of fine-grained volcanic sandstone containing pebbles of gray dacite; 20-40% subangular to rounded granules/pebbles composed mostly of light gray hornblende- and or biotite-dacites. +35F: contains up to 20% Precambrian quartzite and granitic grains.	**Tpf**	
1000–1015	Volcaniclastic sediments –light brownish gray (5YR 6/1) silty coarse to fine gravels with fine gravels with sand grading downward in the interval to fine to medium sands, moderately well sorted, moderately cemented. Detritus predominantly volcanic lithologies and trace quartzo-feldspathic rocks. 1000–1005 ft Pebble gravel with sand. WR/+10F: subrounded pebbles (up to 15 mm) almost exclusively of light gray hornblende-phyric dacites; trace white rhyolite. 1005–1015 ft Coarse to fine sands. WR/10F: 97–98% sand-sized grains of predominantly gray dacite; 1-2% Precambrian quartzo-feldspathic grains.	**Tpf**	Note: Drilling of the R-53 borehole was terminated at 1015 ft TD.

ABBREVIATIONS

5YR 8/4 = Munsell rock color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g., 4) are expressed. Hue indicates soil color's relation to red, yellow, green, blue, and purple. Value indicates soil color's lightness. Chroma indicates soil color's strength.

% = estimated percent by volume of a given sample constituent

AMSL = above mean sea level

bgs = below ground surface

TD = total depth

Cpx = clinopyroxene

ft = feet

GM = groundmass

Qal = Quaternary alluvium.

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed

Qbt = Tshirege Member of the BandelierTuff

Qct = Cerro Toledo interval

Tb 4 = Cerros del Rio volcanic rocks

Tpf = Puye Formation

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in

1 in = 25.4 mm

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-53

Screening groundwater samples were collected during drilling, development, and aquifer testing at well R-53. Two borehole samples [GW53-10-11670 and GW53-10-11671] were collected during drilling at R-53 from 840 and 979 ft below ground surface (bgs), respectively, within regional saturation in the Puye Formation. Aliquots of these two borehole samples were submitted to analytical laboratories external to Los Alamos National Laboratory (LANL or the Laboratory) for analyses of volatile organic compounds (VOCs) and low-level tritium (LH3) and to the Laboratory's Earth and Environmental Sciences Group 14 (EES-14) laboratory for analysis of anions (including perchlorate), cations and metals.

Seventeen groundwater samples were collected from well R-53 during development and aquifer testing from the upper screened interval (849.2 to 859.2 ft bgs) and from the lower screened interval (959.7 to 980.2 ft bgs) and analyzed only for total organic carbon (TOC) by EES-14.

B-1.1 EES-14 Analytical Techniques

Groundwater samples were filtered using 0.45-µm membranes before preservation and chemical analyses. Samples were acidified at the EES-14 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (EPA Method 300, Revision 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limit for perchlorate was 0.005 ppm in borehole water samples collected from R-53 (EPA Method 314.0, Revision 1). Inductively coupled (argon) plasma optical emission spectroscopy (EPA Method 200.7, Revision 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, total chromium, iron, lithium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved antimony, arsenic, beryllium, cadmium, cesium, chromium, cobalt, copper, lead, lithium, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (EPA Method 200.8, Revision 5.4). Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques.

The precision limits (analytical error) for major ions and trace elements were generally less than ±7%. Charge balance errors for total cations and anions for the two borehole water samples collected during drilling of R-53 were –6% and –13%. The negative cation-anion charge balance values indicate excess anions for the filtered samples.

TOC analyses were performed following EPA Method 415.1. No groundwater samples were collected for TOC analyses at borehole R-53 before development because of sample matrix and potential presence of drilling fluids.

B-1.2 Field Parameters

B-1.2.1 Well Development

Water samples were drawn from the pump discharge line into sealed containers, and field parameters were measured using a YSI multimeter. Results of field parameters, consisting of potential of hydrogen (pH), temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during development at well R-53, are provided in Table B-1.2-1.

Upper Screen

During well development of the upper screen, pH and temperature varied from 7.04 to 8.18 and from 20.07°C to 21.11°C, respectively. Concentrations of DO ranged from 6.60 to 7.02 ppm. Corrected Eh values determined from field ORP measurements varied from 376.2 to 438.4 millivolts (mV) (Table B-1.2-1). A temperature-dependent correction factor of 203.9 mV at 20ºC was used to convert ORP values to Eh concentrations; it was based on an Ag/AgCl, KCl-saturated filling solution contained in the ORP electrode. Specific conductance varied from 358 to 380 microsiemens per centimeter (μS/cm); these values were approximately twice the specific conductance measurements recorded for the upper screen during aquifer testing, so it is possible the meter was malfunctioning. Turbidity varied slightly from 0.2 to 0.8 nephelometric turbidity units (NTU) (Table B-1.2-1). The final parameter measurements for the upper screen at the end of development were: pH 8.05, temperature 20.14°C, specific conductance 360 μS/cm, and turbidity 0.7 NTU.

Lower Screen

During development of the lower screen, pH and temperature varied from 6.88 to 8.07 and from 19.14°C to 20.45°C, respectively. Concentrations of DO varied from 6.23 to 7.46 mg/L. Corrected Eh values determined from field ORP measurements ranged from 372.9 to 391.7 mV. Specific conductance varied from 158 to 175 μS/cm. Turbidity values were 0.0 NTU throughout development of the lower screen; given that turbidity values above 0.0 NTU were recorded during the latter part of aquifer testing of the lower screen, the well development turbidity measurements are likely inaccurate. The final parameter measurements for the lower screen at the end of development were pH 8.01, temperature 20.45°C, specific conductance 161, and turbidity 0.0 NTU (not accurate).

B-1.2.2 Aquifer Testing

Upper Screen

During aquifer testing of the upper screen, pH and temperature varied from 7.54 to 8.00 and from 19.72°C to 20.82°C, respectively. DO concentrations varied from 7.05 to 7.23 mg/L. Corrected Eh values determined from field ORP measurements varied from 401.6 to 432.4 mV. Specific conductance ranged from 162 to 167 μS/cm, and all of the turbidity values were 0.0 NTU during aquifer testing of the upper screen; these values contrast with the measurements obtained during well development, again indicating that the meter was malfunctioning (Table B-1.2-1).

Lower Screen

During aquifer testing of the lower screen, pH and temperature varied from 7.56 to 8.20 and from 18.56°C to 21.90°C, respectively. DO concentrations varied from 6.07 to 7.75 ppm. Corrected Eh values determined from field ORP measurements ranged from 283.4 to 354.5 mV. Specific conductance varied from 150 to 166 μS/cm, and turbidity varied from 65.7 to 0.0 NTU, with a final reading of 5.9 NTU (Table B-1.2-1).

B-1.3 Analytical Results for Screening Groundwater Samples

Analytical results from the off-site laboratories and from EES-14 are presented below.

B-1.3.1 External Laboratory Analytical Results for VOCs and LH3

The two borehole water samples (GW53-10-11670 and GW53-10-11671 from 840 and 970 ft bgs, respectively) were analyzed for VOCs and LH3. The VOCs 1-butanol and 2-butanone were detected at estimated concentrations of 329.0 and 1.99 μg/L (0.329 and 0.00199 ppm), respectively, in sample GW53-10-11670 from 840 ft bgs (Table B-1.3-1). These compounds were not detected in sample GW53-10-11671 from 979 ft bgs. Tritium activity was 0.39 tritium units (1.26 pCi/L) in the borehole sample GW53-10-11670; tritium was not detected in sample GW53-10-11671.

B-1.3.2 EES-14 Results for Cations, Anions, Perchlorate and Metals

EES-14 analytical results for the two borehole samples collected at well R-53 during drilling are provided in Table B-1.3-2. The filtered borehole samples (GW53-10-11670 and GW53-10-11671) consisted of disaggregated colloidal aquifer material, drilling material, water used during drilling, and native groundwater.

Key anion results are as follows:

- Dissolved concentrations of fluoride were 0.60 and 0.33 ppm in GW53-10-11670 and GW53-10-11671, respectively. For comparison purposes only to developed regional aquifer wells, background mean, median, and maximum concentrations of dissolved fluoride are 0.37 ppm, 0.35 ppm, and 0.57 ppm, respectively, for the regional aquifer (LANL 2007, 095817).
- Dissolved concentrations of nitrate(N) were 0.03 and 0.57 ppm in GW53-10-11670 and GW53-10-11671, respectively. The median background concentration for dissolved nitrate(N) in the regional aquifer is 0.31 ppm (LANL 2007, 095817).
- Dissolved concentrations of sulfate were 3.34 and 3.04 ppm in the same two borehole water samples. Median background concentrations for dissolved sulfate in the regional aquifer is 2.83 ppm (LANL 2007, 095817).
- Perchlorate was not detected in the two borehole water samples collected during drilling of well R-53.

Results for selected metals are as follows:

- Dissolved molybdenum was detected at slightly elevated concentrations of 0.024 and 0.005 ppm from the 840 and 979 ft bgs samples, respectively. Median and maximum background molybdenum concentrations from developed wells in the regional aquifer are 0.0011 and 0.0044 ppm, respectively. These samples likely contained a component of lubricant used during drilling.
- Dissolved boron concentrations were 0.197 and 0.090 ppm in the two borehole water samples collected during drilling; the maximum background concentration for dissolved boron from developed wells in the regional aquifer is 0.0516 ppm (LANL 2007, 095817).
- Dissolved concentrations of barium were 1.68 and 0.161 ppm in the two borehole water samples; the maximum background concentration for dissolved barium from developed wells in the regional aquifer is 1.15 ppm (LANL 2007, 095817).
- Total dissolved chromium concentrations were 0.003 and 0.004 ppm in the two borehole water samples. Median and maximum background concentrations of total dissolved chromium are 0.003 and 0.007 ppm, respectively, for developed wells in the regional aquifer (LANL 2007, 095817).

B-1.3.3 Total Organic Carbon

During development of the upper screen, TOC concentrations varied from 0.79 to 0.98 mgC/L (Table B-1.3-3); TOC was not detected in groundwater samples collected from the upper screen during aquifer testing.

During development of the lower screen, TOC concentrations decreased from an initial concentration of 6.17 mgC/L to the final concentration of 0.99 mgC/L. TOC was not detected in groundwater samples collected from the lower screen during aquifer testing.

B-1.4 Summary

Corrected Eh values and DO concentrations at both water-bearing zones in well R-53 are indicative of the known relatively oxidizing conditions characteristic of the regional aquifer beneath the Pajarito Plateau.

Two VOCs, 1-butanol and 2-butanone, were detected in the sample from 840 ft bgs; VOCs were not detected in the sample from 979 ft bgs. Molybdenum was slightly elevated in the two borehole water samples, which is likely attributable to the lubricant used during drilling. Tritium was detected at 1.26 pCi/L in the upper borehole sample but was not detected in the lower borehole sample. Concentrations of TOC at the end of well development were 0.80 and 0.99 mgC/L for the upper and lower screens, respectively.

B-2.0 REFERENCE

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

Copies of the master reference set are maintained at the 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)

Table B-1.2-1
Purge Volumes and Field Parameters during Well Development and Aquifer Testing at R-53

Date	pH	Temp (°C)	DO (ppm)	ORP, Eha (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development – Combined Water from Upper and Lower Screens								
03/30/10	n/r[b]; swabbing/bailing						175	175
03/31/10	n/r; swabbing/bailing						335	510
04/01/10	n/r; swabbing/bailing						135	645
Well Development Upper Screen								
04/03/10	n/r, pumped while swabbing screen						1841	2486
	7.04	21.11	6.94	234.5, 438.4	380	0.5	279	2765
	7.31	20.71	7.02	210.6, 414.5	370	0.2	335	3100
	n/r, pumped before shutting off pump						85	3185
04/04/10	8.02	20.08	6.60	230.1, 434.0	358	0.8	453	3638
	8.18	20.13	6.82	230.5, 434.6	363	0.6	509	4147
	7.92	20.07	6.87	225.4, 429.3	362	0.2	396	4543
	7.23	20.07	6.94	172.3, 376.2	362	0.4	566	5109
	8.05	20.14	6.95	199.0, 402.9	360	0.7	623	5732
	n/r, pumped prior to shutting off pump						113	5845
Well Development Lower Screen								
04/06/10	n/r, pumped while swabbing screen						2400	8245
	7.27	19.72	6.23	174.1,378.0	175	0.0	261	8506
	8.07	19.94	7.37	173.9, 377.8	160	0.0	313	8819
	7.20	19.87	6.75	169.0, 372.9	158	0.0	313	9132
	6.88	19.14	6.96	181.3, 385.2	158	0.0	469	9601
	6.99	19.60	7.46	181.1, 385.0	160	0.0	625	10,226
	7.92	20.33	6.75	187.8, 391.7	160	0.0	469	10,695
	7.48	19.95	6.80	173.8, 377.7	159	0.0	469	11,164
	8.01	20.45	6.80	186.0, 389.9	161	0.0	469	11,633
	n/r, pumped prior to shutting off pump						312	11,945
Aquifer Test Lower Screen								
04/10/10	n/r, pumping, mini-test preparation						259	12,204
04/11/10	n/r, pumping, mini-test						2398	14,602
04/13/10	7.89	21.00	6.51	137.4, 341.3	164	0.6	1210	15,812
	7.92	21.90	6.62	97.1, 301.0	164	0.0	1209	17,021
	7.88	21.81	6.73	81.1, 285.0	165	0.0	1209	18,230
	7.86	21.41	6.78	80.9, 284.8	163	0.0	1207	19,437
	7.87	20.06	6.57	81.1, 285.0	164	0.0	1207	20,644

Table B-1.2-1 (continued)

Date	pH	Temp (°C)	DO (ppm)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	7.84	22.18	6.64	79.5, 283.4	164	0.0	1206	21,850
	7.66	21.80	6.07	87.9, 291.8	160	0.0	1207	23,057
	7.58	21.67	6.53	87.5, 291.4	155	0.0	1207	24,264
	7.56	21.65	6.61	85.4, 289.3	151	0.0	1206	25,470
	7.78	21.53	6.86	81.7, 285.6	150	0.0	1207	26,677
	7.75	21.28	7.21	92.3, 296.2	158	0.2	1207	27,884
	7.85	20.31	6.59	99.7, 303.6	164	0.6	1209	29,093
	8.05	20.67	7.02	98.5, 302.4	164	8.2	1212	30,305
	8.13	20.40	7.31	105.2, 309.1	164	42.2	1217	31,522
	8.20	20.75	7.35	112.7, 316.6	166	65.7	1216	32,738
04/14/10	8.17	20.46	7.39	120.3, 324.2	164	16.8	1221	33,959
	8.15	19.53	7.11	127.2, 331.1	161	10.3	1222	35,181
	8.14	18.56	6.80	123.1, 327.0	160	6.1	1220	36,401
	8.14	18.66	6.83	137.6, 341.5	159	5.2	1221	37,622
	8.12	19.75	7.50	141.7, 345.6	159	4.6	1221	38,843
	8.10	21.05	7.75	142.9, 346.8	161	6.3	1220	40,063
	8.08	21.06	7.72	148.0, 351.9	160	3.6	1220	41,283
	8.09	21.06	7.48	150.6, 354.5	160	5.9	1220	42,503
	n/r, pumped prior to shutting off pump						1204	43,707
Aquifer Test Upper Screen								
04/16/10	n/r, pumping, mini-test preparation						55	43,762
04/17/10	n/r, pumping, mini-test						1255	45,017
04/18/10	7.91	20.17	7.21	226.9, 430.8	166	0.0	634	45,651
	7.94	20.71	7.20	220.9, 424.8	167	0.0	632	46,283
	7.54	20.82	7.05	224.7, 428.6	163	0.0	633	46,916
	7.81	20.54	7.23	203.6, 407.5	162	0.0	642	47,558
	7.86	20.03	7.14	200.8, 424.7	167	0.0	634	48,192
	7.92	20.31	7.23	200.6, 424.5	167	0.0	636	48,828
	7.93	20.68	7.20	201.0, 404.9	167	0.0	634	49,462
	7.63	20.42	7.19	209.4, 413.3	166	0.0	632	50,094
	7.79	20.31	7.20	202.5, 406.4	167	0.0	630	50,724
	7.91	20.59	7.21	197.7, 401.6	166	0.0	633	51,357
	7.69	20.50	7.13	211.9, 415.8	166	0.0	634	51,991
	7.97	20.40	7.19	200.7, 404.6	166	0.0	630	52,621
	7.91	20.47	7.22	206.4, 410.3	165	0.0	628	53,249
	7.97	20.34	7.20	207.0, 410.9	164	0.0	629	53,878

Table B-1.2-1 (continued)

Date	pH	Temp (°C)	DO (ppm)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	7.93	19.72	7.20	212.4, 416.3	164	0.0	628	54,506
	7.99	20.55	7.22	214.2, 418.1	163	0.0	627	55,133
04/19/10	7.86	20.51	7.21	222.2, 416.1	163	0.0	1259	56,392
	7.98	20.36	7.21	219.1, 423.0	163	0.0	632	57,024
	7.97	20.33	7.22	222.6, 426.5	162	0.0	632	57,656
	8.00	20.00	7.23	224.2, 428.1	162	0.0	632	58,288
	8.00	20.09	7.23	226.7, 430.6	162	0.0	632	58,920
	7.97	20.40	7.22	228.5, 432.4	162	0.0	623	59,543
	n/r, pumped before shutting off pump						630	60,173

[a] Eh (mV) is calculated from an Ag/AgCl saturated KCl electrode filling solution at 20ºC by adding a temperature-sensitive correction factor of 203.9 mV.

