LA-UR-10-0995
June 2010
EP2010-0143

Completion Report for Regional Aquifer Well R-54

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

LA-UR-10-0995
EP2010-0143

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EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for regional aquifer well R-54, located in Pajarito Canyon, Technical Area 54, at Los Alamos National Laboratory (the Laboratory) in Los Alamos County, New Mexico. The R-54 monitoring well is intended to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the groundwater protection program for the Laboratory and the Compliance Order on Consent and the New Mexico Environment Department−(NMED-) approved drilling work plan.

The R-54 monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was used only above the anticipated regional aquifer; no drilling-fluid additives other than small amounts of potable water were used below 705 ft below ground surface (bgs), 100 ft above the expected top of the regional aquifer. The R-54 borehole was successfully completed to total depth using dual-rotary casing-advance drilling methods.

During drilling, a retractable 16-in. casing was advanced through alluvium, Bandelier Tuff, Guaje Pumice Bed, and the top of the Cerros del Rio basalt to a depth of 352.3 ft bgs. Then a 15-in. open borehole was advanced with fluid-assisted air-rotary methods and a downhole hammer bit into the Cerros del Rio basalt to a depth of 827.0 ft bgs. A retractable 12-in. casing was then advanced through the bottom of the Cerros del Rio basalt and into the Puye Formation, to a total depth of 944.5 ft bgs.

Well R-54 was completed as a dual-screen well to allow evaluation of water quality and water levels at two discrete depth intervals within the regional aquifer. The upper 10-ft-long screened interval is set between 830.0 and 840.0 ft bgs within the basaltic sediments at the bottom of the Cerros del Rio basalt, while the lower 10-ft-long screened interval is set between 915.0 and 925.0 ft bgs within the Puye Formation. The composite depth to water after well installation and well development was 815.0 ft bgs. The well screens are separated by a packer as part of the permanent sampling system to ensure isolation of each screened interval.

The well was completed in accordance with an NMED-approved well design. The well was thoroughly developed and target water-quality parameters were met at both screened intervals. Aquifer testing indicates that both screen intervals at monitoring well R-54 are productive and will perform effectively to meet the planned objectives. A sampling system and transducers have been placed in the upper and lower screened intervals, and groundwater sampling at R-54 will be performed as part of the facility-wide groundwater monitoring program.

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Acronyms and Abbreviations

amsl	above mean sea level
BETCO	barometric and earth tide correction (software)
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
DOE	Department of Energy (U.S.)
EES-14	Earth and Environmental Sciences Group 14
Eh	decreasing oxidation-reduction potential
EP	Environmental Programs Directorate
EPA	Environmental Protection Agency (U.S.)
gpd/ft	gallons per day per foot
gpm	gallons per minute
HE	high explosives
hp	horsepower
I.D.	inside diameter
LANL	Los Alamos National Laboratory
LH3	low-level tritium
μS/cm	microsiemens per centimeter
MDA	material disposal area
mV	millivolt
NAD	North American Datum
NMED	New Mexico Environment Department
NMSW	New Mexico special waste
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
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
Tb4	Cerros del Rio basalt
TD	total depth
TOC	total organic carbon
Tpf	Puye Formation
VOC	volatile organic compound
WCSF	waste characterization strategy form
WES-EDA	Waste and Environmental Services Division-Environmental Data and Analysis

1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for regional aquifer well R-54. 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-54 monitoring well borehole was drilled from November 21, 2009, to January 6, 2010, and completed from January 10 to January 29, 2010, at Los Alamos National Laboratory (LANL or the Laboratory) for the LANL Environmental Programs (EP) Directorate.

Well R-54 is located in Pajarito Canyon on Laboratory property within Technical Area 54 (TA-54) (Figure 1.0-1). The purpose of the R-54 well is to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the groundwater protection program for the Laboratory, the Consent Order, and the New Mexico Environment Department− (NMED-) approved drilling work plan. The location was selected to be close to the southwestern lateral extent of volatile organic compound (VOC) contamination present within the vadose zone beneath Material Disposal Area (MDA) L. The well will also monitor for potential contaminants originating from upgradient sources within the Pajarito Canyon watershed.

The primary objective of the drilling activities at R-54 was to install a dual-screen monitoring well in the uppermost part of the regional aquifer to monitor groundwater quality near MDA L. Secondary objectives were to establish water levels and flow characteristics in the regional aquifer in this area, to collect drill-cutting samples, and to conduct borehole geophysical logging.

The R-54 borehole was drilled to a total depth (TD) of 944.5 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 830.0 and 840.0 ft bgs, and the lower 10-ft-long screened interval is between 915.0 and 925.0 ft bgs. The composite depth to water after well installation and well development was recorded on February 9, 2010, at 815.0 ft bgs. A dedicated sampling system was 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 the upper and lower screened 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 conducting a geodetic survey. 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 appendixes completed to date associated with the R-54 project. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy (DOE) policy.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities included preparing administrative planning documents and preparing the drill site. 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-54 project:

- Drilling Work Plan for Regional Aquifer Well R-54 (LANL 2009, 107512);
- Drilling Plan for Regional Aquifer Well R-54 (TerranearPMC 2009, 108565);
- Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (LANL 2007, 100972);
- Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan (LANL 2006, 092600); and
- Waste characterization strategy form for R-54 (LANL 2009, 108526).

2.2 Site Preparation

Site preparation and access road construction were performed by Laboratory personnel before rig mobilization. The drill rig, air compressors, trailers, and support vehicles were mobilized to the drill site on November 20, 2009. Staging of alternative drilling tools and construction materials occurred at the Pajarito Road lay-down yard.

All potable water was obtained from a Pajarito Road fire hydrant at TA-18. 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 approach and provides a chronological summary of field activities conducted at monitoring well R-54.

3.1 Drilling Approach

The drilling methodology and selection of equipment and drill-casing sizes for the R-54 monitoring well were designed to retain the ability to investigate and case off any perched groundwater encountered 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-54 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 air compressor, and general drilling equipment. Auxiliary equipment included two Ingersoll Rand trailer-mounted air compressors. Two sizes of A53 grade B flush-welded mild carbon-steel casing (16-in. and 12-in. inside-diameter [I.D.]) were used for the R-54 project.

The dual-rotary technique at R-54 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 the foaming agent was terminated at 705.0 ft bgs, roughly 100 ft above the expected top of the regional aquifer. No additives other than potable water were used for drilling below 705.0 ft bgs. Total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-54 Well

Mobilization of drilling equipment and supplies to the R-54 drill site occurred on November 20, 2009. Decontamination of the equipment and tooling was performed before mobilization to the site. On November 21, following on-site equipment inspections, the monitoring well borehole was initiated at 1225 h using dual-rotary methods with 16-in. drill casing (16.75-in. O.D.) and a 15-in. (15.75-in. O.D.) tricone bit.

Drilling and advancing the 16-in. casing proceeded rapidly through the 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 to 352.3 ft bgs where the 16-in. drill casing was landed on November 23. No indications of groundwater were observed while advancing the 16-in. casing.

On December 1, after the Thanksgiving holiday break, open-hole drilling commenced using a 15-in. hammer bit. Drilling proceeded through stacked basaltic lavas, basalt cinders, interbedded lavas and cinders, and basaltic sediments of the Cerros del Rio basalt. Water flow of 15 gallons per minute (gpm) was noted on December 4 at 767.0 ft bgs and open-hole drilling proceeded to 827.0 ft bgs. On December 5, the 16-in. casing was retracted to 335.8 ft bgs in preparation for geophysical logging. Video, gamma, and induction logs were run on December 6 to document conditions in the open portion of the borehole. On December 7, the 16-in. casing was reset at 352.3 ft bgs. The 16-in. casing shoe was cut off at 348.0 ft bgs on December 9, and 12-in. drill casing was started into the borehole on December 10.

On December 15, the 12-in. casing was landed at 785.2 ft bgs. Approximately 42 ft of slough was encountered at the bottom of the open hole. The borehole was cleaned out with a tricone bit to the original depth of 827 ft bgs. On December 17, the 12-in. casing was advanced using an underreaming hammer bit to 845 ft bgs. The next day, water flow of 10−15 gpm was noted at 845.5 and 865.5 ft bgs. The 12-in. casing was advanced to 885 ft bgs on the same day.

From December 19, 2009, to January 3, 2010, field activities were suspended for the Christmas holiday. Field activities resumed on January 4 and consisted of equipment maintenance. On January 5, the 12-in. casing was advanced to 925 ft bgs. Water flow of 55−60 gpm was noted at 905 ft bgs. On January 6, the 12-in. casing was advanced to borehole TD at 944.5 ft bgs, and depth to water was measured at 815.0 ft bgs. On January 7, the gamma log (Laboratory equipment) was run from surface to TD (944.5 ft bgs). The 12-in. casing shoe was cut off at 939.8 ft bgs in preparation for well construction.

During drilling, field crews worked 24-h shifts from November 20 to November 22, 2009, and thereafter worked 12-h shifts, 7 d/wk. All associated activities proceeded normally without incident or delay.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-54. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-54 monitoring well borehole at 5-ft intervals from ground surface to the TD of 944.5 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 removal from the site. All screening measurements were within the range of background values. The core boxes and chip trays were delivered to the Laboratory's archive at the conclusion of drilling activities.

R-54 stratigraphy is summarized in section 5.1 and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

Two groundwater-screening samples were collected from the drilling discharge at 845.5 and 865.5 ft bgs. These water samples were analyzed for anions, cations, metals, perchlorate, VOCs, low-level tritium (LH3), and high-explosive (HE) compounds. These samples were collected after reaching 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 presents a summary of screening samples collected during the R-54 monitoring well installation project. Groundwater chemistry and field water-quality parameters are discussed in Appendix B.