[b] n/r = Not recorded.

Table B-1.3-1
Off-Site Analytical Data at R-53

Lab Request Number	Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2271	GW53-10-11670	LH3	Generic:Low_Level_Tritium	Tritium	0.39	TU[a]	NQ[b]
10-2178	GW53-10-11670	VOC	SW-846:8260B	Acetone	10	µg/L	U[c]
10-2178	GW53-10-11670	VOC	SW-846:8260B	Acetonitrile	25	µg/L	R[d]
10-2178	GW53-10-11670	VOC	SW-846:8260B	Acrolein	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Acrylonitrile	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Benzene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Bromobenzene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Bromochloromethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Bromodichloromethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Bromoform	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Bromomethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Butanol[1-]	329	µg/L	J[e]
10-2178	GW53-10-11670	VOC	SW-846:8260B	Butanone[2-]	1.99	µg/L	J
10-2178	GW53-10-11670	VOC	SW-846:8260B	Butylbenzene[n-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Butylbenzene[sec-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Butylbenzene[tert-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Carbon disulfide	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Carbon tetrachloride	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chlorobenzene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chlorodibromomethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chloroethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chloroform	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chloromethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chlorotoluene[2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Chlorotoluene[4-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dibromo-3-chloropropane[1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dibromomethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichlorodifluoromethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	µg/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Diethyl ether	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Ethyl methacrylate	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Ethylbenzene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Hexachlorobutadiene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Hexanone[2-]	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Iodomethane	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Isobutyl alcohol	50	µg/L	R
10-2178	GW53-10-11670	VOC	SW-846:8260B	Isopropylbenzene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Methacrylonitrile	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Methyl methacrylate	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Methyl tert-butyl ether	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Methylene chloride	10	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Naphthalene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Propionitrile	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Propylbenzene[1-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Styrene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Tetrachloroethene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Toluene	0.536	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichloroethene	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichlorofluoromethane	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	µg/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2178	GW53-10-11670	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Vinyl acetate	5	µg/L	UJ[f]
10-2178	GW53-10-11670	VOC	SW-846:8260B	Vinyl chloride	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Xylene[1,2-]	1	µg/L	U
10-2178	GW53-10-11670	VOC	SW-846:8260B	Xylene[1,3-]+xylene[1,4-]	2	µg/L	U
10-2583	GW53-10-11671	LH3	Generic:Low_Level_Tritium	Tritium	-0.07	TU	U
10-2502	GW53-10-11671	VOC	SW-846:8260B	Acetone	10	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Acetonitrile	25	µg/L	R
10-2502	GW53-10-11671	VOC	SW-846:8260B	Acrolein	5	µg/L	R
10-2502	GW53-10-11671	VOC	SW-846:8260B	Acrylonitrile	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Benzene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Bromobenzene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Bromochloromethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Bromodichloromethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Bromoform	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Bromomethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Butanol[1-]	50	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Butanone[2-]	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Butylbenzene[n-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Butylbenzene[sec-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Butylbenzene[tert-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Carbon disulfide	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Carbon tetrachloride	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chlorobenzene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chlorodibromomethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chloroethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chloroform	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chloromethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chlorotoluene[2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Chlorotoluene[4-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dibromo-3-chloropropane[1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dibromomethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	µg/L	UJ

Table B-1.3-1 (continued)

Lab Request Number	Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichlorodifluoromethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Diethyl ether	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Ethyl methacrylate	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Ethylbenzene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Hexachlorobutadiene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Hexanone[2-]	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Iodomethane	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Isobutyl alcohol	50	µg/L	R
10-2502	GW53-10-11671	VOC	SW-846:8260B	Isopropylbenzene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Methacrylonitrile	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Methyl methacrylate	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Methyl tert-butyl ether	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Methylene chloride	10	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Naphthalene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Propionitrile	5	µg/L	R
10-2502	GW53-10-11671	VOC	SW-846:8260B	Propylbenzene[1-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Styrene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Tetrachloroethene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Toluene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	µg/L	UJ

Table B-1.3-1 (continued)

Lab Request Number	Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichloroethene	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichlorofluoromethane	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Vinyl acetate	5	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Vinyl chloride	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Xylene[1,2-]	1	µg/L	UJ
10-2502	GW53-10-11671	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2	µg/L	UJ

[a] TU = Tritium unit.

[b] NQ = Data are not valid and not qualified.

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

[d] R = The data are rejected as a result of major problems with quality assurance/quality control (QA/QC) parameters.

[e] J = The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.

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

Table B-1.3-2
Analytical Results for EES-14 Groundwater Screening Samples Collected at R-53

Sample ID	Date Received	Sample Type	ER/RRES-WQH	Depth (ft bgs)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)	Br(-) ppm	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl(-) ppm
GW53-10-11670	3/1/2010	Borehole	10-2177	840.0	0.001	U	0.081	0.009	0.0003	0.0000	0.197	0.002	1.68	0.01	0.001	U	0.05	10.28	0.04	0.001	U	8.28
GW53-10-11671	3/31/2010	Borehole	10-2503	979.0	0.001	U	0.014	0.000	0.0004	0.0000	0.090	0.001	0.161	0.001	0.001	U	0.04	11.99	0.05	0.001	U	3.06

ClO4(-) ppm	ClO4(-) (U)	Co rslt (ppm)	stdev (Co)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F(-) ppm	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)
0.005	U	0.001	0.000	0.8	U	0.003	0.000	0.001	U	0.001	U	0.60	0.70	0.00	92.3	0.00005	U	1.10	0.01	0.031	0.003	3.39	0.02	0.184	0.002
0.005	U	0.001	U	0.8	U	0.004	0.000	0.001	U	0.002	0.000	0.33	0.62	0.00	82.8	0.00010	0.00001	1.66	0.01	0.029	0.000	3.48	0.02	0.033	0.000

Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)	stdev (Na)	Ni rslt (ppm)	stdev (Ni)	NO2 (ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	C2O4 rslt (ppm)	C2O4 (U)	Pb rslt (ppm)	stdev (Pb)	Lab pH	PO4(-3) rslt (ppm)	PO4(-3) (U)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)	Si rslt (ppm)	stdev (Si)
0.024	0.000	18.52	0.18	0.005	0.001	0.01	0.003	U	0.14	0.03	0.19	0.01	0.0002	U	6.95	0.06	0.01	0.001	U	0.001	U	0.001	0.000	18.8	0.1
0.005	0.000	11.11	0.04	0.001	0.000	0.01	0.003	U	2.52	0.57	0.01	U	0.0002	U	7.21	0.01	U	0.001	0.000	0.001	U	0.001	U	31.1	0.4

SiO2 rslt (ppm)	stdev (SiO2)	Sn rslt (ppm)	stdev (Sn)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
40.2	0.3	0.001	U	3.34	0.057	0.000	0.001	U	0.019	0.000	0.001	U	0.0002	U	0.002	0.000	0.034	0.000	201	1.66	2.15	-0.13
66.6	0.9	0.001	U	3.04	0.037	0.000	0.001	U	0.002	U	0.001	U	0.0003	0.0000	0.003	0.000	0.034	0.000	189	1.42	1.60	-0.06

Table B-1.3-3
TOC Concentrations at R-53

Sample ID	Date Received	Sample Type	ER/RRES-WQH	Depth (ft bgs)	TOC (ppm)
GW53-10-11680	4/7/2010	Well development	10-2670	849.2-859.2	0.79
GW53-10-11681	4/8/2010	Well development	10-2670	849.2-859.2	0.98
GW53-10-11682	4/8/2010	Well development	10-2670	849.2-859.2	0.80
GW53-10-11683	4/8/2010	Well development	10-2690	959.7-980.2	6.17
GW53-10-11684	4/8/2010	Well development	10-2690	959.7-980.2	0.99
GW53-10-11685	4/14/2010	Aquifer testing	Not provided	959.7-980.2	0.2 U*
GW53-10-11686	4/14/2010	Aquifer testing	Not provided	959.7-980.2	0.2 U
GW53-10-11687	4/14/2010	Aquifer testing	Not provided	959.7-980.2	0.2 U
GW53-10-11688	4/14/2010	Aquifer testing	Not provided	959.7-980.2	0.2 U
GW53-10-11689	4/14/2010	Aquifer testing	Not provided	959.7-980.2	0.2 U
GW53-10-11690	4/14/2010	Aquifer testing	Not provided	959.7-980.2	0.2 U
GW53-10-11691	4/21/2010	Aquifer testing	Not provided	849.2-859.2	0.2 U
GW53-10-11692	4/21/2010	Aquifer testing	Not provided	849.2-859.2	0.2 U
GW53-10-11693	4/21/2010	Aquifer testing	Not provided	849.2-859.2	0.2 U
GW53-10-11694	4/21/2010	Aquifer testing	Not provided	849.2-859.2	0.2 U
GW53-10-11695	4/21/2010	Aquifer testing	Not provided	849.2-859.2	0.2 U
GW53-10-11696	4/21/2010	Aquifer testing	Not provided	849.2-859.2	0.2 U

* U = The analyte was analyzed for but not detected.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted during April 2010 at R-53, a dual-screen regional aquifer well located in the south fork of Cañada del Buey at Los Alamos National Laboratory (the Laboratory). The tests on R-53 were conducted to quantify the hydraulic properties of the two zones in which the well is screened, evaluate the hydraulic interconnection of the zones, and check for interference effects among neighboring wells.

Testing planned for each screen interval consisted of brief trial pumping, background water level data collection, and a 24-h constant-rate pumping test. Water levels were monitored in both zones during each of the pumping tests in each screen.

As in most of the R-well pumping tests conducted on the plateau, an inflatable packer system was used in R-53 to both hydraulically isolate the screen zones and try to eliminate casing storage effects on the test data. Storage effects were eliminated successfully from most of the tests. The lone exception occurred during recovery following the 24-h test on screen 1 in which it appeared that gas buildup beneath the upper packer may have caused a storage-like response.

Air or gas was produced with the groundwater from both screen zones, similar to what has been observed in many of the recent pumping tests on the Pajarito Plateau (the Plateau). It is not known whether the source of the gas is natural or a byproduct of air drilling the boreholes.

Conceptual Hydrogeology

Both screens in R-53 lie within sands and gravels of the Puye Formation. Screen 1 is 10 ft long, extending from 849.2 to 859.2 ft below ground surface (bgs). Screen 2 is 20.5 ft long and is positioned about 100 ft beneath screen 1, extending from 959.7 to 980.2 ft bgs.

The composite static water level measured on April 10, 2010 prior to testing was 831.75 ft bgs. The ground surface elevation (brass cap) at the well was surveyed at 6689.98 ft above mean sea level (amsl), making the composite water level elevation 5858.23 ft amsl.

When the screen zones were isolated using an inflatable packer, the water level in screen 1 rose 2.90 ft, to a depth of 828.85 ft bgs and an approximate elevation of 5861.13 ft amsl. At the same time, the water level in screen 2 declined 6.25 ft, making its depth to water 838.00 ft bgs at an elevation of approximately 5851.98 ft amsl. Thus, the water levels showed a large head difference of 9.15 ft and a strong downward hydraulic gradient, implying highly resistive sediments separating the two screen zones.

R-53 Screen 1 Testing

The two screens were tested in reverse order, with screen 1 testing occurring after screen 2 testing. Screen 1 was tested from April 16 to 21, 2010. After filling the drop pipe on April 16, testing began with brief trial pumping on April 17 followed by a 24-h constant-rate pumping test that was started on April 18. Following shutdown of the 24-h test on April 19, recovery/background data were recorded for 2 d until April 21.

Trial testing of screen 1 began at 7:00 a.m. on April 17 at a discharge rate of 10.4 gallons per minute (gpm) and continued for 60 min until 8:00 a.m. Recovery data were recorded for 60 min until 9:00 a.m. when trial 2 pumping began at a discharge rate of 10.5 gpm. Following shutdown at 10:00 a.m., trial 2 recovery data were collected for 1320 min until 8:00 a.m. on April 18.

At 8:00 a.m. on April 18, the 24-h pumping test was initiated at a discharge rate of 10.5 gpm. Pumping continued for 1440 min until 8:00 a.m. on April 19. Following shutdown, recovery/background data were recorded for 2847 min until 7:27 a.m. on April 21 when the pump was pulled from the well.

R-53 Screen 2 Testing

Well R-53 screen 2 was tested from April 10 to 15. After the drop pipe was filled on April 10, testing began with brief trial pumping on April 11, background data collection, and a 24-h constant-rate pumping test that began on April 13.

Two trial tests were conducted on April 11. Trial 1 was conducted at a discharge rate of 20.1 gpm for 60 min from 8:00 to 9:00 a.m. and was followed by 60 min of recovery until 10:00 a.m. Trial 2 was conducted for 60 min, from 10:00 to 11:00 a.m., at a rate of 19.9 gpm. Following shutdown, recovery/background data were recorded for 2700 min, until 8:00 a.m. on April 13.

At 8:00 a.m. on April 13, the 24-h pumping test was begun at a rate of 20.2 gpm. Pumping continued for 1440 min until 8:00 a.m. on April 14. Following shutdown, recovery measurements were recorded for 1440 min until 8:00 a.m. on April 15, when the pump was tripped out of the well.

Aerated Groundwater

Consistent with observations in many of the recent R-well pumping tests, the presence of gas or air was detected in the groundwater during the R-53 pumping tests. It is possible the gas detected is natural. On the other hand, it is possible that high-pressure compressed air used in the drilling process invaded the aquifer zones during drilling, collecting in the formation pore spaces, and/or dissolving in the groundwater. When water is pumped from the aquifer, trapped gas or air in the formation pores can move with the pumped water as well as expand and contract in response to pressure changes. Also, pressure reduction associated with pumping can allow dissolved gas or air to come out of solution. The significant quantity of gas or air present in the formations in recently tested wells has had several effects, including (1) interfering with pump operating efficiency, (2) causing transient changes in aquifer permeability, (3) inducing pressure transients as the gas or air expands and contracts, and (4) causing storage-like effects associated with changes in gas or air volume in the formation voids, filter pack, and/or well casing.

The presence of air/gas in the R-53 tests did not present much difficulty. The primary side effect was apparent accumulation of air in the well during the 24-h test on screen 1, which caused a storage-like effect in the subsequent recovery data set, precluding analytical interpretation of that portion of the data. Possibly related, during the 24-h test a spontaneous reduction in drawdown occurred with no corresponding change in discharge rate and no noticeable increase in turbidity. It is possible that the change in drawdown may have been associated with air/gas being expelled from the formation, increasing the permeability of the sediments near the borehole.

C-2.0 BACKGROUND DATA

The background water-level data collected in conjunction with running the pumping tests allow the analyst to see what water-level fluctuations 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 to 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 R-53, have utilized nonvented transducers. These devices 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, when a nonvented transducer is used, 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 6689.98 ft amsl. The static water level in R-53 was 831.75 ft below land surface, making the water-table elevation 5858.23 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-53.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{R-53} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-53}}{T_{WELL}} \right) \right]$$ **Equation C-1**

where, P_{WT} = barometric pressure at the water table inside R-53

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-53} = land surface elevation at R-53 site, in feet (6689.98 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-53, in feet (5858.23 ft)

T_{TA54} = air temperature near TA-54, in degrees kelvin (assigned a value of 52.7 degrees Fahrenheit, or 284.7 degrees kelvin)

T_{WELL} = air temperature inside R-53, in degrees kelvin (assigned a value of 65.9 degrees Fahrenheit, or 292.0 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 before 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, an additional storage contribution can come from the filter pack around the screen. 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 the test is conducted. This approach was largely successful in the R-53 pumping test effort, with the exception of the 24-h recovery data from screen 1, as mentioned above.

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. Using these match-point values, transmissivity and storage coefficient are computed 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 to 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 that are 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 not known, 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:

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

In this equation, L is the well screen length, in feet. Incorporating the dimensionless drawdown parameter, 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). The screen 1 zone was treated as unconfined in this analysis, while the screen 2 zone was considered confined. Arbitrary storage coefficient values of 0.10 and 5×10^{-4} were used for the calculations for screen 1 and screen 2, respectively. 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 screen 1, the aquifer was considered to extend from the static water level to the midpoint between the screen zones—a distance of about 80 ft. 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. As described below, early data from screen 2 were used in the specific capacity calculations and, thus, fully penetrating conditions were assumed, as it was assumed that the cone of depression had not expanded significantly in the vertical direction at early time.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-53 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-53 screen 1 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-53 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-53 pumping tests are included on the figure for reference.

R-53 screen 1 showed no significant pressure change in response to barometric pressure fluctuations, suggesting a barometric efficiency near 100%. The data did show a slight diurnal perturbation of a couple hundredths of a ft that likely resulted from Earth-tide effects.