Ten groundwater-screening samples were collected during well development from the development pump's discharge line. Development screening samples were analyzed only for total organic carbon (TOC). Additionally, 10 groundwater-screening samples were collected during aquifer testing from the pump's discharge line. These samples were also analyzed for TOC only.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for the full suite of constituents including radioactive elements; anions/cations; general inorganic chemicals; volatile and semivolatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sample frequency at R-54 will be evaluated and presented in the annual Interim Facility-Wide Groundwater Monitoring Plan.

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-54 is presented below. The Laboratory's geology task leader and project site geologists examined cuttings and geophysical logs to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, water-level measurements, and geophysical logs were used to characterize groundwater occurrences encountered at R-54.

5.1 Stratigraphy

Stratigraphic units for the R-54 borehole are presented below in order of youngest to oldest geologic occurrence. Lithologic descriptions are based on microscopic 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 illustrates the stratigraphy at R-54. A detailed lithologic log is presented in Appendix A.

Quaternary Alluvium, Qal (0–14 ft bgs)

Quaternary alluvium consisting of unconsolidated, poorly sorted sand and gravelly sand composed of tuffaceous and volcanic detritus was encountered from 0 ft to 14 ft bgs. No evidence of alluvial groundwater was observed.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (14–159 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff occurs from 14 ft to 159 ft bgs and is locally 145 ft thick. Unit 1g is a poorly welded ash-flow tuff (i.e., ignimbrite) that is pumiceous, lithic-poor, crystal-bearing to locally crystal-rich. Abundant ash matrix is locally preserved in cuttings. Characteristic of Unit 1g are white to pale-orange, lustrous, glassy pumice lapilli that are quartz- and sanidine-phyric. Cuttings commonly contain minor small (generally less than 10 mm in diameter) volcanic lithic inclusions (predominantly dacites) and abundant free quartz and sanidine crystals.

Cerro Toledo Interval, Qct (159–180 ft bgs)

The Cerro Toledo interval, a layer of poorly consolidated volcaniclastic sediments that occurs stratigraphically between the Tsciherge and Otowi Members of the Bandelier Tuff, is present from 159 ft to 180 ft bgs. Cerro Toledo deposits are estimated to be 21 ft thick. Locally, these sediments consist of poorly sorted pebble gravels with silty fine to coarse sands made up of tuffaceous and volcanic debris. Commonly subrounded detrital clasts (up to 20 mm in diameter) are composed of various dacites, flow-banded rhyolite, basalt scoria, black vitrophyre, quartz and sanidine crystals, and locally abundant pumice.

Otowi Member of the Bandelier Tuff, Qbo (180–335 ft bgs)

The Otowi Member of the Bandelier Tuff is present from 180 ft to 335 ft bgs and is estimated to be 155 ft thick. The Otowi Member is a poorly welded ash-flow tuff (i.e., ignimbrite) that is pumiceous, crystal-bearing, and locally lithic-rich. Abundant pumice lapilli are pale-orange to white, glassy, and quartz- and sanidine-phyric. Orange pumices, denoting weak oxidation and iron oxide staining, are most common near the top of the Otowi section. Locally abundant volcanic lithic fragments, or xenoliths (up to 12 mm in diameter), are commonly subangular to subrounded and of intermediate volcanic composition, including porphyritic dacites and andesite.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (335–350 ft bgs)

The Guaje Pumice Bed occurs from 335 ft to 350 ft bgs and has an estimated local thickness of 15 ft. Considered an air-fall tephra deposit, the unit contains abundant (up to100% by volume) rounded, lustrous, vitric, phenocryst-poor pumice lapilli and fragments with trace occurrences of small volcanic lithic fragments and quartz and sanidine crystals.

Cerros del Rio Basalt, Tb4 (350–860 ft bgs)

The Cerros del Rio basalt section, present in R-54 from 350 ft to 860 ft bgs, locally forms a complex sequence of basaltic lavas, tephras, and volcaniclastic sedimentary deposits with a cumulative thickness of approximately 510 ft. The upper part of the sequence, from 350 ft to 527 ft bgs, is composed of a 177-ft-thick stacked sequence of basaltic flows with a thin vesicular, rubbly, clay-rich top. The basaltic lavas are weakly porphyritic with phenocrysts (less than 1% by volume) of olivine, plagioclase, and minor clinopyroxene (more common in the lower part of the flow) enclosed in an aphanitic groundmass that becomes weakly altered with depth. The Cerros del Rio section, from 527 ft to 585 ft bgs, is interpreted to be made up of cinder deposits composed of poorly consolidated hematite-rich scoriaceous, locally glassy, basaltic tephra. Complexly interlayered thin basalt lavas and intercalated cinder deposits make up the volcanic section from 585 ft to 735 ft bgs. The basal part of the Cerros del Rio sequence, from 735 ft to 860 ft bgs, is composed of poorly to moderately consolidated pebble gravels and fine to coarse sands predominantly composed of rounded olivine-basalt detritus with locally minor granular occurrences that include various volcanic lithologies and quartzite.

Puye Formation, Tpf (860–944.5 ft bgs)

Puye Formation clay-rich and volcaniclastic sediments occur from 860 ft to the R-54 borehole TD at 944.5 ft bgs. This unit has a minimum thickness of 85 ft. A thin layer of light-tan claystone, noted from 860 ft to 872 ft bgs, suggests the occurrence of lacustrine sediments. The remaining Puye section, from 872 ft to 944.5 ft bgs, consists of poorly sorted to unsorted, moderately indurated, fine to coarse gravels with silty fine to coarse sand. Subrounded to well-rounded detrital constituents are predominantly composed of gray porphyritic dacites and less abundant black to reddish vitrophyre, white dacite with fine hornblende phenocrysts, rhyolite, and trace basalt.

5.2 Groundwater

No indications of groundwater were noted while advancing the 16-in. casing to 352.3 ft bgs. Open-hole drilling proceeded without any groundwater indications until 767.0 ft bgs, where estimated water production of 15 gpm was noted in the basaltic sediments of the lower Cerros del Rio basalt. Water production of 10−15 gpm was noted at 845.5 and 865.5 ft bgs, also within the basaltic sediments. Drilling proceeded to 905 ft bgs with estimated water production from 10−15 gpm. At 905 ft bgs, in the Puye Formation, water flow increased to 55−60 gpm. Drilling continued from 905 to 944.5 ft bgs (TD) with water flow rates from 40−80 gpm. The depth to water stabilized at approximately 815.0 ft bgs on January 6, 2010, before well installation.

6.0 BOREHOLE LOGGING

A video log, induction log, and two gamma-ray logs were collected during the R-54 drilling project using Laboratory-owned equipment. Table 6.0-1 presents a summary of video and geophysical logging.

6.1 Video Logging

A video log was made in the R-54 borehole on December 6, 2009, from ground surface to 827 ft bgs, with the 16-in. drill casing retracted to 335.8 ft bgs in order to expose the top of the Cerros del Rio basalt. The video recorded a water level at 783.0 ft bgs. The video log is presented on DVD as Appendix D, included with this document.

6.2 Geophysical Logging

A natural gamma-ray survey and induction log were run in the borehole on December 6, 2009, to document conditions in the open portion of the borehole between 335.8 and 827 ft bgs. Another natural gamma-ray survey was obtained on January 7, 2010, from 0−944.5 ft bgs inside the drill casing before well construction. Geophysical logging data are presented on CD as part of Appendix E, included with this document.

7.0 WELL INSTALLATION

The R-54 well was installed between January 10 and January 29, 2010.

7.1 Well Design

The R-54 well was designed in accordance with the NMED Consent Order. NMED approved the well design before installation. The well was designed with an upper screened interval between 830.0 and

840.0 ft bgs and a lower screened interval between 915.0 and 925.0 ft bgs. The R-54 well was designed with dual screens to monitor groundwater quality near the top of the regional aquifer within the lower Cerros del Rio basalt and deeper in the regional aquifer within the Puye Formation.

7.2 Well Construction

The R-54 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-O.D., type A304 passivated stainless steel, beveled casing fabricated to American Society for Testing and Materials A312 standards. Each screened section used one 10-ft length of 5.0-in.-I.D. rod-based 0.020-in. wire-wrapped well screen. Welding, using compatible stainless-steel welding rods, was used to join all individual casing and screen sections. All casings and screens were steam pressure-washed on-site before installation. A 2.2-in.- O.D. steel, flush-threaded tremie pipe, also decontaminated before use, was used to deliver annular fill materials downhole during well construction. Short lengths of 12-in. casing/shoe (4.7-ft-long) and 16-in. casing/ shoe (4.3-ft-long) remain in the borehole. The 12-in. and 16-in. casing stubs were both entombed in bentonite (Figure 7.2-1).

Decontamination of the stainless-steel well casing, screens, and tremie pipe, along with mobilization of the Pulstar workover rig and initial well construction materials to the site, took place on January 9, 2010. An 11-ft-long 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 January 10 at 0850 h, the 5-in. well casing was started into the borehole. Each casing and screen joint was welded as it was installed in the borehole; fireproof matting was used to keep welding slag from falling into the borehole. The well casing was hung by wireline with the bottom at 936.0 ft bgs.

The installation of annular materials began on January 12 after the bottom of the borehole was measured at 942.3 ft bgs (approximately 2.2 ft of slough in borehole). From January 12 to January 13, the lower bentonite seal was installed from 930.0 to 942.3 ft bgs using 8.2 ft^3 of 3/8-in. bentonite chips. Figure 7.2-1 is a schematic showing construction details for the completed well.

From January 13 to January 16, the lower filter pack was installed from 910.1 to 930.0 ft bgs using 28.0 ft^3 of 10/20 silica sand. The filter pack was then surged to promote compaction. The filter pack volume exceeded the calculated filter pack volume of 14.1 ft^3, which is likely attributable to a relatively soft formation that allowed the filter sand to push and extend into the formation as the surging activity achieved compaction and a density greater than that of the surrounding formation material. Installation of annular fill materials was temporarily suspended on January 15 to deploy an inflatable packer inside the well casing between the two screens. The inflatable packer was deployed before installing the middle bentonite seal in order to isolate the more productive lower screen zone from the relatively low producing upper screen zone. On January 16 the lower fine sand collar was installed above the lower filter pack from 907.7 to 910.1 ft bgs using 1.5 ft^3 of 20/40 silica sand.

From January 16 to January 18, the middle bentonite seal was installed from 845.2 to 907.7 ft bgs using 44.7 ft^3 of 3/8-in. bentonite chips. From January 18 to January 19, the upper filter pack was installed from 825.5 to 845.2 ft bgs using 21.0 ft^3 of 10/20 silica sand. Again, the actual filter pack volume exceeded the calculated volume of 114.7 ft^3, which is likely due to a relatively soft formation that allowed the filter sand to push and extend into the formation as the surging activity achieved compaction and a filter pack density greater than that of the surrounding formation material. Installation of annular fill materials was temporarily suspended on January 18 to retrieve the packer. On January 19, the inflatable packer was removed from the well casing. The filter pack was surged to promote compaction, and installation of annular materials continued. On January 19, the upper fine sand collar was installed above the upper filter pack from 823.7 to 825.5 ft bgs using 2.0 ft^3 of 20/40 silica sand.

From January 19 to January 25, the upper bentonite seal was installed from 300.5 to 823.7 ft bgs using 625.0 ft^3 of 3/8-in. bentonite chips. From January 25 to January 29, the surface seal was installed from 3.0 to 300.5 ft bgs using 532.4 ft^3 of Portland Type I/II/V cement. The volume of cement required for this zone exceeded the calculated volume of 407.5 ft^3, which represents cement losses to the dry upper formation. Installation of the cement surface seal on January 29, 2010, at 1705 h marked the end of well construction per NMED Consent Order guidelines. Table 7.2-1 itemizes volumes of all materials used during well construction, and Figure 7.2-1 shows the completed well schematic.

Operationally, well construction proceeded smoothly, 12 h/d, 7 d/wk, from January 10 through January 29, 2010.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation at R-54, the well was developed and aquifer tests were conducted. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system has been installed. Site restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees.

8.1 Well Development

Well development was conducted between January 31 and February 7, 2010, and additional development of the upper screen was conducted between February 23 and February 27, 2010. Initially, composite water from both screened intervals was bailed and swabbed to remove formation fines in the filter packs and well sump. Bailing continued until water clarity visibly improved. Final development of each screened interval was then performed with a submersible pump.

The swabbing tool employed was a 4.5-in.-O.D., 1-in.-thick nylon disc attached to a weighted steel rod. The wireline conveyed tool was drawn repeatedly in both directions across the 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 the well, and dumped into the cuttings pit. Approximately 1590 gal. of composite groundwater was removed during bailing activities. After bailing, a 10-horsepower (hp), 4-in. Grundfos submersible pump and an inflatable packer located above the pump were installed in the well for the final stage of well development of each screen.

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 for TOC analysis were collected. The required values for TOC and turbidity to determine adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTU), respectively.

Table B-1.2-1 in Appendix B presents a summary of volumes purged during each phase of development as well as measured and calculated water-quality parameters.

Lower Screened Interval

On February 4, the development pump was set below the bottom of the lower well screen at 930.3 ft bgs and 315 gal. of water was purged from the well. The pump was raised to 926.0 ft bgs, and the lower screen was purged from bottom to top in 2-ft increments from 926 to 913 ft bgs. After pumping throughout the lower screened interval, the pump was set 2 ft above the screen at 913 ft bgs and the packer was inflated to ensure discrete water-quality parameter samples. Purged water from the lower screened interval immediately displayed turbidity values less than 2 NTU. Approximately 3431 gal. of groundwater was purged during the lower screen development.

Upper Screened Interval

On February 5, the 10-hp pump was used to purge the upper screen from bottom to top in 2-ft increments from 841 to 829 ft bgs. The pump assembly was removed from the well and reconfigured to include a pump shroud and inflatable packer below the pump on February 6. Additional pumping was conducted on February 6 and 7. Initially, the pump was located 1.5 ft above the screened interval at 828.5 ft bgs with the (lower) packer inflated, but the pump was observed to continually break suction and cavitate, indicating a lack of available water. The pump was relocated 2.5 ft below the screen at 842.5 ft bgs with the packer inflated, and an additional 532 gal. was purged at approximately 1.8 gpm. Turbidity values ranged between 59.8 and 4.7 NTU during the discrete pumping activities at the upper screen. Turbidity values for the upper screened interval did not meet turbidity standards during this initial phase of well development. Approximately 3186 gal. of groundwater was purged during the initial phase of development at the upper well screen.

After aquifer testing, between February 23 and February 27, development of the upper screen continued in order to adequately meet well development objectives. Only discrete pumping with the pump set below the upper screen was conducted for the additional development. The development standard for turbidity of less than 5 NTU was achieved. An additional 14,921 gallons of groundwater was purged from the upper screen during the second phase of development.

Total Purge Volumes

Approximately 8207 gal. of groundwater was purged at R-54 during initial well development activities (1590 gal. from composite water from both screens; 3431 gal. from the lower screen; and 3186 gal. from the upper screen). Another 29,778 gal. was purged during aquifer testing (1042 gal. from the upper screen and 28,736 gal. from the lower screen) and an additional 14,921 gal. was purged during the second phase of development of the upper well screen after aquifer testing (for a total of 18,107 gal. removed during development of the upper screen). Total groundwater purged during postinstallation activities was 52,906 gal.

8.1.1 Well Development Field Parameters

Field parameters during well development were measured at well R-54 by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This condition may have resulted in a slight variation of field parameters during well development. 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.

During development of the lower screen, measurements of pH and temperature varied from 6.83 to 7.86 and from 19.04 to 21.57°C, respectively. Concentrations of DO generally decreased from 8.73 to 7.60 mg/L. Eh values decreased from 440.5 to 363.1 millivolts (mV). Specific conductance varied from 213 to 274 microsiemens per centimeter (µS/cm), and turbidity values decreased from 1.0 to 0.1 NTU.

During final development of the upper screen, measurements of pH and temperature varied from 6.86 to 8.00 and from 19.03 to 20.92°C, respectively. Concentrations of DO varied from 37.3 to 56.8% (DO in mg/L was not recorded). Eh values varied from 360.0 to 318.8 mV. Specific conductance varied from 151 to 80 µS/cm, and turbidity values varied from 5.4 to 4.7 NTU.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-54 between February 10 and 21, 2010. Several short-duration tests with short-duration recovery periods were performed on the first day of testing for each of the two screened intervals.

A 5-hp pump was used for the aquifer test on the upper screened interval. Initially, the pump's flow rate was set to approximately 2.0 gpm. The 24-h upper screen aquifer test was suspended after 8.25 h when the water from the discharge pipe appeared significantly aerated. The test was restarted at a lower flow rate of 0.7 gpm to minimize drawdown. The upper screen aquifer test was continued in short-duration periods for 4 h at the end of the 24-h period. Approximately 1042 gal. of groundwater was purged from the upper screened interval. A 24-h recovery period completed the testing of the upper screened interval.

A10-hp pump was used for the aquifer test on the lower screened interval. A 24-h test followed by a 24-h recovery period completed the testing of the lower screened interval. Approximately 28,736 gal. of groundwater was purged from the lower screened interval at a flow rate of approximately 18.5 gpm.

Turbidity, temperature, pH, DO, ORP, and specific conductance parameters were measured during the 24-h tests. In addition, water samples were collected for TOC analysis. TOC results are presented in Appendix B. The R-54 aquifer test results are presented in Appendix C.

Approximately 1042 gal. of groundwater was purged from the upper screen and 28,376 gal. from the lower screen during aquifer testing activities.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-54 was installed between May 14 and 17, 2010. The system is a Baski Inc. manufactured system that uses a single 2-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump capable of purging each screened interval discretely via pneumatically actuated access port valves. The system includes a viton-wrapped isolation packer between the screened intervals. The pump riser pipe consists of threaded and coupled nonannealed 1-in.-diameter stainless steel. Two 1-in.-diameter schedule 80 polyvinyl chloride (PVC) tubes for dedicated transducers were banded to the pump riser. The upper PVC transducer tube is equipped with a 6-in. section of 0.010-in. slot screen with a threaded end cap at the bottom of the tube. 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 screened interval. Two In-Situ, Inc. Level TROLL 500 transducers were installed in the PVC tubes to monitor water levels in each screened interval.

Sampling system components for R-54 are shown 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-54 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 16-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 four bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are shown in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on April 9, 2010 (Table 8.5-1). The survey data collected conform to Laboratory Information Architecture project standards IA-CB02, GIS Horizontal Spatial Reference System, and IA-D802, Geospatial Positioning Accuracy Standard for A/E/C and Facility Management. All coordinates are expressed relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83), and elevation is expressed in ft above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground-surface elevation near the concrete pad, the top of the brass pin in the concrete pad, the top of the well casing, and the top of the protective casing for the R-54 monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-54 project included drilling fluids, purged groundwater, drill cuttings, decontamination water, and contact waste. Table 8.6-1 presents a summary of the waste characterization samples collected during drilling, construction, and development of the R-54 well.

All waste streams produced during drilling and development activities were sampled in accordance with the waste characterization strategy form for R-54 (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 EP-Directorate Standard Operating Procedure (SOP) 010.0, Land Application of Groundwater. If it is determined the drilling fluids are nonhazardous but cannot meet the criteria for land application, they will be evaluated for treatment and disposal at one of the Laboratory's six wastewater treatment facilities. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

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

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

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-54 were performed as specified in the "Drilling Plan for Regional Aquifer Well R-54" (TerranearPMC 2009, 108565).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-54 monitoring well.

Pat Longmire wrote Appendix B, Groundwater Analytical Results.

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

LANL personnel ran downhole video equipment.