The data on Figure C-7.0-1 showed no response in screen 1 to pumping screen 2. The apparent hydrograph signal became noisier, however, when screen 2 was pumped, possibly because of electrical interference from the pump cable or vibrations from operating the pump affecting the screen 1 transducer.

Figure C-7.0-2 shows aquifer pressure data collected from R-53 screen 2 during the pumping test effort. The data did not show a response in screen 2 to pumping screen 1. The data appeared to show response to barometric pressure changes, although the two curves did not coincide in that the steady overall decline in barometric pressure observed from April 16 to 21 was not mimicked by the hydrograph. It was hypothesized that ongoing recovery of screen 2 water levels from previous pumping, or some other background trend, may have offset this declining barometric pressure trend. To check this, the hydrograph data were modified by subtracting out an assumed background rising trend. The magnitude of the assumed trend was adjusted to optimize the fit between the barometric pressure and hydrograph curves. Figure C-7.0-3 shows the modified hydrograph, adjusted for an assumed background water-level-rise rate of 0.045 ft/d. With this trend subtracted out, the hydrograph and barometric pressure curves were similar. This suggested a low barometric efficiency—not often seen in wells on the Plateau, especially deeper screens. A possible explanation is that the screen 2 sediments may be in communication with a basalt that is in communication with the atmosphere through voids and fractures. While this is speculation, as discussed below, the screen 2 pumping test data showed the possibility of a nearby boundary which could be a sediment/volcanic rock contact.

Hydrograph data from additional nearby R-wells were downloaded to check for a possible pumping response to the R-53 tests. Wells examined included R-21 (1384 ft away), R-32 (2265 ft), and R-38 (937 ft). Figures C-7.0-4 through C-7.0-6 show data retrieved from R-21, R-32, and R-38, respectively.

Because the barometric pressure fluctuations in the hydrographs 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 and Rasmussen 2007, 104799) to modify the data. The BETCO correction not only removes barometric pressure effects but can remove Earth tide effects as well. The BETCO barometric corrected data for each of the nearby monitoring wells are included in the data plots on Figures C-7.0-4 through C-7.0-6.

No response to pumping R-53 screen 1 can be seen in any of the wells in these figures. Pumping R-53 screen 2 had no discernable effect in R-32 and R-38 but caused significant drawdown (0.5 ft) at R-21.

C-8.0 WELL R-53 SCREEN 1 DATA ANALYSIS

This section presents the data obtained from the R-53 screen 1 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-53 Screen 1 Trial Test

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from the 60-min trial 1 test on screen 1 at a discharge rate of 10.4 gpm. The transmissivity estimated from the early data in the plot was 2190 gallons per day (gpd)/ft. Based on the screen length of 10 ft, the computed hydraulic conductivity was 219 gpd/ft^2, or 29.3 ft/day. Note that the earliest data points showed some scatter and did not fit the straight line very well because the upper portion of the drop pipe had been drained overnight to prevent freezing, and after the pump was started, it took several seconds for the pipe to refill and for water to reach the backpressure valve that controlled the flow rate.

The observed drawdown curve became progressively flatter with increasing pumping time. The most likely explanation for this was vertical expansion of the cone of depression through greater thickness of sediments over time (partial-penetration effects). It is also possible that lateral changes in transmissivity and hydraulic conductivity could have contributed to the observed trend, but the steady and uniform flattening was consistent with partially penetrating screen response.

The drawdown data were analyzed using the Hantush method for partially penetrating wells. Plots were prepared for four assigned values of vertical anisotropy—1.0, 0.1, 0.01 and 0.001—as shown in Figures C-8.1-2 through C-8.1-5, respectively. The analyses were performed for an arbitrary assigned aquifer thickness of 80 ft—the distance from the screen 1 static water level to the midpoint between the two well screens. The type curve matches shown in the figures were poor for moderate values of anisotropy (1.0 and 0.1) but became better for more severe anisotropy values (0.01 and 0.001). The transmissivity values for severe anisotropy were similar to the value obtained from the semilog plot in Figure C-8.1-1. Unfortunately, it was not possible to constrain the transmissivity values obtained from the Hantush analyses, as multiple values could be obtained that produced good curve matches (as shown in Figures C-8.1-4 and C-8.1-5, for example). Nevertheless, the computed transmissivity values obtained from the better curve matches (severe anisotropy) were on the same order as the value obtained from the Cooper-Jacob analysis and the exercise suggested severe, rather than moderate, vertical anisotropy.

Figure C-8.1-6 shows the recovery data collected following shutdown of the trial 1 pumping test. The very early data suggested a transmissivity of 1820 gpd/ft and a hydraulic conductivity of 182 gpd/ft^2, or 24.3 ft/d.

As with the drawdown data, the recovery data showed continuous flattening over time and were analyzed using the Hantush method for partially penetrating wells. Figures C-8.1-7 and C-8.1-8 show the resulting analyses for the severe vertical anisotropy values of 0.01 and 0.001, respectively. The curve matches were good and yielded transmissivity values on the order of those obtained using the Theis recovery method.

C-8.2 Well R-53 Screen 1 Trial 2 Test

Figure C-8.2-1 shows a semilog plot of the drawdown data collected from the 60-min trial 2 test on screen 1 at a discharge rate of 10.5 gpm. The transmissivity estimated from the early data in the plot was 1870 gpd/ft. Based on the screen length of 10 ft, the computed hydraulic conductivity was 187 gpd/ft^2, or 25.0 ft/day.

The trial 2 drawdown data were analyzed using the Hantush method for partially penetrating wells. Plots were prepared for two values of vertical anisotropy—0.01 and 0.001—as shown in Figures C-8.2-2 and C-8.2-3, respectively. The type curve matches shown in the figures were good and produced transmissivity values on the same order as the value obtained from the Cooper-Jacob analysis.

Figure C-8.2-4 shows the recovery data collected following shutdown of the trial 2 pumping test. The very early data suggested a transmissivity of 1800 gpd/ft and a hydraulic conductivity of 180 gpd/ft^2, or 24.1 ft/d.

As with the drawdown data, the recovery data showed continuous flattening over time and were analyzed using the Hantush method for partially penetrating wells. Figures C-8.2-5 and C-8.2-6 show the resulting analyses for the severe vertical anisotropy values of 0.01 and 0.001, respectively. The curve matches were good and yielded transmissivity values on the order of those obtained using the Theis recovery method.

C-8.3 Well R-53 Screen 1 24-Hour 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 10.5 gpm. Again, the drop pipe had to be drained to prevent freezing overnight before the 24-h test was conducted, and as a result, the earliest data points showed some scatter while the pipe filled and the pumping rate stabilized. The analysis shown on the graph suggested a screen interval transmissivity of 1930 gpd/ft and a hydraulic conductivity of 193 gpd/ft^2, or 25.8 ft/d.

Several hours into the pumping test, a spontaneous reduction in drawdown of about 0.5 ft occurred even though the discharge rate remained constant throughout the pumping test. Thus, the efficiency of the well had suddenly improved. Sometimes this effect can be an indication of continued well development but is usually associated with production of sediment and dirtying of the water produced from the well. However, no noticeable increase in the turbidity content of the water occurred during this event that would have suggested that the improvement in efficiency resulted from removal of fines from around the well screen. It is possible the observed increase in permeability was attributable to gas/air being expelled from the sediments around the borehole. Supporting this idea, as described below, the subsequent recovery data showed a storage effect that could have been an indication of trapped gas/air under the upper packer. Figure C-8.3-2 shows an expanded-scale plot of the portion of the drawdown data corresponding to the surprising spontaneous reduction in drawdown. As indicated on the figure, the change in drawdown was gradual, occurring over a period of about 40 min.

Figure C-8.3-3 shows the recovery data collected following shutdown of the 24-h constant-rate pumping test. As indicated on the plot, the transmissivity computed from the line of fit was 800 gpd/ft—in disagreement with all of the previously obtained transmissivity values. The underestimate of transmissivity was symptomatic of a storage effect and could have been caused by accumulation of air beneath the upper packer during the pumping phase of the test.

C-8.4 Well R-53 Screen 1 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound transmissivity value for the permeable zone penetrated by R-53 screen 1 to provide a frame of reference for evaluating the foregoing analyses.

At the end of the 24-h pumping test, the discharge rate was 10.5 gpm, with a resulting drawdown of 7.20 ft for a specific capacity of 1.46 gpm/ft. In addition to specific capacity and pumping time, other input values used in the calculations included a storage coefficient value of 0.1, a borehole radius of 0.54 ft (inferred from the volume of filter pack required to backfill the screen zone), a screen length of 10 ft, a pumping time of 1440 min, and a saturated thickness of 80 ft (from the static water level to the midpoint between screens 1 and 2).

Applying the Brons and Marting method to these inputs yielded a lower-bound hydraulic conductivity value of 106 gpd/ft^2, or 14.1 ft/d. The average hydraulic conductivity value from the foregoing pumping test analyses was 192 gpd/ft^2, or 25.7 ft/d. Thus, the lower-bound value was consistent with the pumping test results and suggested a well efficiency of a little more than 50%.

C-9.0 WELL R-53 SCREEN 2 DATA ANALYSIS

This section presents the data obtained from the R-53 screen 2 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-9.1 Well R-53 Screen 2 Trial 1

Figure C-9.1-1 shows a semilog plot of the screen 2 drawdown data collected from trial 1 at a discharge rate of 20.1 gpm. Note that the earliest data points showed scatter until the pumping rate stabilized. The upper portion of the drop pipe had been drained to prevent freezing overnight, and thus, the pump operated initially against reduced head until water reached the backpressure valve.

The early drawdown data suggested a transmissivity of 1290 gpd/ft for the 20.5-ft-long screened interval, making the estimated average hydraulic conductivity of the sediments near the borehole 63 gpd/ft^2, or 8.4 ft/d. Within several minutes of pumping, the drawdown curve steepened, reflecting a calculated transmissivity of 430 gpd/ft. The steeper slope could have been caused by a lateral reduction in hydraulic conductivity and transmissivity or might have been an indication of a lateral boundary. Although the trial 1 drawdown data showed a 3:1 ratio in the computed slopes and transmissivity values, as described below, the subsequent analyses showed ratios closer to 2:1, characteristic of the expected response near a linear boundary such as a fault. Thus, a possible interpretation of the data was the presence of a linear boundary near the pumped well.

Figure C-9.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. The transmissivity estimated from the early data was 1050 gpd/ft, making the computed hydraulic conductivity 51 gpd/ft^2, or 6.8 ft/d. The subsequent data showed a slope increase, as was observed in the drawdown data set, with a calculated transmissivity of 540 gpd/ft, about half the early-time value.

C-9.2 Well R-53 Screen 2 Trial 2

Figure C-9.2-1 shows a semilog plot of the drawdown data collected from the trial 2 test at a discharge rate of 19.9 gpm. The transmissivity value computed from the early data was 1050 gpd/ft, making the average hydraulic conductivity of the screened interval 51 gpd/ft^2, or 6.8 ft/d. The subsequent steeper slope yielded a transmissivity value of 510 gpd/ft, about half the early-time value.

Figure C-9.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. The transmissivity estimated from the early data was 1000 gpd/ft, making the computed hydraulic conductivity 49 gpd/ft^2, or 6.5 ft/d. The subsequent data showed a slope increase, as was observed in the drawdown data set, with a calculated transmissivity of 420 gpd/ft, about half the early-time value.

C-8.3 Well R-53 Screen 2 24-Hour Constant-Rate Test

Figure C-9.3-1 shows a semilog plot of the drawdown data collected from the 24-h constant-rate pumping test conducted at 20.2 gpm. Again, the drop pipe had to be drained to prevent freezing overnight before the 24-h test was conducted, and as a result, the earliest data points showed some scatter and exaggerated drawdown while the pipe filled and the pumping rate stabilized. The early-time analysis shown on the graph suggested a screen interval transmissivity of 1250 gpd/ft and a hydraulic conductivity of 61 gpd/ft^2, or 8.2 ft/d.

The increased slope associated with the subsequent data supported a transmissivity calculation of 440 gpd/ft—again, either a reduction in hydraulic conductivity away from the well or an indication of a nearby boundary.

A few hours into the test, the drawdown slope flattened substantially, with water levels approaching equilibrium. This indicated one of the following: (1) vertical growth of the cone of depression through a greater thickness of sediments (partial penetration effects); (2) leakage from overlying or underlying strata; or (3) a lateral increase in hydraulic conductivity and transmissivity some distance away from the well.

As shown on Figure C-9.3-1, about halfway through the 24-h pumping test, the pumping water level began to rise for a couple of hours, reached a local high, and then began declining again. During this period, the drawdown declined from about 40 ft to 35 ft and then increased to near 39 ft. The discharge rate remained constant throughout this period so clearly the well efficiency increased temporarily and then decreased again. At the same time, the pumped water became turbid with material having a “chalky” color, not unlike the bentonite grout used in the well completion. Figure C-9.3-2 shows a linear plot of the drawdown data along with measured turbidity values obtained from water samples collected during the test. It appeared possible that a void may have opened up temporarily adjacent to the well screen, reducing the hydraulic resistance to water entering the well and permitting movement of solids into the screen. This appeared to be a temporary phenomenon, with the drawdown eventually returning to near previous values and the turbidity dropping back to acceptable levels.

Figure C-9.3-3 shows the recovery data collected following shutdown of the 24-h constant-rate pumping test. As indicated on the plot, the transmissivity computed from the early data was 960 gpd/ft with a corresponding hydraulic conductivity of 47 gpd/ft^2, or 6.3 ft/d. Subsequent data showed a steeper slope and a computed transmissivity value of 490 gpd/ft, about half the early-time value. Very late data showed a flat slope and nearly complete water level stabilization characteristic of the effects of partial penetration (vertical growth of the recovery cone of impression) or leakage from overlying and/or underlying strata.

C-9.4 Well R-53 Screen 2 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-53 screen 2 to provide a frame of reference for evaluating the foregoing analyses.

Because of the complexity evident in the multiple slope changes observed in the test data, a simplified approach was used by extrapolating the *initial* slope on Figure C-9.3-1 to a pumping time of 24 h. This produced the drawdown that would have been observed under idealized conditions, that is, if the sediment permeability did not change or there was no boundary, and there were no leakage or partial penetration effects. This extrapolation yielded a hypothetical 24-h drawdown of 28.7 ft at the measured discharge rate of 20.2 gpm, making the idealized specific capacity 0.70 gpm/ft. (Note that this is the specific capacity that would have been observed from a fully penetrating well [no partial penetration of leakage effects] having no boundaries or lateral permeability changes. As such, a lower-bound transmissivity value corresponding to this specific capacity could be compared to the transmissivity determined for the sediments immediately adjacent to the well screen.)

In addition to specific capacity and pumping time, other input values used in the calculations included a storage coefficient value of 5×10^{-4} and a borehole radius of 0.49 ft (inferred from the volume of filter pack required to backfill the screen zone).

Iterating these inputs yielded a lower-bound transmissivity for the screened interval of 1200 gpd/ft. This result was consistent with the computed value of 1250 gpd/ft obtained from the line of fit on Figure C-9.3-1.

C-10.0 SUMMARY

Constant-rate pumping tests were conducted on R-53 screens 1 and 2. The tests were performed to gain an understanding of the hydraulic characteristics of the screen zones and the degree of interconnection between them. Numerous observations and conclusions were drawn for the tests as summarized below.

Aerated groundwater was produced from both screens 1 and 2 during the pumping tests.

The static water level observed in screen 1 was substantially higher (9.15 ft) than that in screen 2, showing a strong downward hydraulic gradient, highly resistive sediments separating the screen zones, and little hydraulic connection between the screens.

A comparison of barometric pressure and R-53 screen 1 water level data showed a high barometric efficiency, around 100%. The data for screen 2, on the other hand, suggested a barometric efficiency near zero—relatively unusual for deep screens at the Laboratory.

Pumping screen 1 at more than 10 gpm for 1440 min had no discernable effect on water levels in screen 2 and likewise no effect on water levels in nearby wells R-21, R-32 and R-38. Pumping screen 2 at more than 20 gpm had no discernable effect on screen 1. Similarly, it had no measurable effect in R-32 (2265 ft away) or R-38 (937 ft away). It did, however, induce about 0.5 ft of drawdown in R-21 at a distance of 1384 ft.

Analysis of the screen 1 pumping tests showed an average hydraulic conductivity value of 192 gpd/ft^2, or 25.7 ft/d.

Screen 1 produced 10.5 gpm for 1440 min with 7.20 ft of drawdown for a specific capacity of 1.46 gpm/ft. The lower-bound hydraulic conductivity computed from this information was 106 gpd/ft^2 or 14.1 ft/d, consistent with the pumping tests values and suggesting a screen zone efficiency of more than 50%.