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

11.0 REFERENCES

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 2009. "Drilling Work Plan for Regional Aquifer Well R-54," Los Alamos National Laboratory document LA-UR-09-7265, Los Alamos, New Mexico. (LANL 2009, 107512)

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)

TerranearPMC, November 2009. "Drilling Plan for Regional Aquifer Well R-54," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2009, 108565)

11.2 Map Data Sources

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

Hypsography, 100 and 20 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.

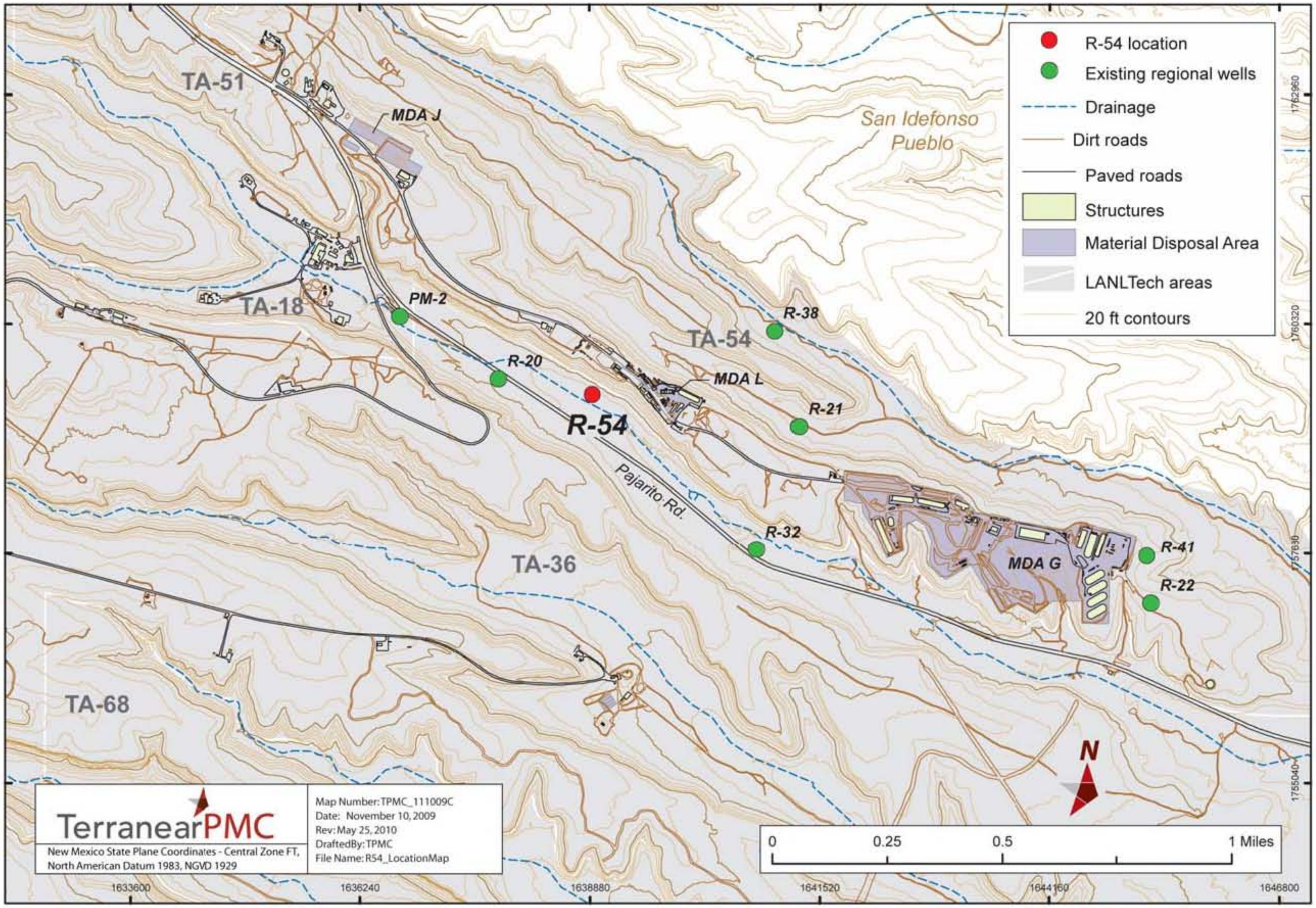

Figure 1.0-1 Location of monitoring well R-54

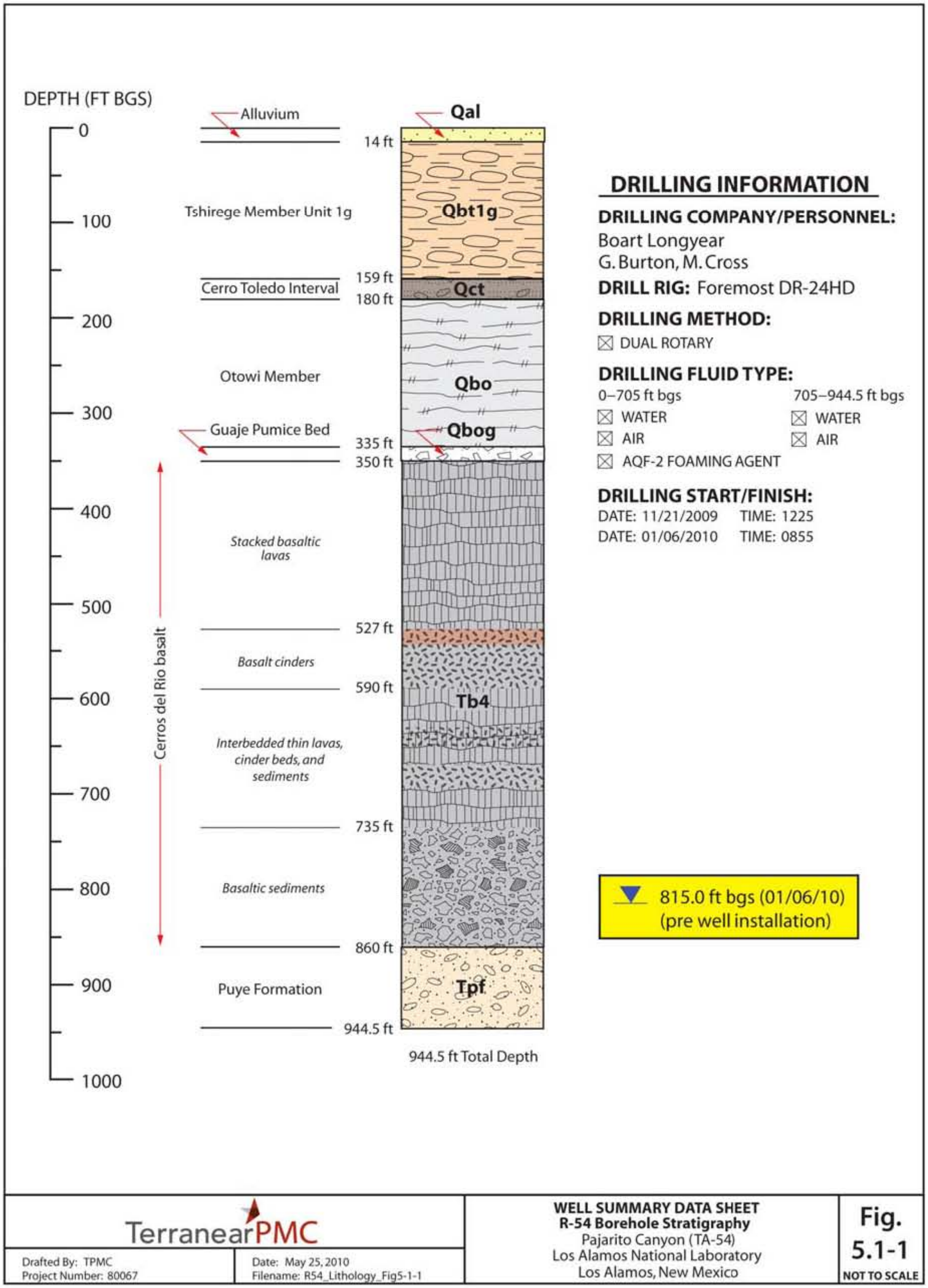

Figure 5.1-1 Monitoring well R-54 borehole stratigraphy

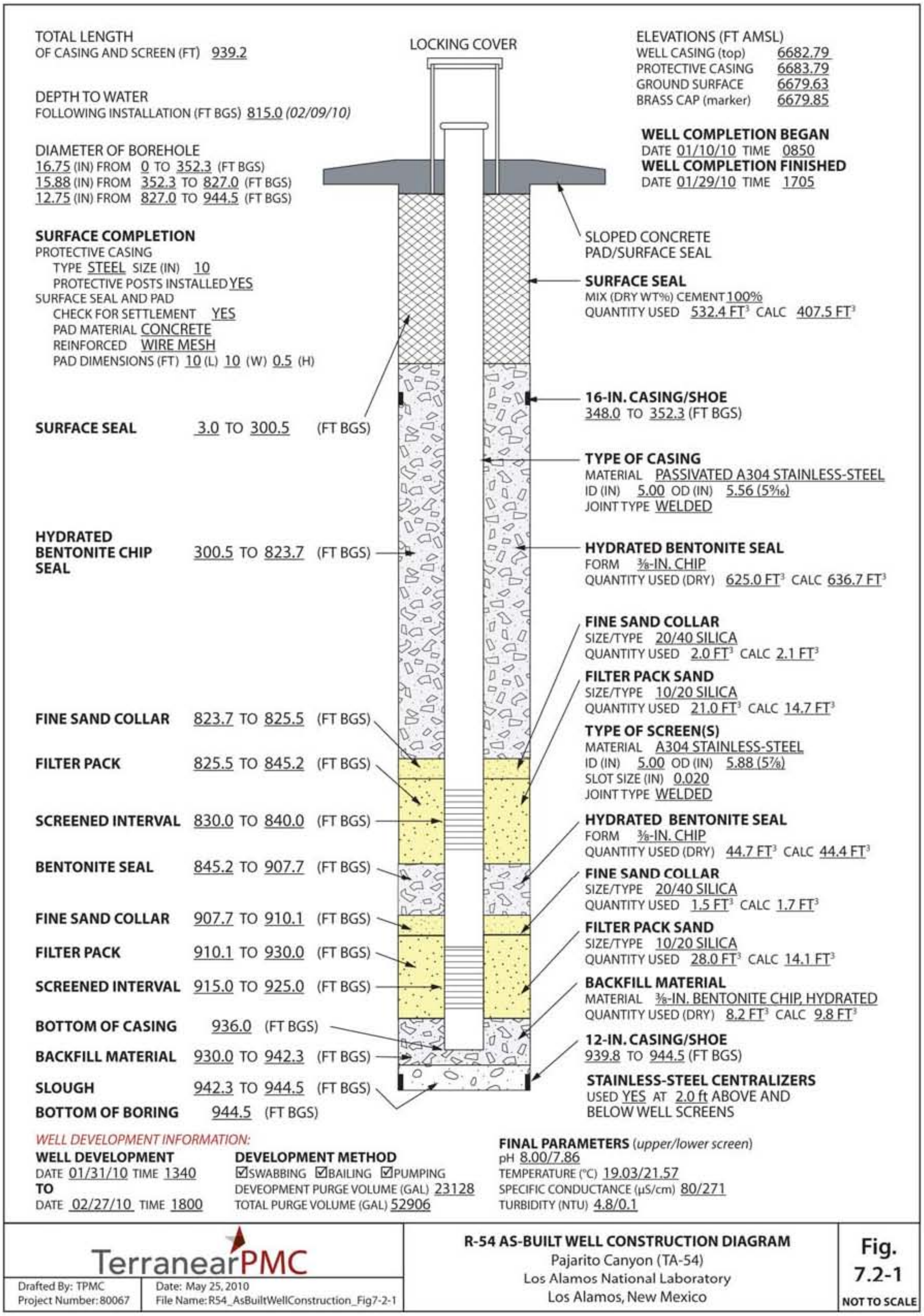

Figure 7.2-1 Monitoring well R-54 as-built well construction diagram

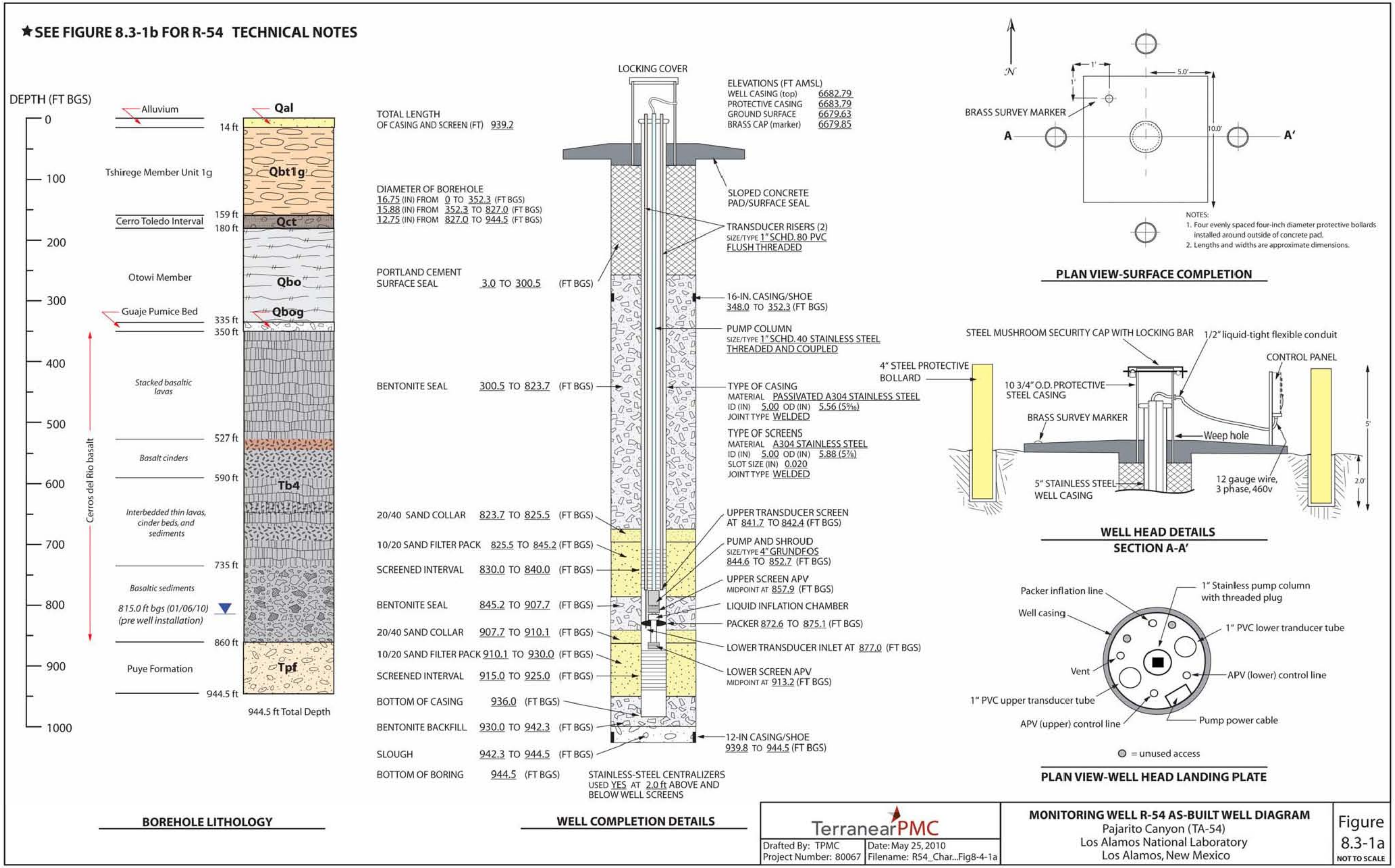

Figure 8.3-1a As-built schematic for regional water monitoring well R-54

R-54 TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker

Northing:	1759602.87 ft
Easting:	1638803.48 ft
Elevation:	6679.85 ft AMSL

Well Casing (top of stainless steel)

Northing:	1759597.73 ft
Easting:	1638804.44 ft
Elevation:	6682.79 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

LANL: Video, Natural Gamma Ray, Induction

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 705 ft bgs)

MILESTONE DATES

Drilling

Start:	11/21/2009
Finished:	01/06/2010

Well Completion

Start:	01/10/2010
Finished:	01/29/2010

Well Development

Start:	01/31/2010
Finished:	02/27/2010

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 23128 gallons

Parameter Measurments (Final, upper screen/lower screen)

pH:	8.00/7.86
Temperature:	19.03/21.57°C
Specific Conductance:	80/271 μS/cm
Turbidity:	4.8/0.1 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Upper Screen

Water Produced:	1042 gallons
Average Flow Rate:	0.7 gpm
Performed on:	02/10–15/2010

Lower Screen

Water Produced:	28736 gallons
Average Flow Rate:	18.5 gpm
Performed on:	02/17–21/2010

DEDICATED SAMPLING SYSTEM

Pump
Make: Grundfos
Model: 5S20-665CBM
3 U.S. gpm, APVs (Acccess Port Valves) midpoints at 857.9 (upper) and 913.2 (lower) ft bgs
Environmental retrofit

Motor
Make: Franklin Electric
Model: 2343259404
2 hp, 3-phase

Pump Column
1-in. threaded/coupled schd. 40, 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 841.7–842.4 ft bgs,
Lower flexible tube from transducer set at 877.0 ft bgs

Transducers
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/Ns: 227190, 227191

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: 80067

Date: May 25, 2010
Filename: R54_TechnicalNotes_Fig8-3-1b

R-54 TECHNICAL NOTES
Pajarito Canyon (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 monitoring well R-54

Table 3.1-1
Fluid Quantities Used during R-54 Drilling and Well Construction

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling				
11/21/09	900	900	5	5
11/21/09 N[a]	3000	3900	20	25
11/22/09	3000	6900	15	40
11/22/09 N	1000	7900	4	44
12/1/09	900	8800	20	64
12/2/09	2000	10,800	25	89
12/3/09	2600	13,400	35	124
12/4/09	1800	15,200	0	124
12/9/09	50	15,250	0	124
12/16/09	300	15,550	0	124
12/17/09	300	15,850	0	124
12/18/09	1400	17,250	0	124
1/5/10	800	18,050	0	124
1/6/10	400	18,450	0	124
Well Construction				
1/12/10	600	600	n/a[b]	n/a
1/13/10	1400	2000	n/a	n/a
1/14/10	1800	3800	n/a	n/a
1/16/10	1400	5200	n/a	n/a
1/17/10	3500	8700	n/a	n/a
1/18/10	1400	10,100	n/a	n/a
1/19/10	850	10,950	n/a	n/a
1/20/10	2800	13,750	n/a	n/a
1/21/10	650	14,400	n/a	n/a
1/22/10	1600	16,000	n/a	n/a
1/23/10	1200	17,200	n/a	n/a
1/24/10	700	17,900	n/a	n/a
1/25/10	850	18,750	n/a	n/a
1/26/10	1040	19,790	n/a	n/a
1/28/10	900	20,690	n/a	n/a
1/29/10	580	21,270	n/a	n/a
Total Water Volume (gal.)				
R-54	**39,720**			

[a] N = Night shift.