Analysis of the screen 2 pumping tests suggested a near-well transmissivity for the 20.5-ft-thick screened interval averaging 1100 gpd/ft. The corresponding average hydraulic conductivity was 54 gpd/ft^2, or 7.2 ft/d. Subsequent slope increases on the data graphs yielded an average transmissivity value of 470 gpd/ft—around half the previous result. The approximately 2:1 transmissivity ratio is characteristic of the expected observation near a linear boundary such as a fault or pinch out. Alternatively, this result could indicate a lateral reduction in hydraulic conductivity near the well. The late data from screen 2 showed near stabilization associated with leakage, partial penetration effects (vertical growth of the cone of depression), or a large lateral increase in transmissivity.

Screen 2 produced 20.2 gpm for 1440 min with 38.7 ft of drawdown for an actual specific capacity of 0.52 gpm/ft. However, this value could not be used for comparison to the aquifer parameters because of the complexity associated with multiple slope changes in the data graphs. To achieve the desired comparison, the early-time drawdown slope from the 24-h test was extrapolated to arrive at a hypothetical specific capacity of 0.70 gpm/ft for fully penetrating, homogeneous conditions. The lower-bound transmissivity estimate obtained from this exercise was 1200 gpd/ft, in reasonable agreement with the screen zone transmissivity of 1250 obtained from the 24-h drawdown graph and the overall average value of 1100 gpd/ft obtained from all tests.

A well efficiency increase and subsequent decrease at screen 2 during the 24-h pumping test coupled with a simultaneous turbidity increase suggested the transient occurrence of a void near the well screen and possible movement of the backfill materials.

C-11.0 REFERENCES

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

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

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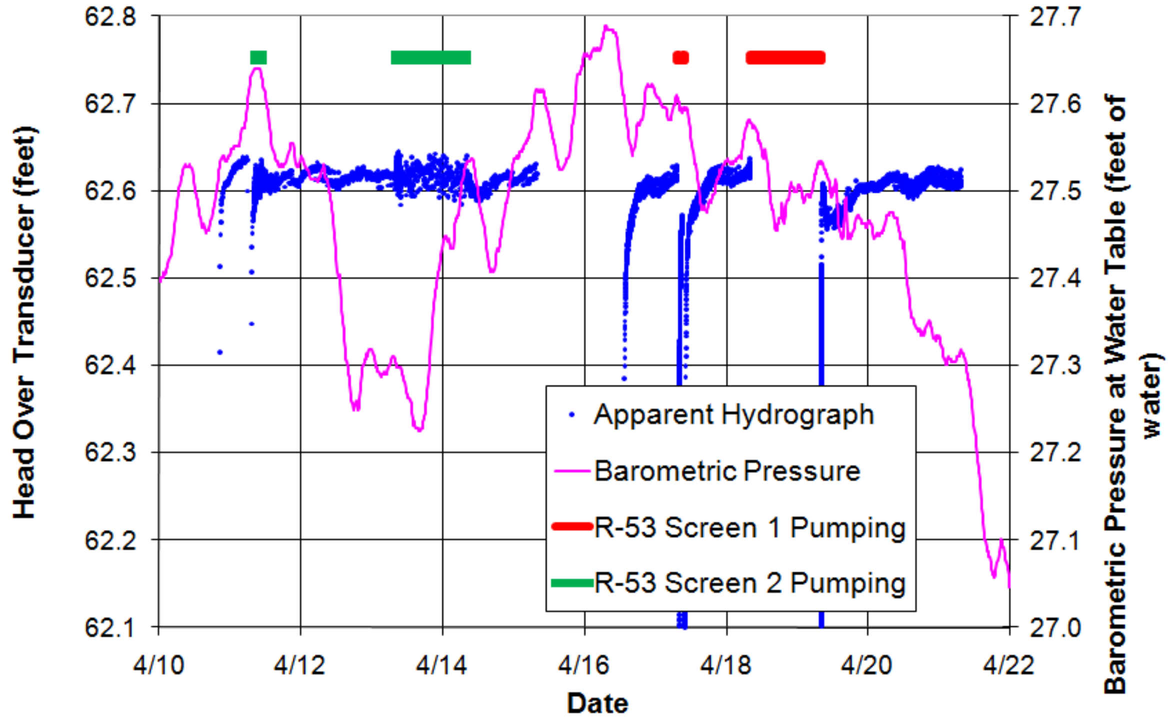