[b] n/a = Not applicable. Foam use terminated at 705.0 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-54

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-54	GW54-10-7740	12/18/2009	845.5	Groundwater, Airlifted	Anions, cations, perchlorate, metals, VOC, LH3, HE
R-54	GW54-10-7741	12/18/2009	865.5	Groundwater, Airlifted	Anions, cations, perchlorate, metals, VOC, LH3, HE
Well Development					
R-54	GW54-10-7749	2/5/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7750	2/5/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7751	2/6/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7752	2/7/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7753	2/7/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7764	2/23/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7765	2/24/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7766	2/25/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7767	2/26/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7768	2/27/2010	830.0−840.0	Groundwater, Pumped	TOC
Aquifer Testing					
R-54	GW54-10-7754	2/14/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7755	2/14/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7756	2/14/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7757	2/15/2010	830.0−840.0	Groundwater, Pumped	TOC
R-54	GW54-10-7758	2/20/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7759	2/20/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7760	2/20/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7761	2/20/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7762	2/21/2010	915.0−925.0	Groundwater, Pumped	TOC
R-54	GW54-10-7763	2/21/2010	915.0−925.0	Groundwater, Pumped	TOC

Table 6.0-1
R-54 Logging Runs

Date	Type	Depth (ft bgs)	Description
12/6/09	Video, gamma, induction	Surface to 827 (open hole from 335.78 to 827 ft bgs).	LANL personnel ran video, gamma, and induction log after the 16-in. casing was retracted to 335.78 ft bgs.
1/7/10	Gamma	Surface to 944.5	LANL personnel ran gamma log in the 12-in. casing after drilling and advancing casing to 944.5 ft bgs (TD).

Table 7.2-1
R-54 Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: cement slurry	532.4 ft^3
Upper bentonite seal: bentonite chips	625.0 ft^3
Fine sand collar: 20/40 silica sand	2.0 ft^3
Filter pack: 10/20 silica sand	21.0 ft^3
Middle bentonite seal: bentonite chips	44.7 ft^3
Fine sand collar: 20/40 silica sand	1.5 ft^3
Filter pack: 10/20 silica sand	28.0 ft^3
Backfill: bentonite chips	8.2 ft^3

Table 8.5-1
R-54 Survey Coordinates

Identification	Northing	Easting	Elevation
R-54 brass cap embedded in pad	1759602.87	1638803.48	6679.85
R-54 ground surface near pad	1759599.64	1638799.32	6679.63
R-54 top of 10-in. protective casing	1759596.85	1638804.05	6683.79
R-54 top of stainless-steel well casing	1759597.73	1638804.44	6682.79

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

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-54

Sample ID	Date Collected	Description	Sample Type
WST54-10-11297	1/19/10	Decon fluid, well casing	Liquid
WST54-10-11301	1/19/10	Decon fluid, well casing	Liquid
WST54-10-11293	1/19/10	Decon fluid, well casing (duplicate)	Liquid
WST54-10-11298	2/2/10	Decon fluid, pump equipment	Liquid
WST54-10-11302	2/2/10	Decon fluid, pump equipment	Liquid
WST54-10-11294	2/2/10	Decon fluid, pump equipment (duplicate)	Liquid
WST54-10-12098	2/5/10	Development water (unfiltered)	Liquid
WST54-10-12097	2/5/10	Development water (unfiltered)	Liquid
WST54-10-12099	2/5/10	Development water (duplicate)	Liquid
WST54-10-12094	3/17/10	Drilling fluids (unfiltered)	Liquid
WST54-10-12093	3/17/10	Drilling fluids (filtered)	Liquid
WST54-10-12095	3/17/10	Drilling fluid (unfiltered, duplicate)	Liquid
WST54-10-14433	5/11/10	NMSW*	Liquid
WST54-10-11300	5/17/10	Decon fluid, pump equipment	Liquid
WST54-10-11304	5/17/10	Decon fluid, pump equipment	Liquid
WST54-10-11295	5/17/10	Decon fluid, pump equipment (duplicate)	Liquid

*NMSW = New Mexico special waste.

Appendix A

Borehole R-54 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-54	**TECHNICAL AREA (TA):** 54	**PAGE:** 1 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225	**END DATE:**1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl		**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence	

Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
0–5	Construction fill—unconsolidated sand with pebble gravel composed of mixed native tuffaceous (alluvial) sediments and quartzite-pebble bearing gravels used as base course to construct the drill pad. WR/:+10F tuffaceous sand and quartz-pebble gravel detrital clasts/grains.	Fill	Note: Drill cuttings for microscopic and descriptive analysis were collected at 5-ft intervals from 0 ft to borehole TD at 944.5 ft bgs.
5–14	**ALLUVIUM:** Tuffaceous sediments— unconsolidated gravelly sand, poorly sorted, composed of tuffaceous and volcanic detritus. + 10F: subangular to angular clasts; 30% weathered pumices; 70% gray dacites.	Qal	Alluvial sediments, encountered from 5 ft to 14 ft, are approximately 9 ft thick.
14–30	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff—moderate orange pink (5YR 8/4), poorly welded, pumiceous, crystal-bearing, lithic-bearing. +10F: 75–85% pinkish orange pumices, strongly weathered but displaying fibrous relict texture indicating glassy pumice, quartz- and sanidine-phyric; 15–25% light gray subangular porphyritic dacite lithic fragments (up to 14 mm); trace quartz and sanidine crystals. +35F: 20–40% fragments of weathered pumice; 40-60% quartz and sanidine crystals; 3–5% volcanic lithics; 1–3% obsidian grains.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 14 ft to 159 ft bgs, is estimated to be 145 ft thick. Note: the upper part of Qbt 1g, from 14 ft to 30 ft bgs, displays moderate weathering and oxidation.

BOREHOLE IDENTIFICATION (ID): R-54	**TECHNICAL AREA (TA):** 54		**PAGE:** 2 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225		**END DATE:**1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD		**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl			**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence		

Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
30–55	Tuff—pale pinkish gray (5YR 8/1) to moderate orange pink (5YR 8/4), poorly welded, pumice-rich, crystal-bearing, lithic-poor. 30'–35' WR: 20–30% fine ash matrix. +10F: 99% white to pale orange glassy pumice fragments, vitreous luster, quartz- and sanidine-phyric, obsidian streaks and rinds surrounding select phenocrysts; less than 1% dacite lithics. 35'–55' WR: 10–20% fine ash matrix. +10F: 3–7% small (up to 7 mm) angular volcanic lithics; 93–97% pale pinkish gray to pale orange quartz- and sanidine-phyric, vitric pumice fragments; vitreous luster. +35F: 60–80% pumice fragments; 20–40% quartz and sanidine crystals; trace volcanic lithics.	Qbt 1g	
55–75	Tuff—pale pinkish gray (5YR 8/1) to moderate orange pink (5YR 8/4), poorly welded, pumice-rich, crystal-bearing, lithic-poor. +10F: 95–98% white to pale orange-brown vitric pumice fragments, vitreous luster, quartz- and sanidine-phyric; 2–5% small (up to 5 mm) volcanic lithic fragments. +35F: variable proportions, 20–70% pumice fragments; 20–70% quartz and sanidine crystals; 2–5% volcanic lithic fragments.	Qbt 1g	
75–100	Tuff—pale pinkish gray (5YR 8/1), poorly welded, pumice-rich, crystal-rich, lithic-poor. +10F: 95–99% white vitric, quartz- and sanidine-phyric pumice fragments, vitreous luster; 1–5%) volcanic lithic fragments (up to 11 mm). +35F: 30–40% pumice fragments; 40–50% quartz and sanidine crystals; 1–15% volcanic lithic fragments.	Qbt 1g	

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DRILLERS: G. Burton and M. Cross	SITE GEOLOGISTS: A. Miller and R. Lawrence		

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
100–125	Tuff—pale yellowish gray (5Y 8/1) to white (N9), poorly welded, pumice-rich, crystal-rich, lithic-poor. 100'–115' +10F: 99–100% white to locally orange-tan, quartz- and sanidine-phyric, glassy pumices (up to 13 mm), fibrous textured with vitreous luster, locally having frequent specks of black manganese oxide; less than 1% volcanic lithics. +35F: 60–70% pumice fragments; 30–40% quartz and sanidine crystals; trace volcanic lithic fragments. 115'–125' +10F: 99–100% coarse subrounded vitric pumice fragments and lapilli (up to 22 mm). +35F: 80–90% pumice fragments; 10–20% quartz and sanidine crystals; trace volcanic lithics.	Qbt 1g	Note: The interval 100'–125' contains unusually coarse pumice fragments and lapilli.
125–135	Tuff—yellowish gray (5Y 8/1), poorly welded, poorly indurated, pumiceous, crystal-rich, lithic-poor. 125'–130' +10F: 99–100% white vitric pumice fragments. +35F: 50% pumice fragments; 50% quartz and sanidine crystals. 130'–135' +10F: no description attempted (sample appears to be contaminated with abundant brown mud). +35F: 40–50% pumice fragments; 50–60% quartz and sanidine crystals; trace volcanic lithics.	Qbt 1g	
135–150	Tuff—pale yellowish gray (5Y 8/1), poorly welded, poorly indurated, pumiceous, crystal-rich, lithic-poor. +10F: 80–90% vitric pumice fragments; 10–20% small (up to 4 mm) volcanic lithic fragments. +35F: 30–40% pumice fragments; 30–40% quartz and sanidine crystals; 20–30% volcanic lithics.	Qbt 1g	Note: The interval 135'–150' is characterized by abrupt increase in proportion of volcanic lithics

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<tr><td>150–159</td><td colspan="2">Tuff—pale pinkish gray (5YR 8/1) to white, poorly welded, pumice-rich, crystal-rich, lithic-poor.