Figure C-7.0-1 Well R-53 screen 1 apparent hydrograph

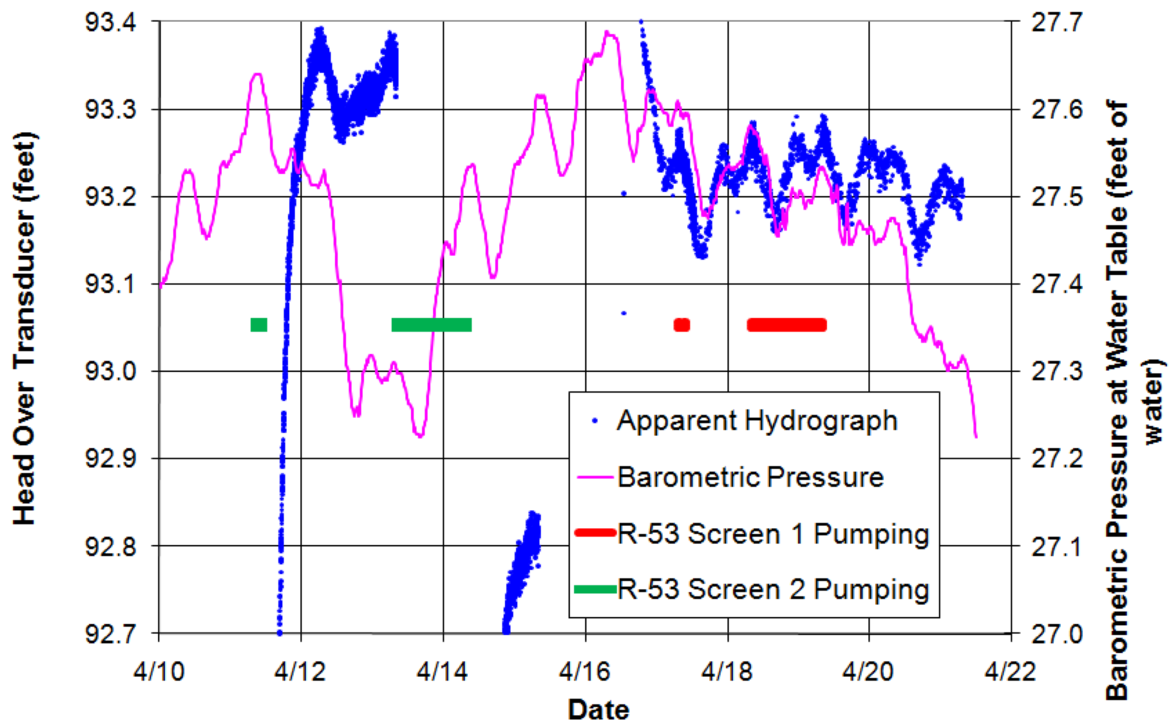

Figure C-7.0-2 Well R-53 screen 2 apparent hydrograph

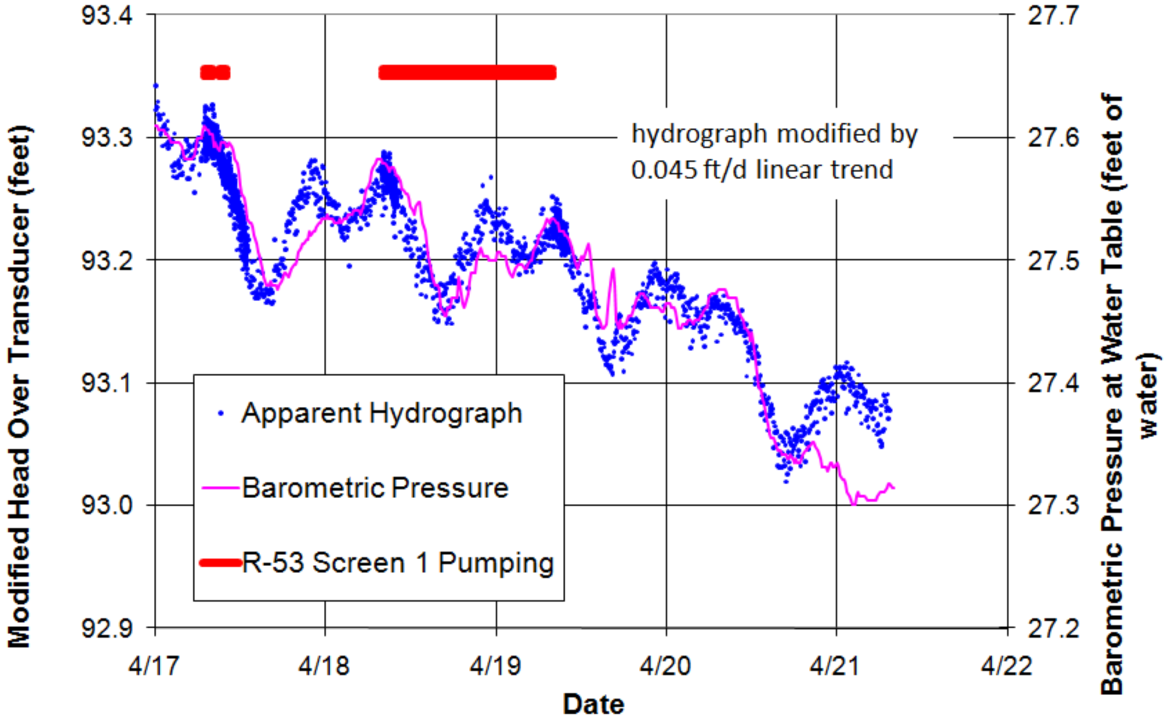

Figure C-7.0-3 Well R-53 screen 2 modified apparent hydrograph

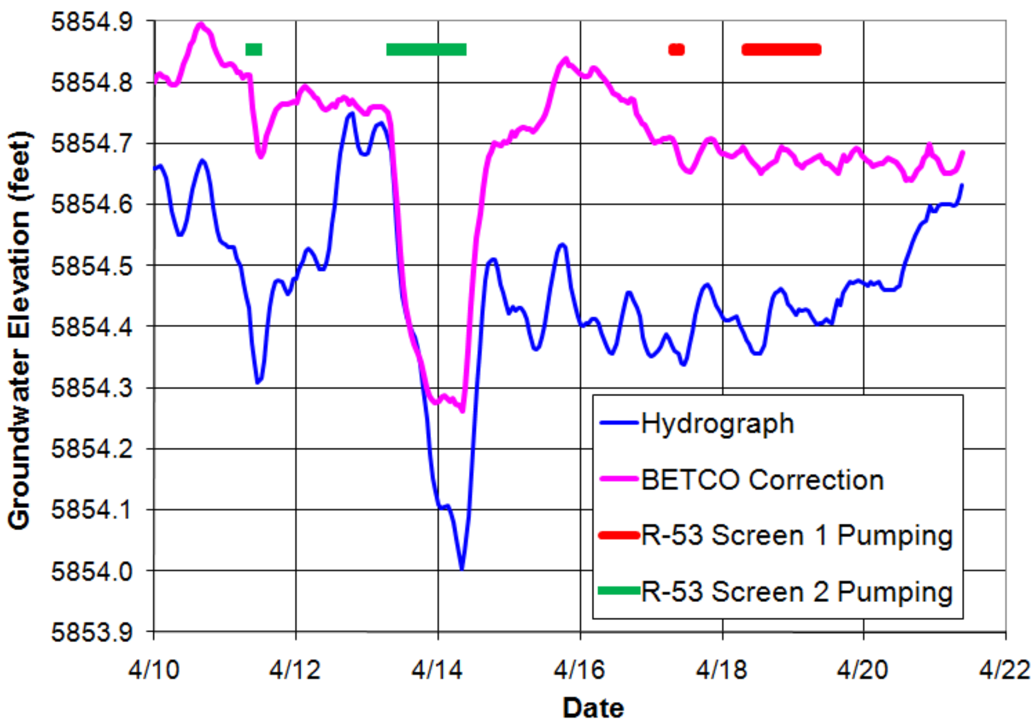

Figure C-7.0-4 Well R-21 hydrograph

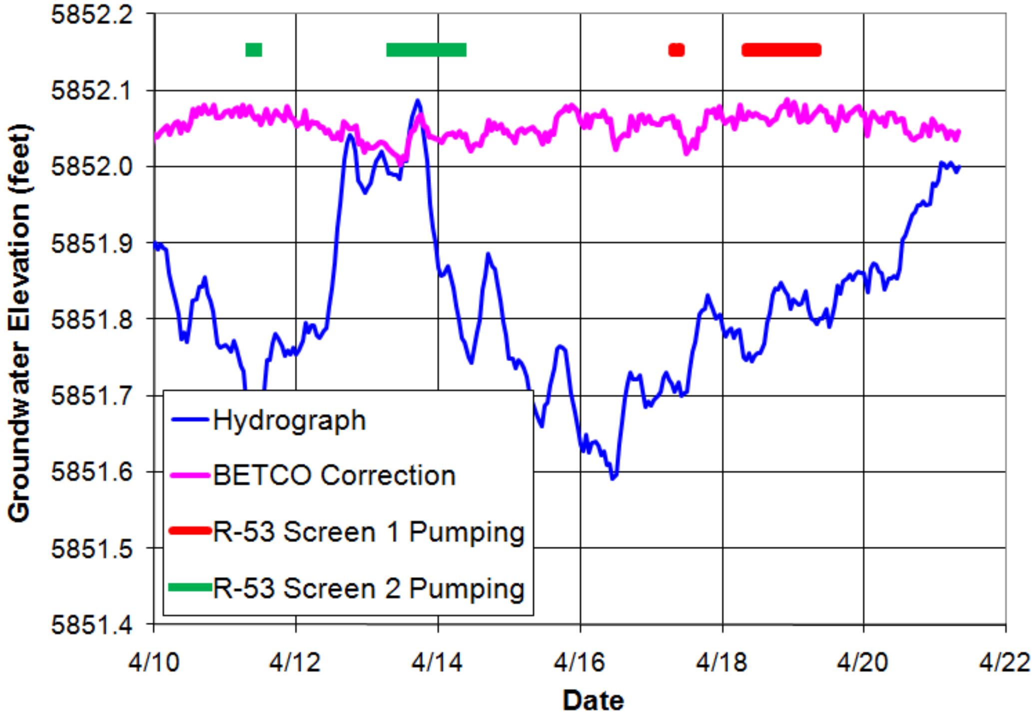

Figure C-7.0-5 Well R-32 hydrograph

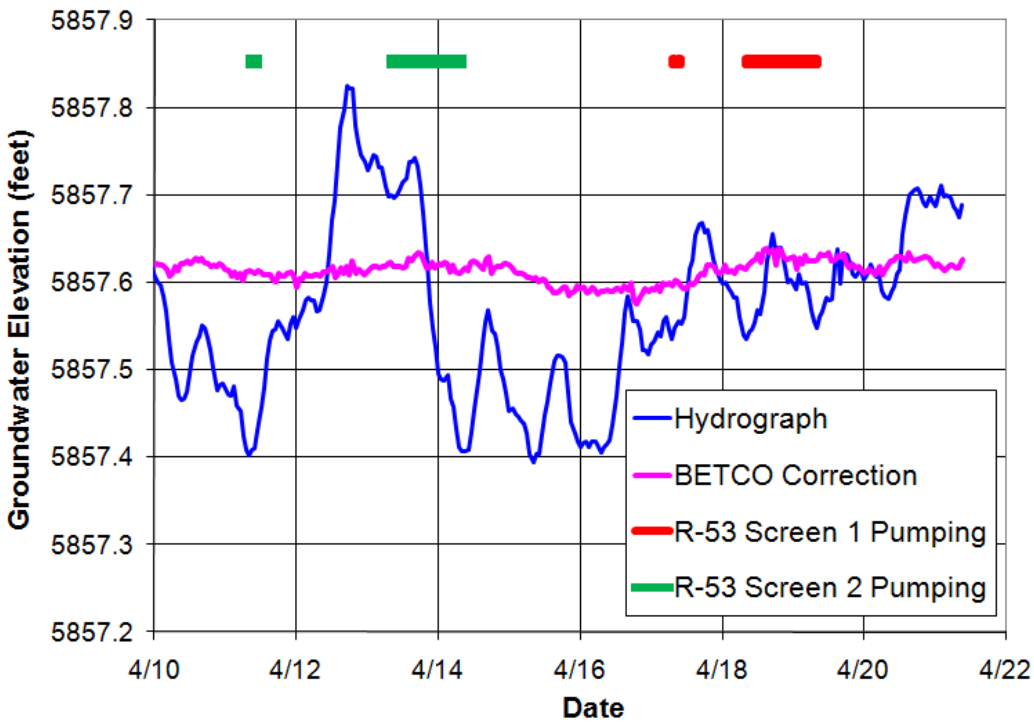

Figure C-7.0-6 Well R-38 hydrograph

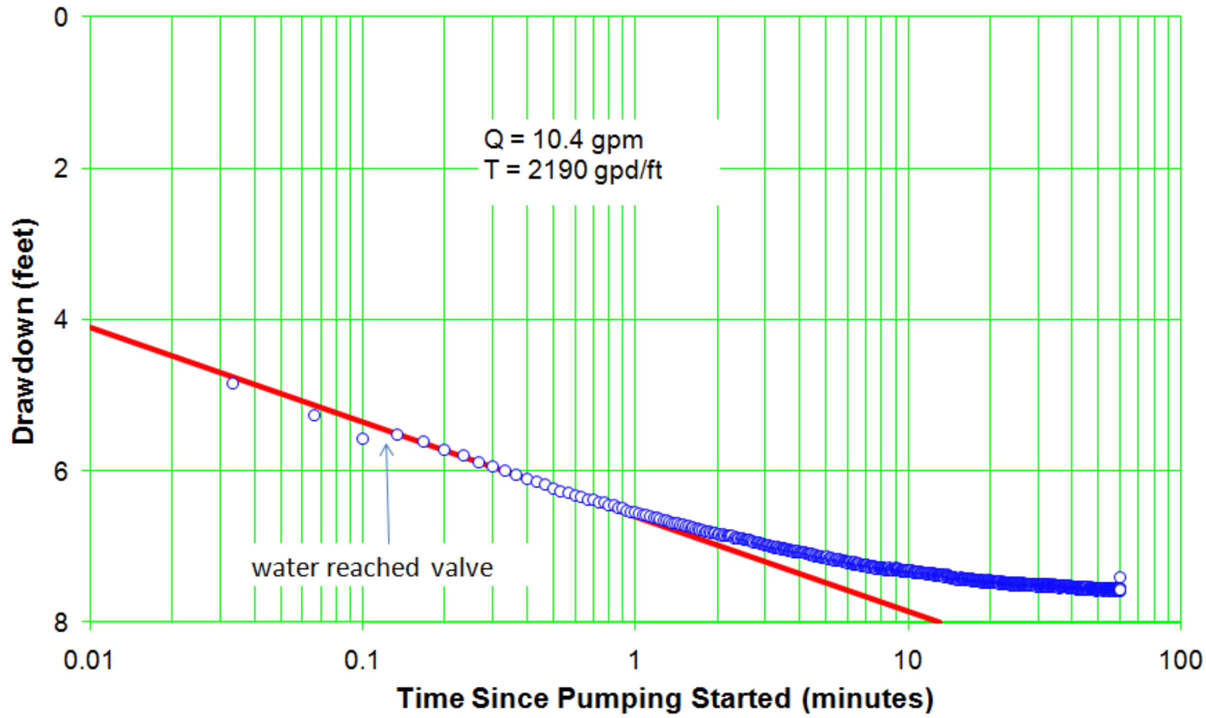

Figure C-8.1-1 Well R-53 screen 1 trial 1 drawdown

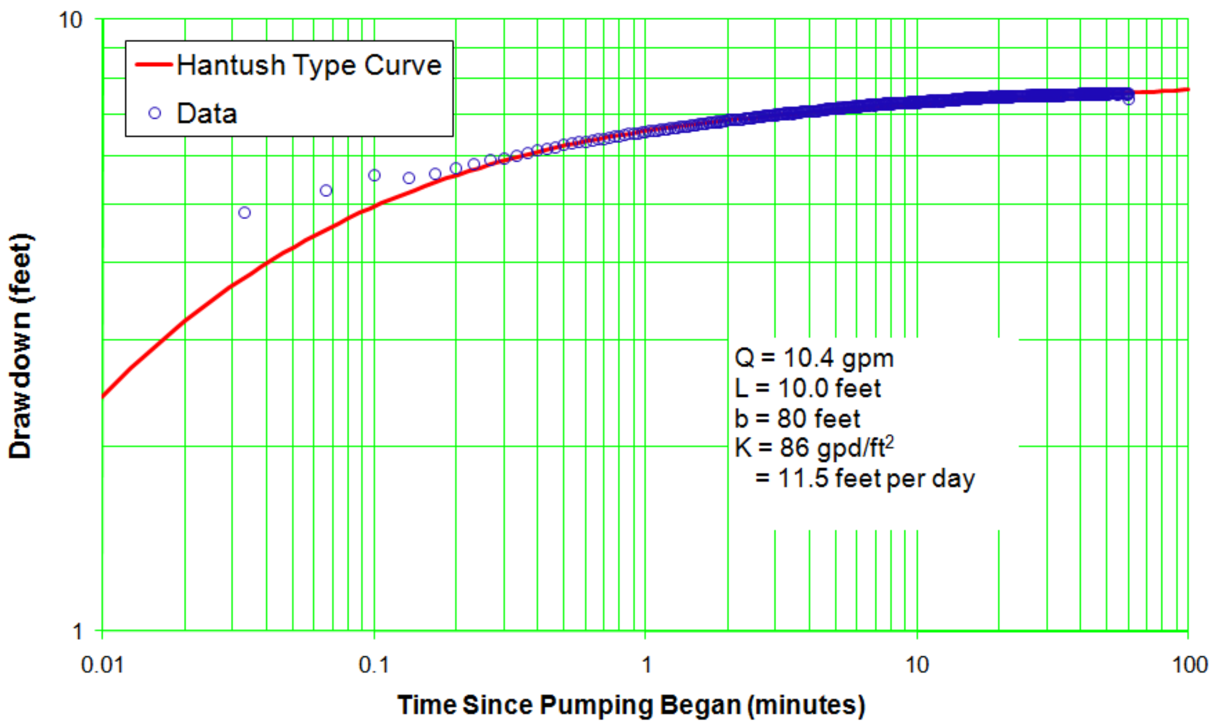

Figure C-8.1-2 Well R-53 screen 1 trial 1 drawdown—Hantush solution for anisotropy of 1.0

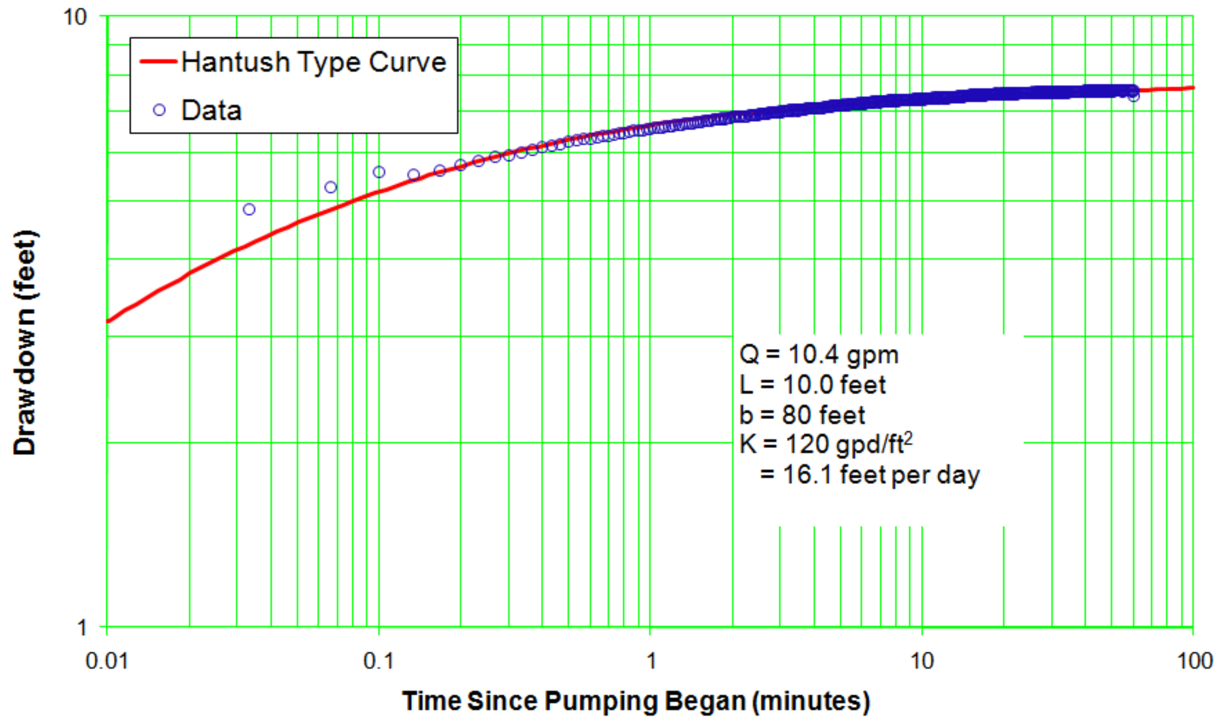

Figure C-8.1-3 Well R-53 screen 1 trial 1 drawdown—Hantush solution for anisotropy of 0.1

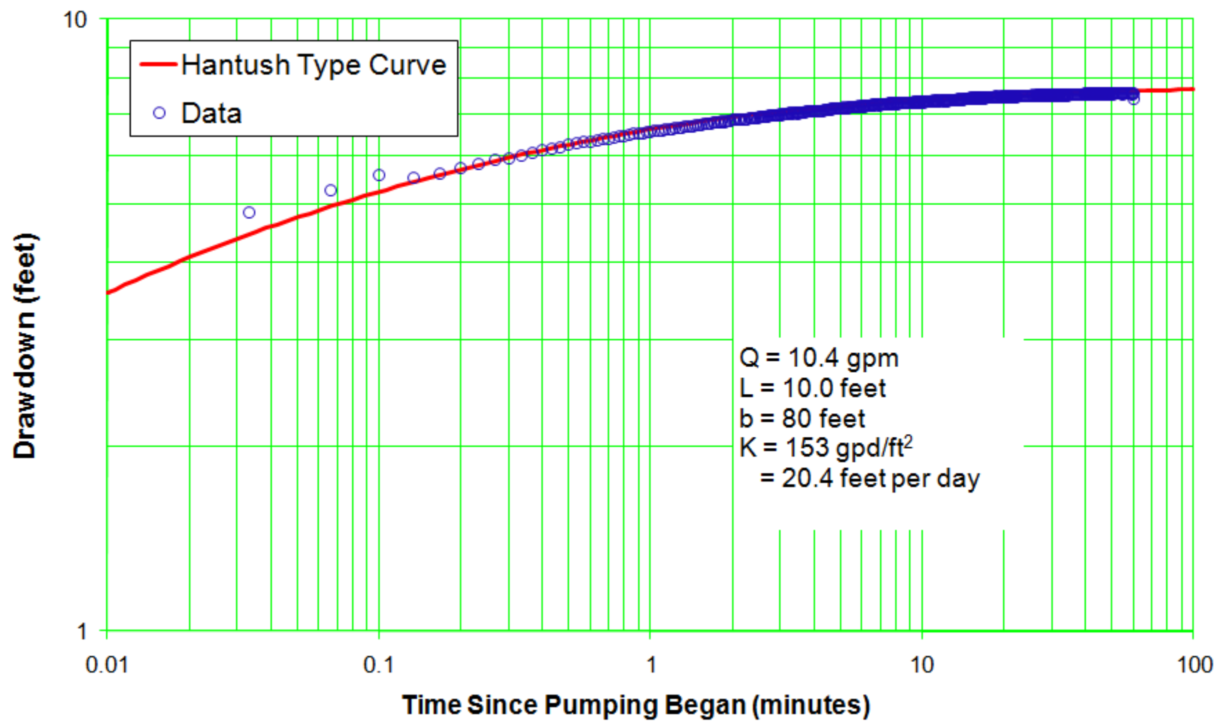

Figure C-8.1-4 Well R-53 screen 1 trial 1 drawdown—Hantush solution for anisotropy of 0.01

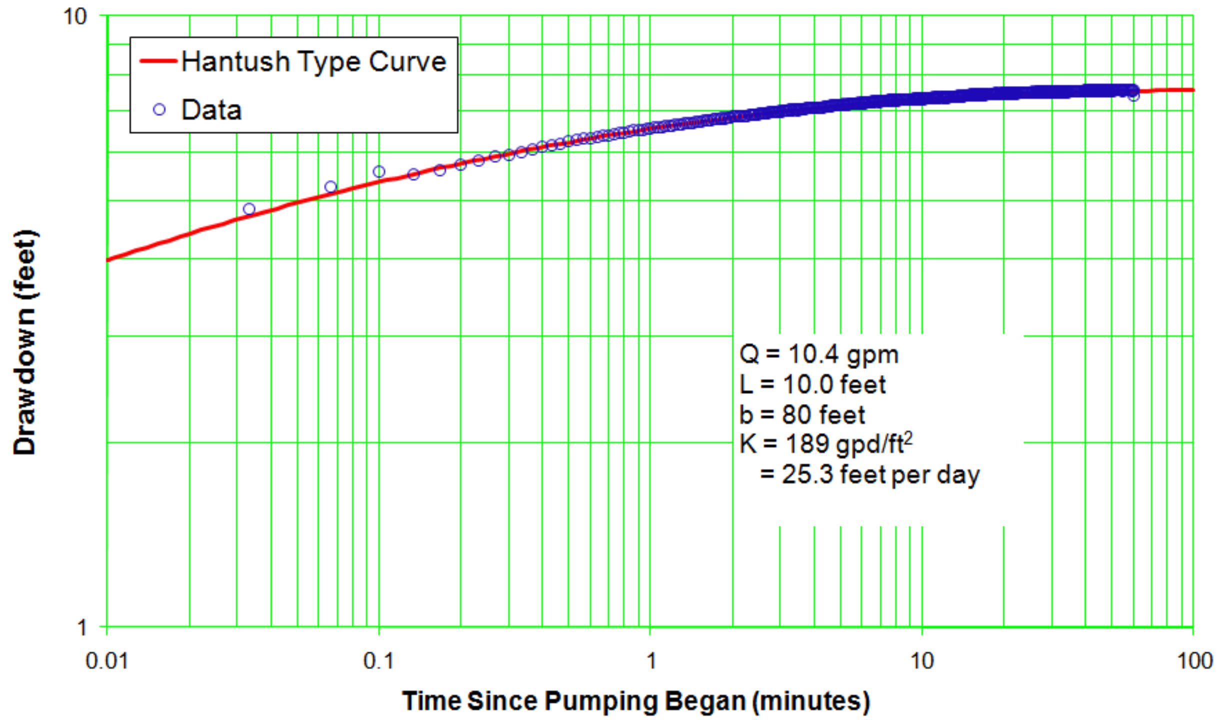

Figure C-8.1-5 Well R-53 screen 1 trial 1 drawdown—Hantush solution for anisotropy of 0.001