WR: abundant silty ash matrix. +10F:
90–95% white to pale orange-brown (i.e. oxidized) vitric pumice fragments, quartz- and sanidine-phyric, generally weathered appearing with relict fibrous textures; 5–10% volcanic lithics (predominantly light pinky rhyodacite) . +35F:
60–70% white pumice fragments;
10–15% quartz and sanidine crystals;
15–25% volcanic lithics.</td><td>Qbt 1g</td><td>The Qbt 1g–Qct contact, estimated to be at 159 ft bgs, is based on microscopic and descriptive analysis.</td></tr>
<tr><td>159–180</td><td colspan="2">CERRO TOLEDO INTERVAL:

Tuffaceous sediments— light olive gray (5Y 6/1) to pale yellowish gray (5Y 8/1) pebble gravels with fine to coarse sand and silt, poorly sorted, partly subrounded detrital clasts composed of diverse volcanic lithologies.

159–165' WR: silty matrix of fine ash mixed with tuffaceous and volcanic components. +10F:
50–60% subangular volcanic detritus (gray porphyritic dacite, flow-banded rhyolite, white hornblende-dacite); 40–-50% pumice fragments.
+35F: 50% pumice fragments; 50% quartz and sanidine crystals.

165'–180' WR: increased predominance of volcaniclastic detritus over tuffaceous components. +10F: detrital clasts (up to 13 mm) display distinct fluvial subrounding;
95–97% subrounded and broken clasts of gray porphyritic dacite, red-brown scoria (basalt), black porphyritic vitrophyre; 3–5% pumices.
+35F: 80–90% subangular volcanic grains;
10–20% pumices and quartz and sanidine crystals.</td><td>Qct</td><td>The Cerro Toledo Interval (Qct), encountered from 159 ft to 180 ft bgs, is estimated to be 21 ft thick.

The Qct–Qbo contact, estimated to be at 180 ft bgs, is based on microscopic and descriptive analysis and interpretation of natural gamma log data.</td></tr>
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DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence		

Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
180–190	**OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff— light olive gray (5Y 6/1), poorly welded, poorly indurated, pumiceous, crystal-bearing, lithic-rich. WR/+10F: 100% broken and subrounded clasts (up to 20 mm) composed of gray hornblende-dacite, light gray fine-grained dacite and rare pumice. +35F: 90–95% angular to subrounded grains of various volcanic lithologies; 5–10% tuffaceous grains (pumices and quartz and sanidine crystals).	Qbo	The Otowi Member of the Bandelier Tuff (Qbo), intersected from 180 ft to 335 ft bgs, is estimated to be 155 ft thick.
190–210	Tuff—pale pinkish gray (5YR 8/1) to pale yellowish orange (10YR 8/6), poorly welded, poorly indurated, strongly pumiceous, crystal-bearing, lithic-bearing. +10F: 80–90% white to pale orange (i.e. oxidized), glassy pumice fragments/lapilli, quartz- and sanidine-phyric, fibrous texture, vitreous luster; 10–20% angular to subrounded volcanic (predominantly light and dark gray porphyritic dacites) lithic fragments.	Qbo	Note: The interval 190'–195', near the apparent top of the Otowi section, marks a distinct color and lithologic change, appearance of predominantly tuffaceous components and distinctive orange (i.e. oxidized) glassy pumices.
210–235	Tuff—light yellowish gray (5Y 8/1) to pale yellowish orange (10YR 8/6), poorly welded, pumiceous, crystal-bearing, lithic-bearing to lithic-rich. 210'–215' +10F: 70–75% pale orange (i.e. oxidized), vitric, quartz- and sanidine-phyric pumice fragments/lapilli, vitreous luster; 25–30% subangular volcanic lithics (up to 12 mm) composed of light and dark gray dacites and minor brown andesite. +35F: 10–15% pumice fragments; 15–25% volcanic lithics; 60–70% quartz and sanidine crystals. 215'–235' +10F: 70–90% white to pale orange vitric pumice, quartz- and sanidine-phyric pumice fragments/lapilli (up to 18 mm), vitreous luster; 10–30% volcanic lithics. +35F: 20–30% pumice fragments; 20–30% volcanic lithics (dacites, trace obsidian); 20–40% quartz and sanidine crystals.	Qbo	Note: interval 210'–235' shows gradual decrease in appearance of orange-tinted oxidized pumices.

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<tr><td>235–255</td><td colspan="2">Tuff—pale pinkish gray (5Y 8/1), poorly welded, pumiceous, crystal-bearing, lithic-bearing.

+10F: 70–90% white vitric, quartz- and sanidine-phyric pumice fragments/lapilli, vitreous luster; 10–30% volcanic lithic fragments (up to 7 mm) composed of light and dark gray porphyritic dacites, fine-grained dacite, and minor dark gray andesite(?). +35F: 40–50% pumice fragments; 20–30% volcanic lithics; 10–30% broken quartz and sanidine crystals.</td><td>Qbo</td><td></td></tr>
<tr><td>255–280</td><td colspan="2">Tuff—pale pinkish gray (5Y 8/1), poorly welded, pumiceous, crystal-bearing, lithic-bearing.

255’–265’ +10F: 60–70% white to pale yellow, vitric, quartz- and sanidine-phyric pumice fragments/lapilli, vitreous luster;
30–40% volcanic lithics (up to 12 mm) including porphyritic dacites and dark gray andesite(?).

265’–280’ +10F: 80–90% white vitric pumice fragments, quartz- and sanidine-phyric, vitreous luster; 10–20% volcanic lithics (up to 8 mm) including dacite, rhyodacite(?) and andesite. +35F: 30–40% white pumices; 20–30% volcanic lithics; 20–30% quartz and sanidine crystals.</td><td>Qbo</td><td></td></tr>
<tr><td>280–310</td><td colspan="2">Tuff—pale yellowish gray (5Y 8/1), poorly welded, pumiceous, crystal-poor, lithic-bearing.

+10F: 80–90% white, vitric, quartz- and sanidine-phyric pumice fragments/lapilli, vitreous luster; 10–20% volcanic lithic fragments (up to 7 mm) composed of light gray porphyritic dacites and minor dark brown andesite(?). +35F:
40–60% white pumice fragments;
10–30% volcanic lithics; 10–32% quartz and sanidine crystals.</td><td>Qbo</td><td></td></tr>
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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
310–335	Tuff—pale yellowish gray (5Y 8/1), poorly welded, pumice-rich, crystal-poor, lithic-bearing. 310'–325' +10F: 98–99% white, vitric, quartz- and sanidine-phyric pumice fragments/lapilli (up to 15 mm), subrounded, vitreous luster; 1–2% volcanic lithics (up to 5 mm). +35F: variable proportions; 40–70% white pumices; 10–20% volcanic lithics; 5–15% quartz and sanidine crystals. 325'–335' +10F: 80–99% broken or subangular white, vitric pumice fragments; 10–20% volcanic lithics (predominantly dacite, up to 5 mm). +35F: 90–95% white vitric pumice fragments; 3–7% volcanic lithics; 3–5% quartz and sanidine crystals.	Qbo	The Qbo-Qbog contact, estimated to be at 335 ft bgs, is based on microscopic and descriptive analysis.
335–350	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff— White (N9), poorly welded to non-welded, pumice-rich, lithic-poor, crystal-poor. WR/+10F: 99–100% well rounded, white, vitric pumices (up to 8 mm), slightly porphyritic, quartz and sanidine-bearing, vitreous luster, overall pristine appearance; trace small (up to 3 mm) volcanic lithic fragments. 335'–345' +35F: 95–97% white pumices; 3–5% volcanic lithics. 345'–350' +35F: 10–15% volcanic lithics; 60–70% quartz and sanidine crystals.	Qbog	The Guaje Pumice Bed (Qbog), intersected from 335 ft to 350 ft bgs, is estimated to be 15 ft thick. Note: the interval 335'–350' reflects diminished presence of volcanic lithics and free quartz and sanidine crystals; distinct rounding of most pumice lapilli.

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Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
350–355	**CERROS DEL RIO BASALT:** Basalt lava with clay—Varicolored medium gray (N4) dark yellowish orange (10YR 6/6) and very pale orange (10YR 8/2). Mixed subangular basalt clasts, pumice lapilli and clay nodules. WR/+10F: 50% subangular vesicular basalt clasts (up to 22 mm); 30% subrounded, white pumice lapilli (up to 8 mm); 20% pale pink clay fragments adhered to and enclosing oxidized basalt grains/granules. +35F: 40% white pumice fragments; 15–30% mixed volcanic grains (dacite and basalt); 10% fragments of light pink clay.	Tb4	The Cerros del Rio basalt sequence (Tb4) section, including lavas, cinder deposits and basaltic sediments, was intersected from 350 ft to 860 ft bgs, and is estimated to be 510 ft thick.
355–370	Basalt lava—Medium dark gray (N4) massive to weakly vesicular, weakly porphyritic with aphanitic groundmass, olivine-phyric; clay-filling apparent fractures. WR/+10F:/+35F: 95-98% angular chips of very fine grained basalt, phenocrysts (less than 1% by volume) of anhedral green olivine (up to 1 mm) and trace plagioclase; 2-5% flakes of pale pinkish clay (clay presence diminishes with depth in the 355'–370' interval).	Tb4	
370–395	Basalt lava—Medium dark gray (N4) and very pale orange (10YR 8/2), vesicular to massive, weakly porphyritic with aphanitic groundmass, olivine-phyric. WR/+10F:/+35F: 99% angular/broken chips of vesicular and massive basalt; phenocrysts (up to 1% by volume) of anhedral, green olivine (up to 1 mm) and white plagioclase (up to 1 mm) frequently occurring in cumulophyric clusters; abundant pale pinkish tan clay filling vesicles; 1% flakes of light pinkish clay.	Tb4	Note: 370'–395' presence of vesicles and clay in this interval may suggest top of separate flow.