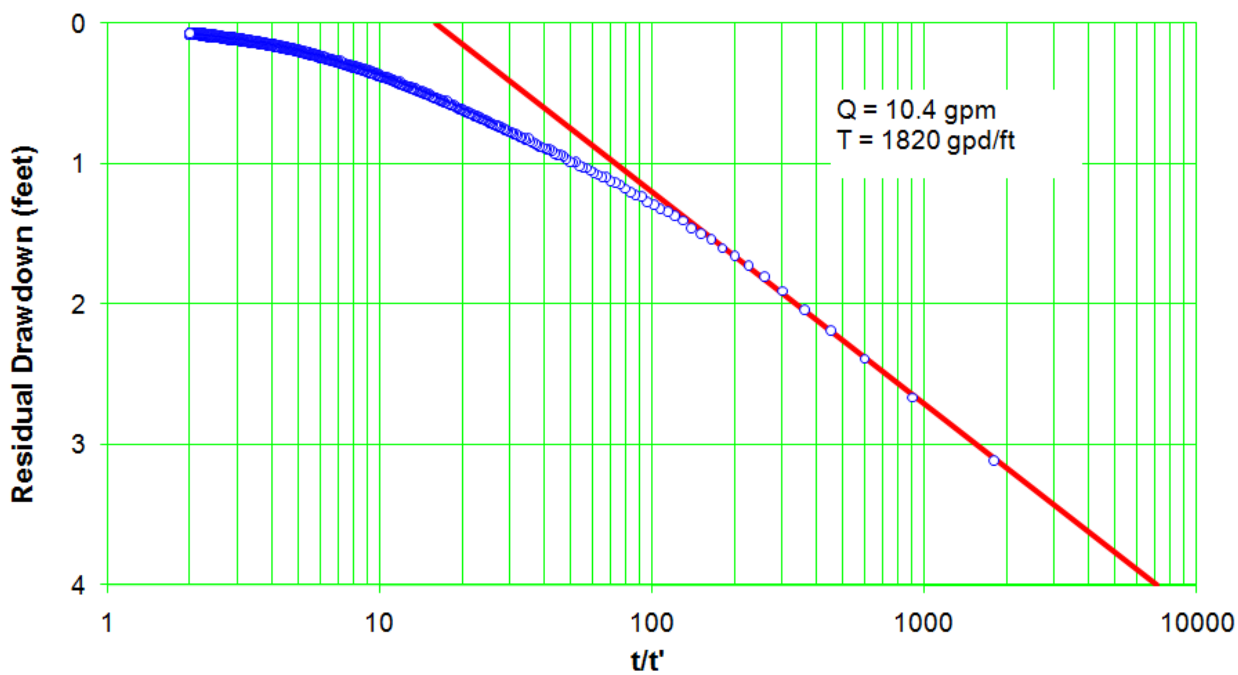

Figure C-8.1-6 Well R-53 screen 1 trial 1 recovery

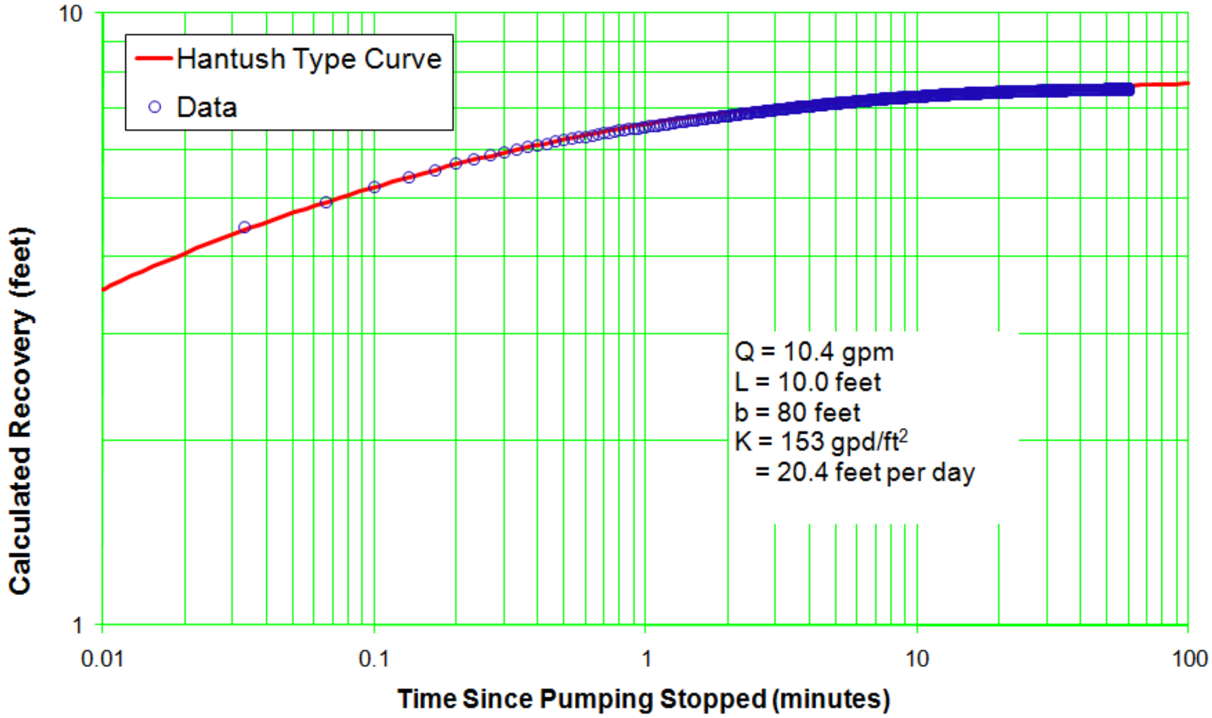

Figure C-8.1-7 Well R-53 screen 1 trial 1 recovery—Hantush solution for anisotropy of 0.01

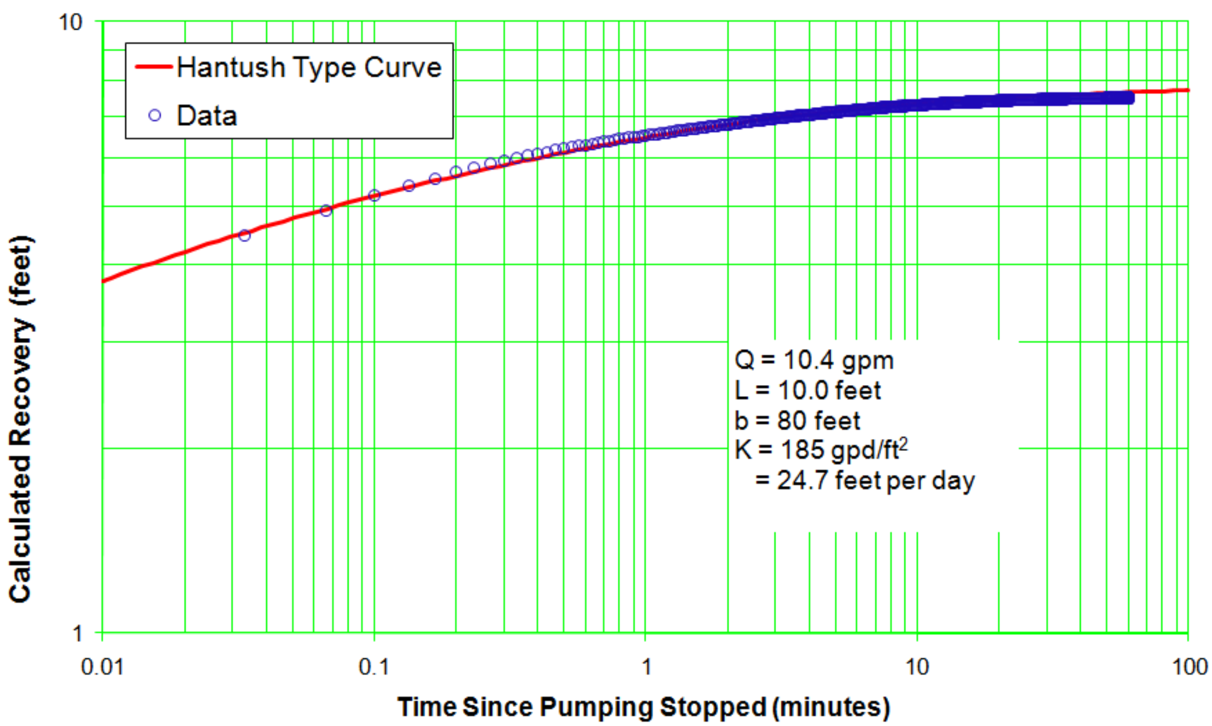

Figure C-8.1-8 Well R-53 screen 1 trial 1 recovery—Hantush solution for anisotropy of 0.001

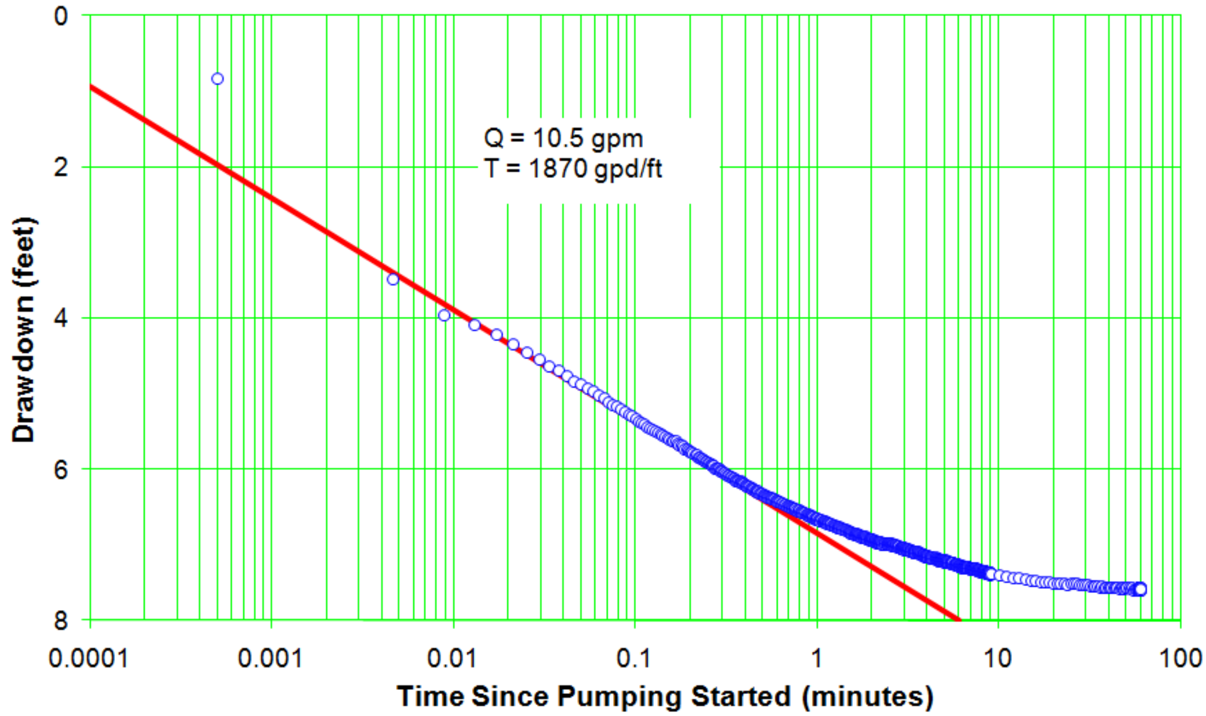

Figure C-8.2-1 Well R-53 screen 1 trial 2 drawdown

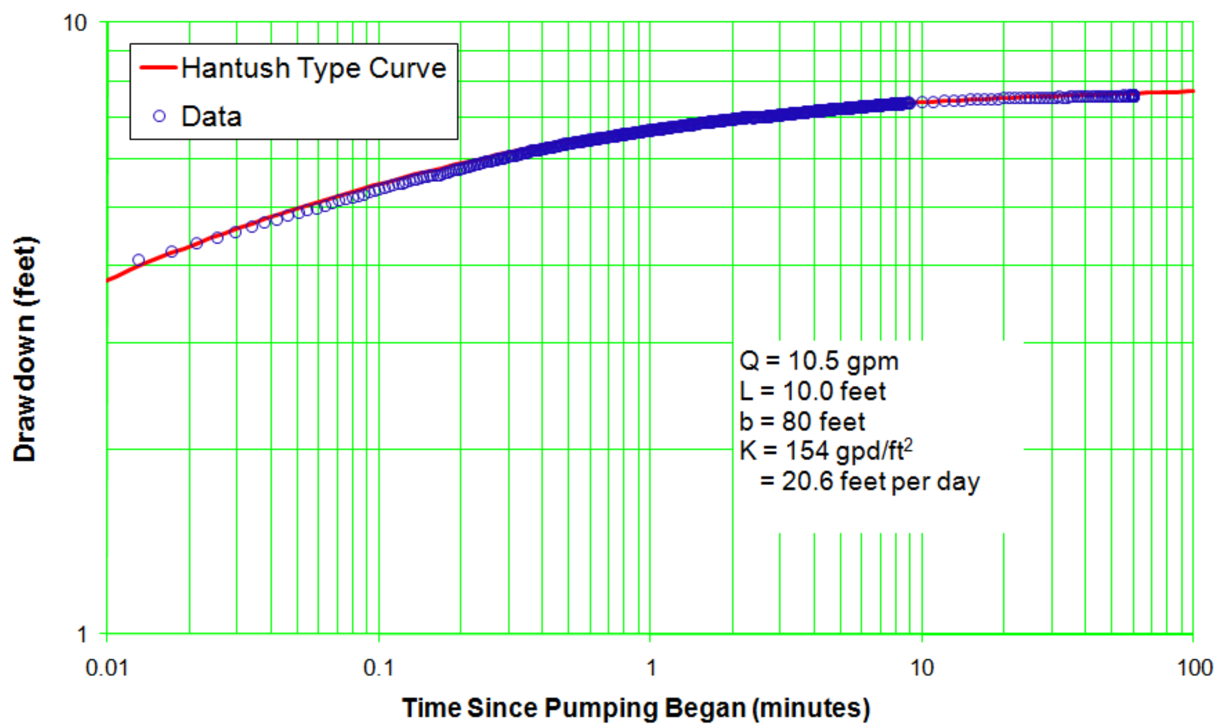

Figure C-8.2-2 Well R-53 screen 1 trial 2 drawdown—Hantush solution for anisotropy of 0.01

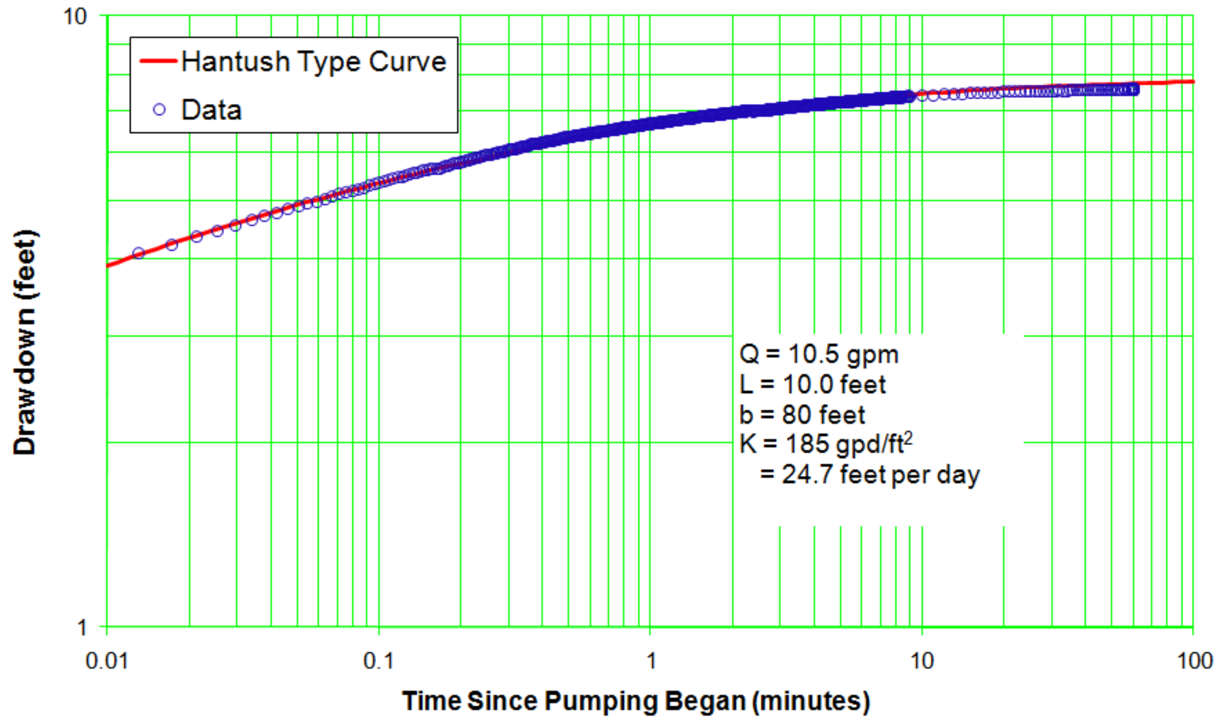

Figure C-8.2-3 Well R-53 screen 1 trial 2 drawdown—Hantush solution for anisotropy of 0.001

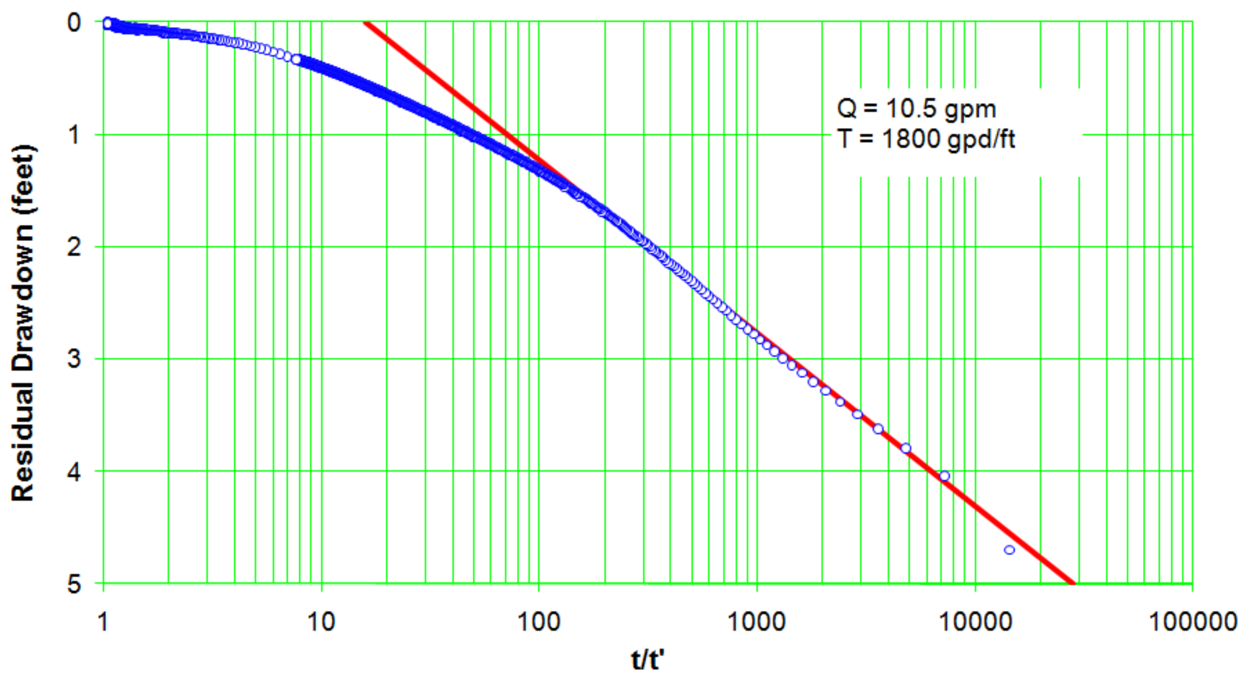

Figure C-8.2-4 Well R-53 screen 1 trial 2 recovery

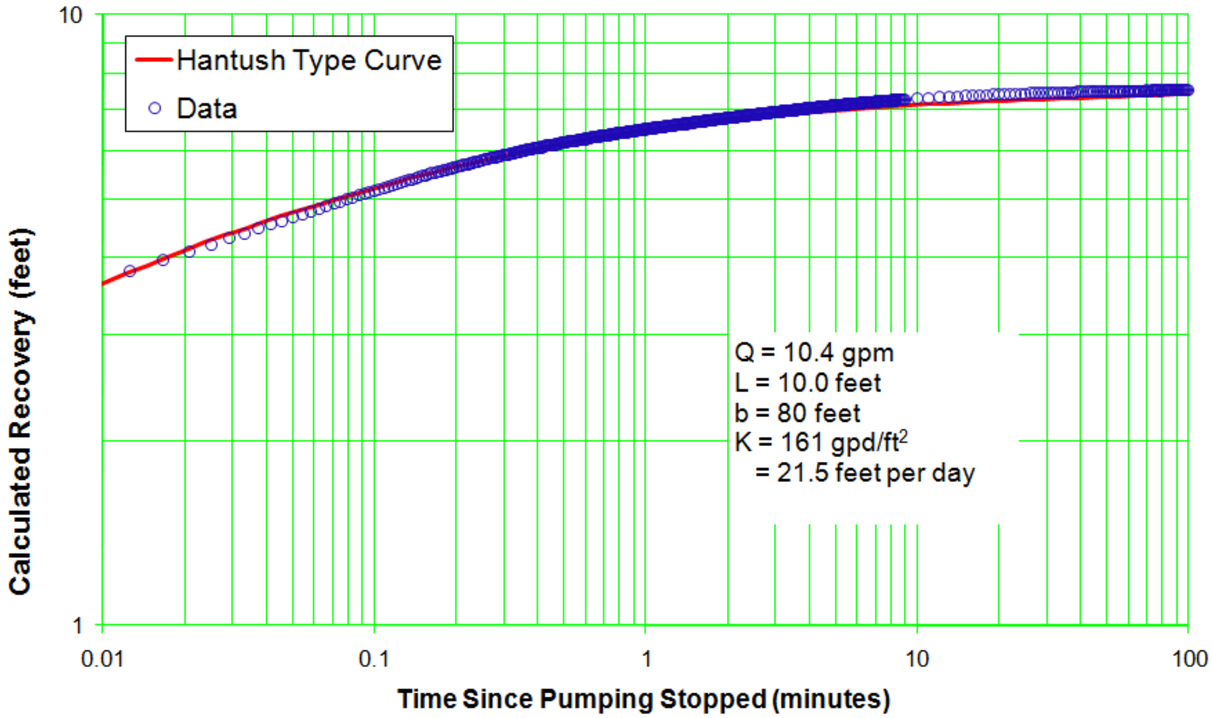

Figure C-8.2-5 Well R-53 screen 1 trial 2 recovery—Hantush solution for anisotropy of 0.01

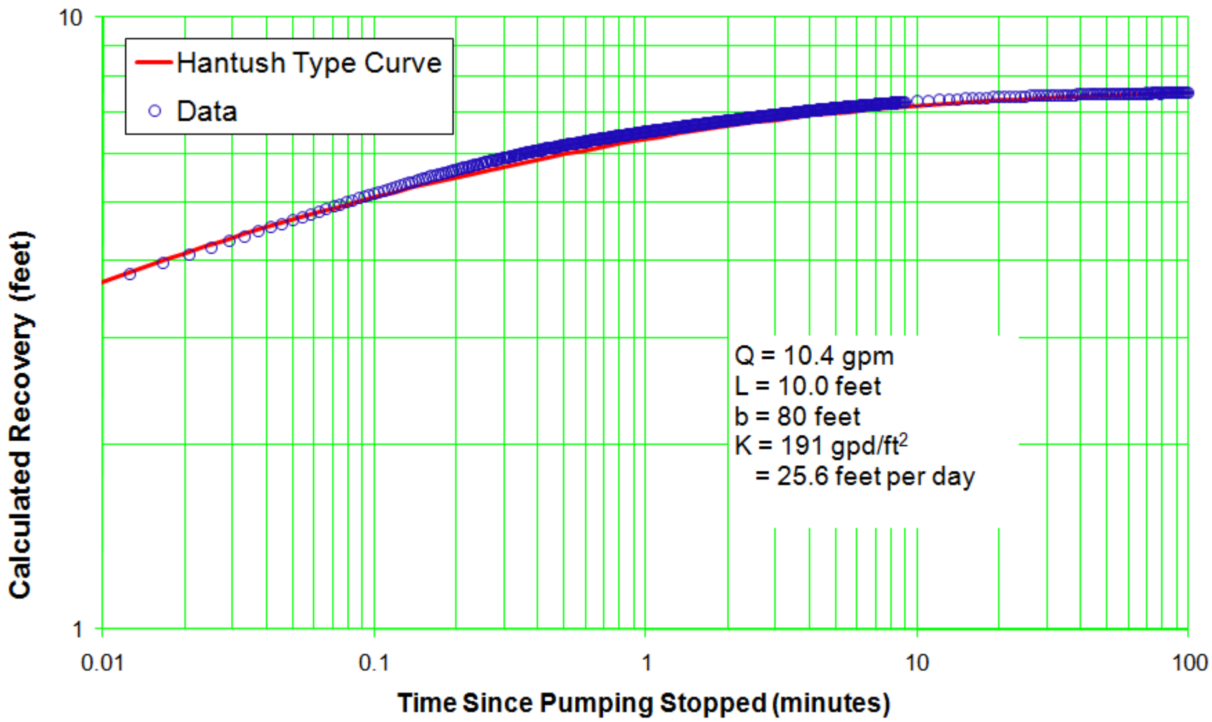

Figure C-8.2-6 Well R-53 screen 1 trial 2 recovery—Hantush solution for anisotropy of 0.001

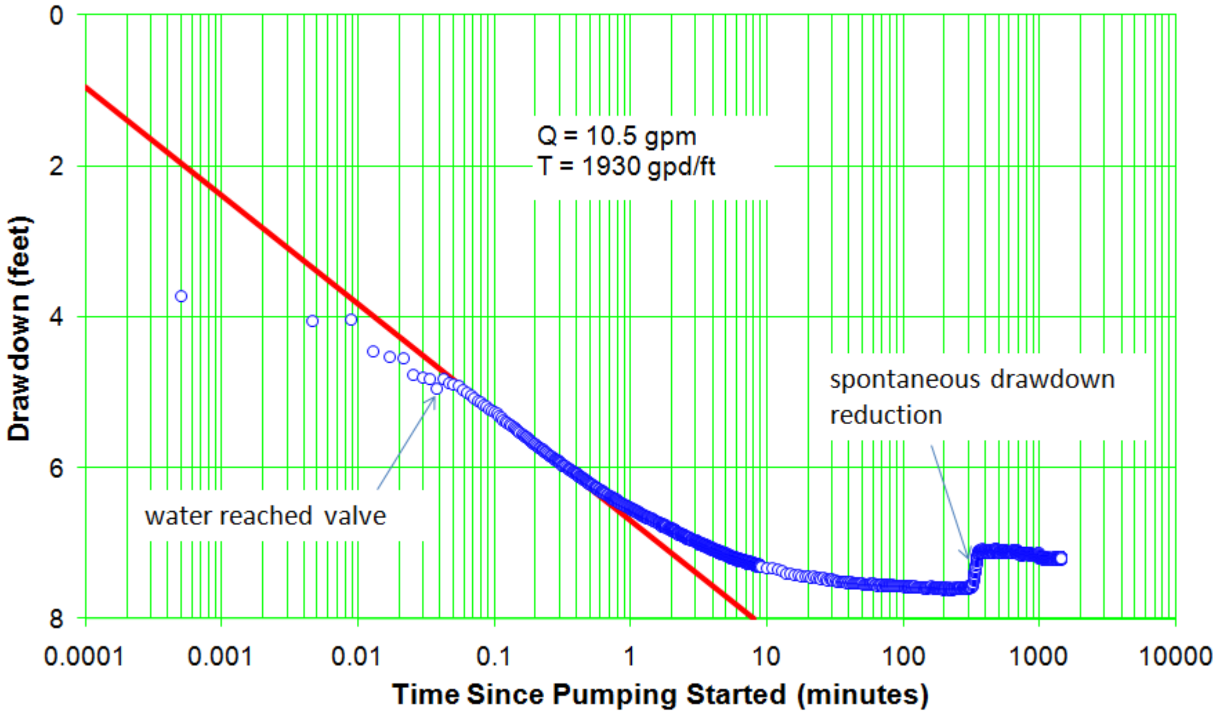

Figure C-8.3-1 Well R-53 screen 1 drawdown

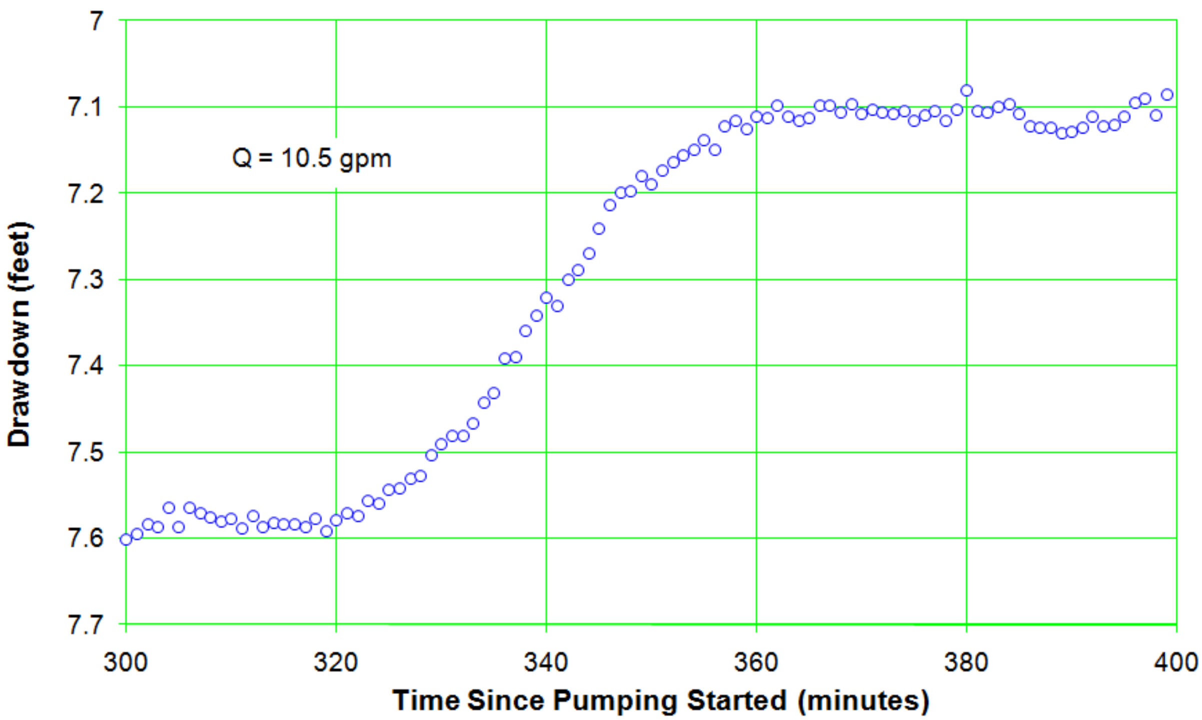

Figure C-8.3-2 Well R-53 screen 1 drawdown—expanded scale

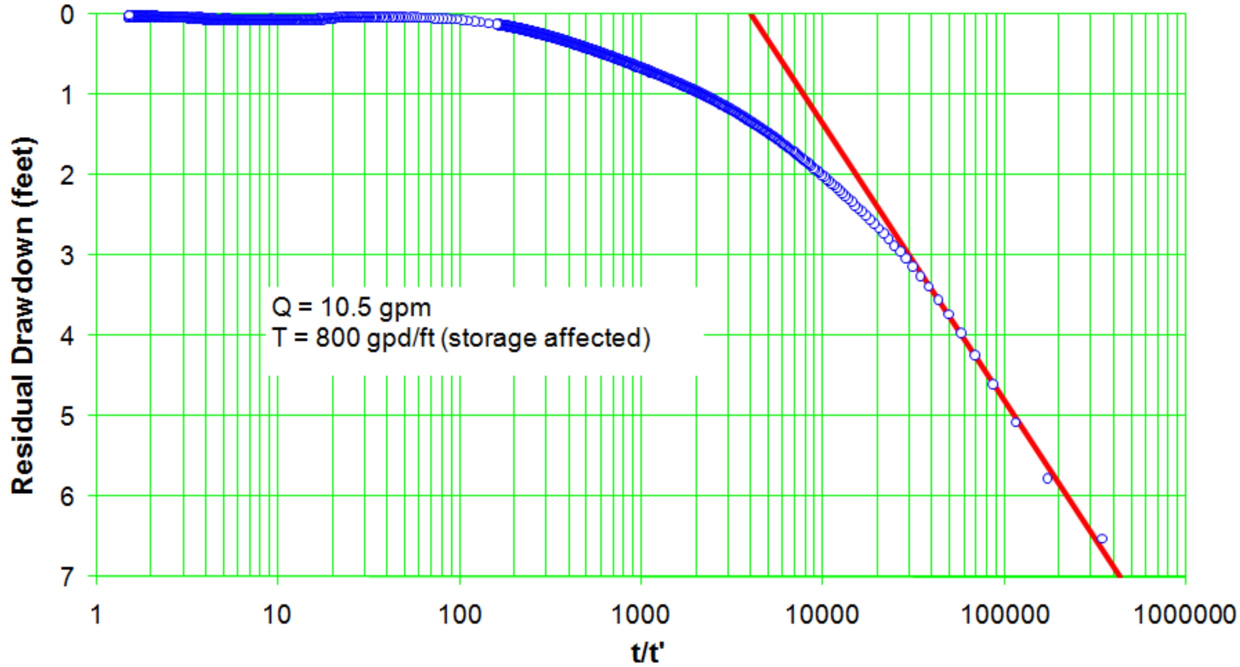

Figure C-8.3-3 Well R-53 screen 1 recovery

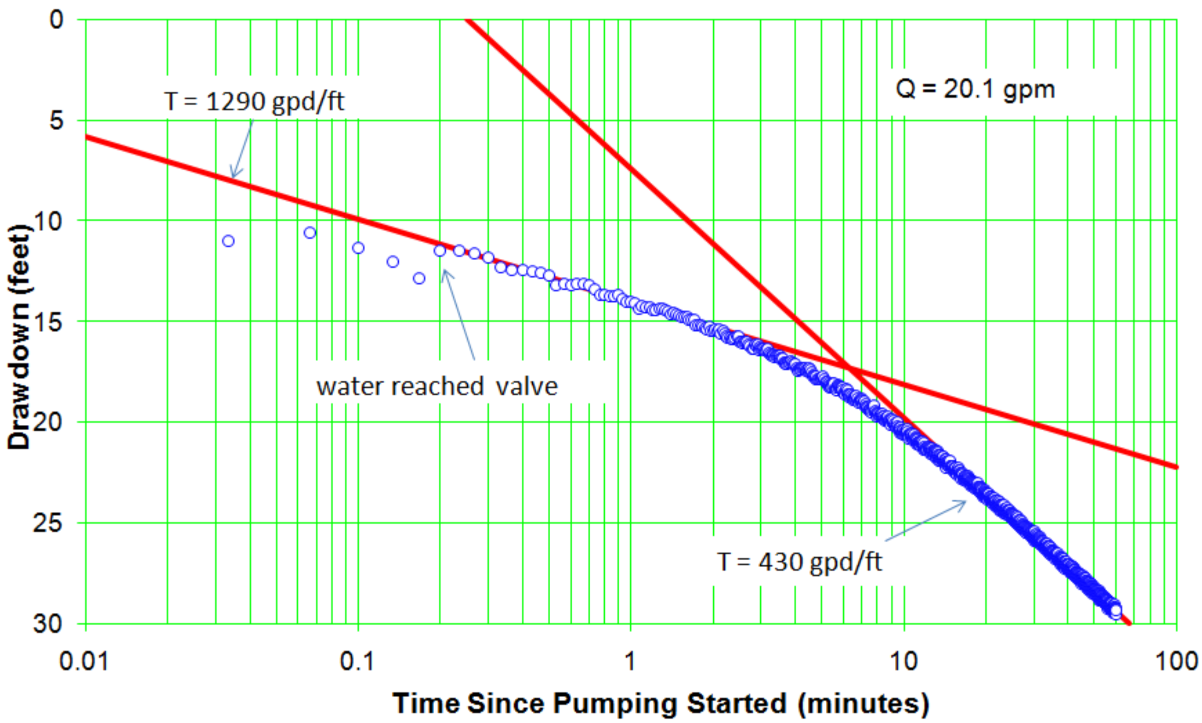

Figure C-9.1-1 Well R-53 screen 2 trial 1 drawdown

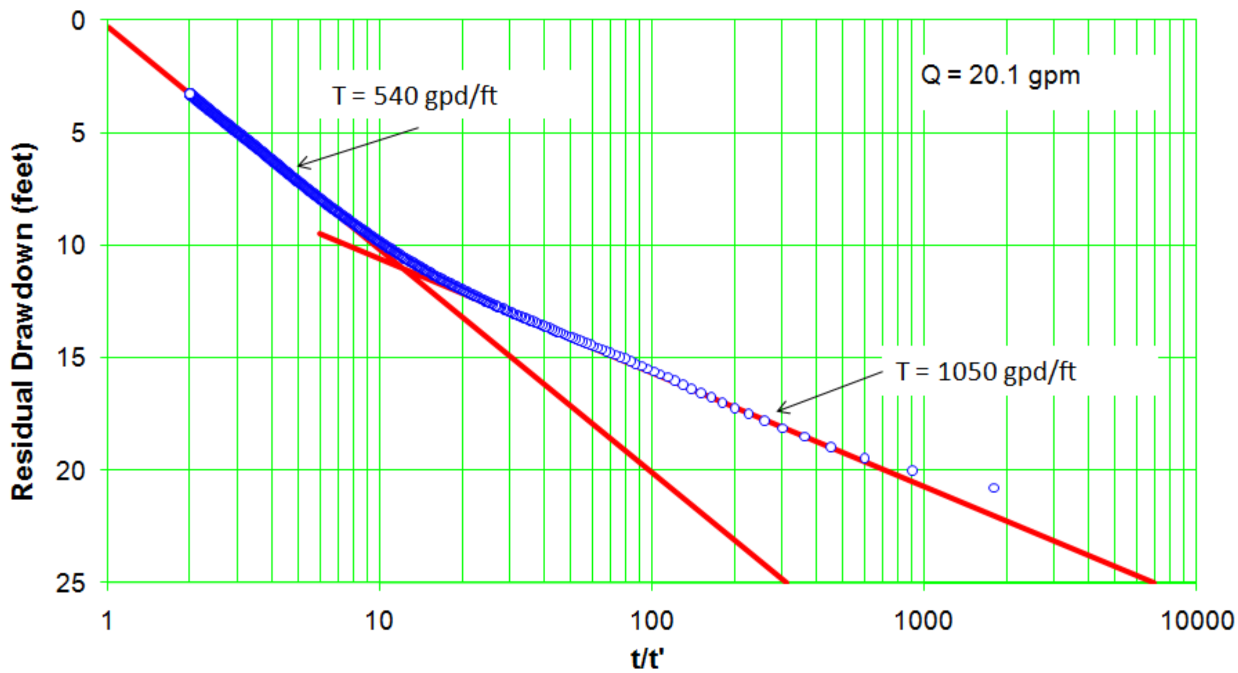

Figure C-9.1-2 Well R-53 screen 2 trial 1 recovery

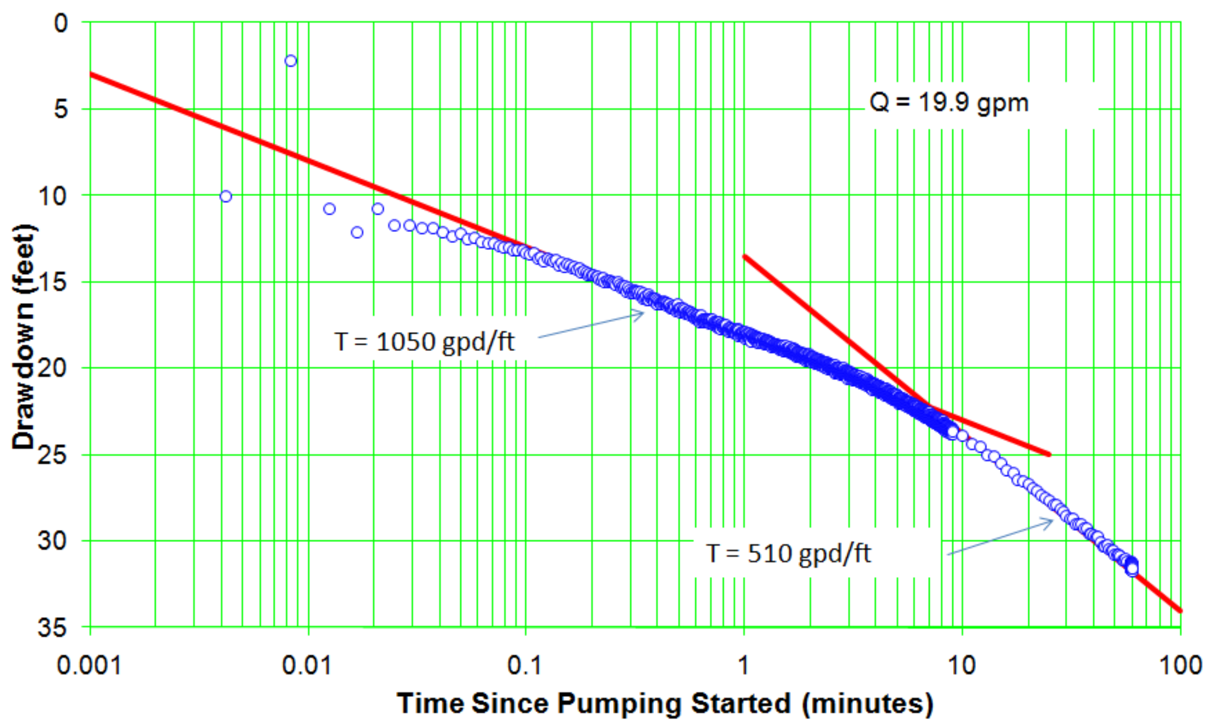

Figure C-9.2-1 Well R-53 screen 2 trial 2 drawdown

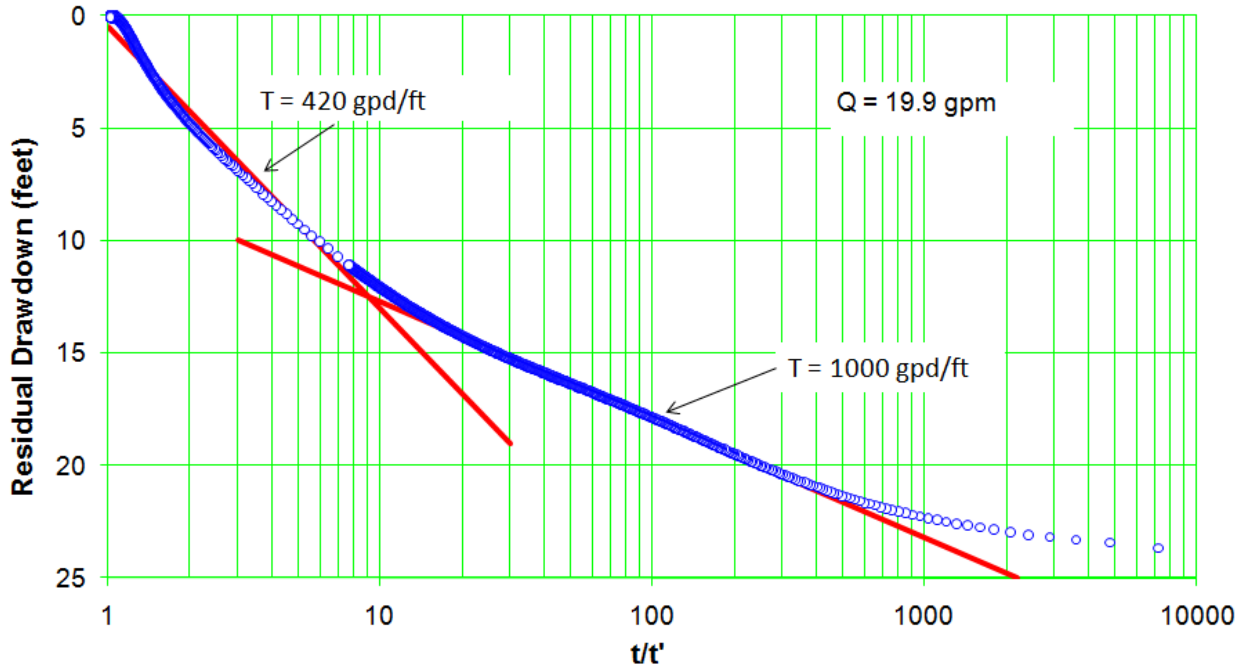

Figure C-9.2-2 Well R-53 screen 2 trial 2 recovery

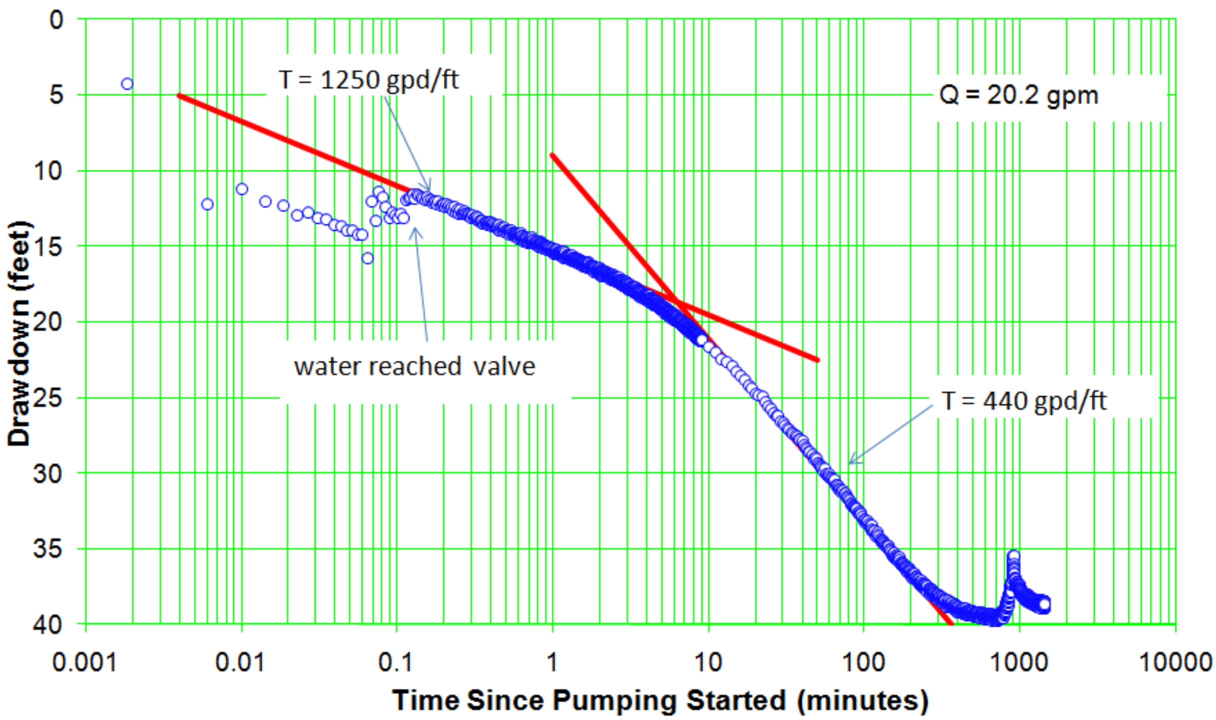

Figure C-9.3-1 Well R-53 screen 2 drawdown

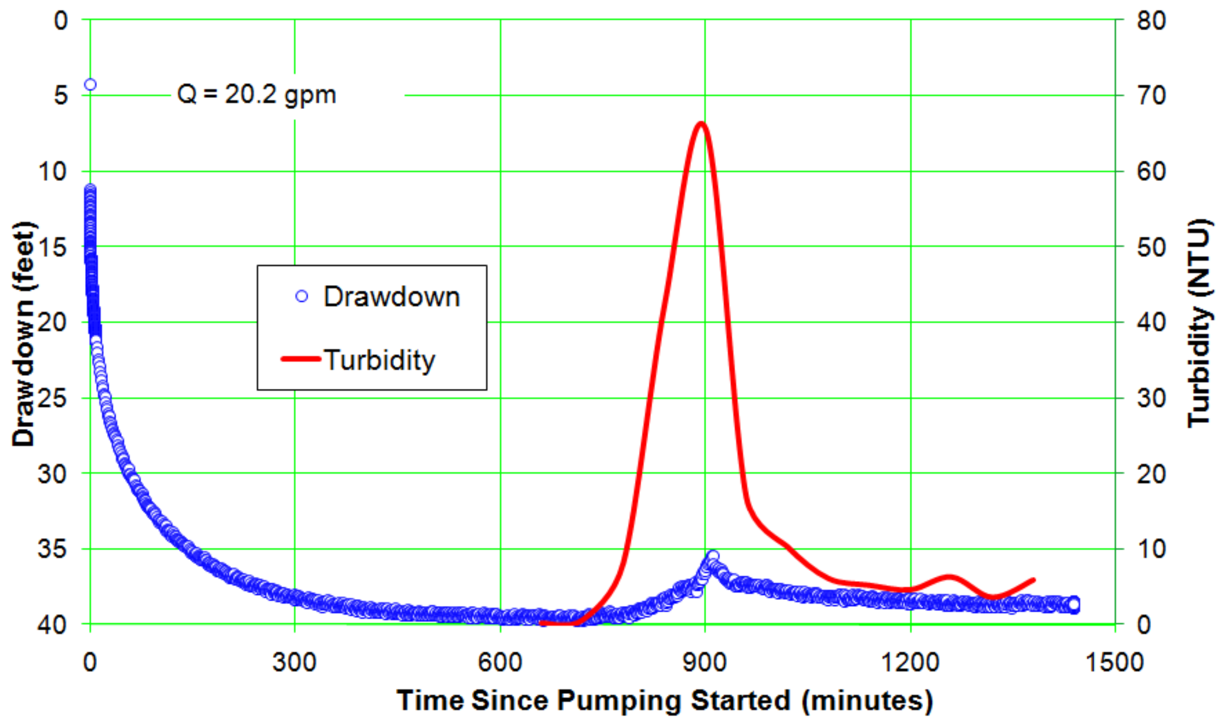

Figure C-9.3-2 Well R-53 screen 2 turbidity

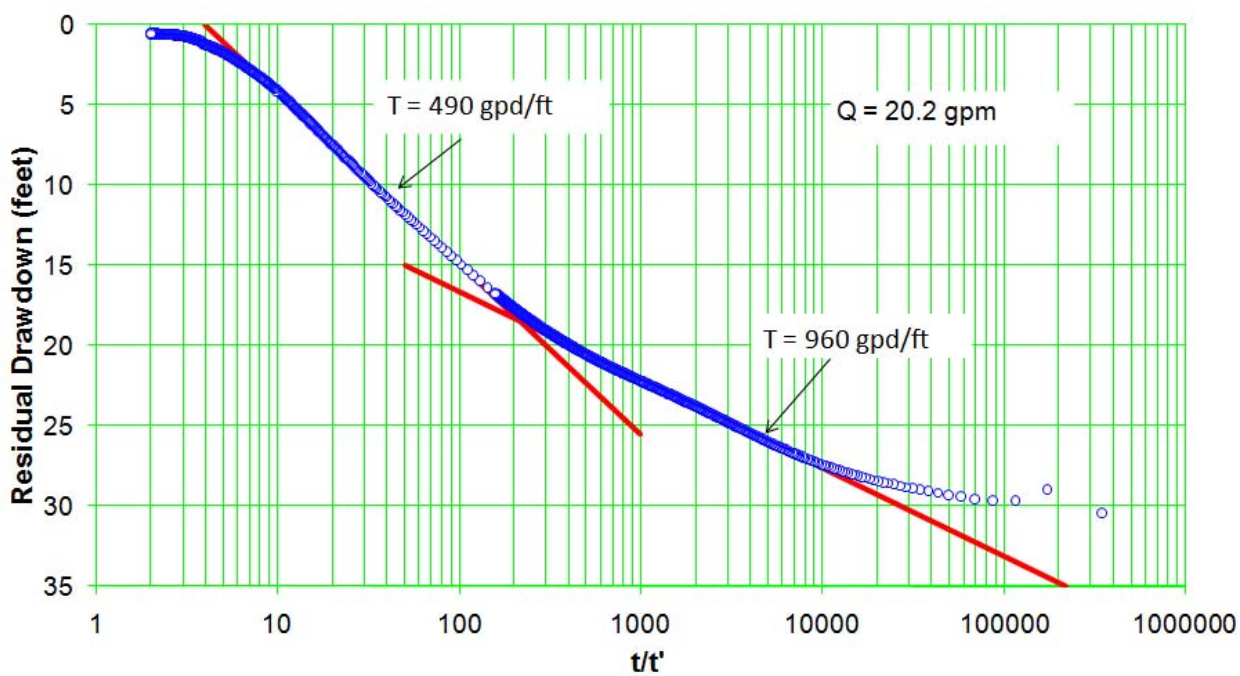

Figure C-9.3-3 Well R-53 screen 2 recovery

Appendix D

Borehole Video Logging
(on DVD included with this document)

Appendix E

Geophysical Logging Files
(on CD included with this document)