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Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
395–420	Basalt lava—Medium dark gray (N4), moderately to strongly vesicular, weakly porphyritic with aphanitic groundmass, olivine and plagioclase-phyric, minor clay lining vesicles. WR/+10F:/+35F: 100% angular/broken chips of vesicular basalt, phenocrysts (up to 1% by volume) of small (up to 2 mm) subhedral olivine and frequently intergrown white plagioclase (up to 1 mm); minor to moderate pale tan clay lining some vesicles.	Tb4	
420–450	Basalt lava—Medium dark gray (N4), strongly vesicular, weakly porphyritic with aphanitic groundmass, olivine and plagioclase-phyric, moderate clay lining vesicles. WR/+10F:/+35F: 100% angular/broken chips of vesicular basalt, phenocrysts (up to 1% by volume) of subhedral olivine (up to 2 mm and frequently iddingsitized) and subhedral white plagioclase (up to 2 mm) that occur in cumulophyric clusters; moderate pale tan clay lining or filling vesicles.	Tb4	
450–480	Basalt lava—Medium dark gray (N4), vesicular, weakly porphyritic with aphanitic groundmass, olivine and plagioclase-phyric, minor clay lining vesicles. WR/+10F:/+35F: 100% angular/broken chips of vesicular basalt, phenocrysts (less than 1% by volume) of subhedral olivine (up to 2 mm and replaced by iddingsite) and subhedral plagioclase (up to 1 mm), groundmass weakly altered; minor clay and/or earthy hematite lining vesicles.	Tb4	

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
480–510	Basalt lava—Medium dark gray (N4), vesicular, weakly porphyritic with aphanitic groundmass, olivine- and plagioclase-phyric, moderately abundant hematite coating vesicles. WR/+10F:/+35F: 100% angular/broken chips of vesicular basalt, phenocrysts (less than 1% by volume) of anhedral olivine (iddingsite replacement common), plagioclase and possible clinopyroxene (as rims on some olivines); moderate to locally strong hematite-goethite lining vesicles and fracture surfaces. Groundmass alteration becoming more advanced with depth.	Tb4	
510–527	Basalt lava—Medium dark gray (N4), weakly vesicular to massive, weakly porphyritic with aphanitic groundmass, olivine- and clinopyroxene-phyric, groundmass moderately altered/bleached; locally moderate hematite lining vesicles. WR/+10F:/+35F: 100% angular/broken chips of vesicular to massive basalt, phenocrysts (less than 1% by volume) of anhedral olivine (up to 2 mm) that are iddingsitized and partly to entirely replaced by black opaque clinopyroxene, anhedral clinopyroxene (up to 2 mm) and rare plagioclase. Groundmass moderately altered and bleached; locally moderate secondary hematite-goethite lining vesicles.	Tb4	

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
527–545	Basalt cinder deposit—moderate red (5R 5/4) and medium gray (N5), mixed vesicular basalt, basalt cinders and clay fragments. 527'–530' WR/+10F: angular and broken chip; 40% gray basalt with altered/bleached groundmass; 60% vesicular basalt with strong reddish hematite alteration. +35F: mixed gray and red (oxidized) basalt plus scoriaceous cinders and trace basaltic vitrophyre (possible hyrdomagmatic deposits); moderate chips of tan clay. 530'–545' +10F: 100% angular/broken chips of predominately vesicular reddish hue (i.e., hematite alteration); sparse olivine (altered) and clinopyroxene phenocrysts. +35F: abundant chips of hematite-altered basalt; minor scoriaceous cinders.	Tb4	Note: The interval 527'–545' is characterized by strong reddish hematite alteration and moderately abundant vesicular to scoriaceous basalt cinders.
545–560	Basaltic cinder deposits—pale reddish brown (10YR 5/4) and medium gray (N5), mixed chips of hematite-altered vesicular and gray massive basalt; relatively sparse basaltic lapilli and glassy scoria cinders. WR/+10F: angular/broken chips of gray altered clinopyroxene-phyric basalt and less abundant red hematite-altered vesicular basalt with locally moderate pale tan clay. +35F: Contains both gray and reddish basalt chips; 5–10% scoriaceous cinders and glassy basalt scoria with adhered white clay, palagonitic alteration.	Tb4	Note: The interval 545'–560' contains glassy basalt scoria with palagonite alteration, though in minor proportions, suggesting hydro-magmatic cinder deposits.

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Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
560–585	Basaltic cinder deposits—pale reddish brown (10YR 5/4) and medium gray (N5), mixed chips of gray and red-brown basalt and relatively minor basalt cinders. WR/+10F: angular/broken chips of gray basalt with altered groundmass and less abundant reddish hematitic vesicular basalt; minor occurrences of basalt scoria. +35F: predominantly (up to 90%) chips of gray basalt; 10–20% hematitic basalt scoria; trace glassy cinders.	Tb4	
585–595	Basalt lava—Medium light gray (N6), massive to weakly vesicular, weakly porphyritic with aphanitic groundmass, olivine-phyric; groundmass moderately altered/bleached. WR/+10F:/+35F: Angular/broken chips predominantly of medium gray, fine-grained basalt, with phenocrysts (less than 1% by volume) of anhedral green (locally iddingsitized) olivine; groundmass moderately altered; 3–7% red-brown hematitic scoriaceous basalt cinders.	Tb4	Note: The interval 585'–595' is interpreted to be thin basalt lava based on relative paucity of cinders in cuttings. Gamma log indicates transition out of cinders at ~590 ft.
595–610	Basaltic cinder deposits—pale reddish brown (10YR 5/4) and medium gray (N5), mixed chips of gray and red-brown basalt and basalt cinders. +10F: subangular chips 50–60% reddish brown and gray scoriaceous cinders; 40–50% chips light gray olivine-phyric basalt with moderately altered groundmass. +35F: 60–70% chips of gray massive basalt; 30–40% red-orange scoriaceous cinders and black glassy cinders	Tb4	

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Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
610–630	Basaltic cinder deposits—moderate red (5R 4/6), dominantly scoriaceous lapilli and small basaltic cinders with less abundant chips of gray altered basalt. WR/+10F: 80–90% subangular to subrounded scoriaceous lapilli (up to 23 mm), locally glassy, moderate to strongly hematite-stained (oxidized); 10–-20% subangular chips of olivine-phyric basalt with moderately altered groundmass. +35F: 85–95% reddish to gray scoriaceous cinders, locally glassy; 5–15% chips of olivine-basalt.	Tb4	
630–650	Basalt lava and cinders—Light gray (N7) and moderate red (5R 5/4), mixed chips of altered gray, clinopyroxene-phyric basalt and less abundant ferruginous cinders. +10F: 60–70% angular/broken chips of plagioclase and clinopyroxene-phyric basalt with altered, fine-grained groundmass; 30–40% reddish to black scoriaceous lapilli (up to 10 mm), partly glassy. +35F: lava chips and cinders in similar proportions to the +10F.	Tb4	Note: The interval 630’–650’ is interpreted as thin basalt flows with interlayered stratified cinder deposits.
650–670	Basalt lava—Light gray (N7) and moderate red (5R 5/4), predominantly altered clinopyroxene-phyric basalt chips and less abundant scoriaceous basalt cinders. 650’–655’ +10F: 80–90% gray and ferruginous scoriaceous basalt lapilli; 10–20% gray altered basalt chips. +35F: 10–15% cinders; 85–90% chips of gray basalt. 655’–670’ +10F: 90–95% angular to subrounded (possibly milled during drilling) chips of weakly porphyritic, clinopyroxene-phyric basalt displaying moderately altered groundmass; 5–10% red ferruginous and black glassy scoriaceous lapilli. +35F: 90–95% basalt lava chips; 5–10% cinders.	Tb4	

BOREHOLE IDENTIFICATION (ID): R-54	**TECHNICAL AREA (TA):** 54	**PAGE:** 14 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225	**END DATE:**1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl		**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
670–695	Basaltic cinder deposits—Light gray (N7) and moderate red (5R 5/4), mixed basalt cinders and chips of altered basalt lava. 670’–680’ +10F: 80–99% subangular to subrounded scoriaceous lapilli (up to 15 mm); 1–20% light gray subangular chips of altered basalt lava. +35F: 50–60% basalt lava chips; 40–50% reddish and black glassy cinders. 680’–695’ +10F: 50–70% subangular chips of very weakly porphyritic plagioclase- and clinopyroxene-phyric basalt with moderately altered groundmass; 30–50% black glassy and reddish (hematitic) scoriaceous lapilli (up to 12 mm). +35F: 70% basalt lava chips; 30% scoriaceous cinders.	Tb4	Note: Samples in the interval 680’–695’ have less abundant scoria in +10F but retain at least 30% cinders in the +35F.
695–705	Basalt lava—Light gray (N7), massive, very weakly porphyritic, clinopyroxene-phyric, groundmass moderately altered/bleached. +10F: 99% altered basalt chips, phenocrysts (less than 1% by volume) of plagioclase and olivine (commonly intergrown), groundmass distinctly altered/ bleached. +35F: 95–97% altered basalt chips; 3–5% basalt scoria.	Tb4	
705–715	Basalt lava—Pale pinkish gray (5YR 7/2), dominantly chips of clinopyroxene-phyric basalt with altered groundmass. WR: Abundant (up to 20% by volume) light pinkish clay matrix. +10F/+35F: 95–98% chips of altered clinopyroxene-phyric basalt; 3–5% scoriaceous cinders.	Tb4	

BOREHOLE IDENTIFICATION (ID): R-54	TECHNICAL AREA (TA): 54		PAGE: 15 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225		**END DATE:** 1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD		**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl			**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence		

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
715–735	Basalt lava—Light gray (N7), massive, weakly porphyritic clinopyroxene-altered basalt with moderately altered/bleached groundmass. 715'–725' +10F: 95% frequently subrounded (i.e. milled by drilling) chips of basalt, phenocrysts (less than 1% by volume) of black clinopyroxene with altered/bleached groundmass; 5% basalt scoriaceous cinders. 725'–735' +10F: 50–70% altered basalt lava chips; 30–50% rounded scoriaceous lapilli suggestive of secondary fluvial reworking. +35F: 97–98% basalt lava chips; 2–3% basaltic cinders; trace abundance of tan clay fragments.	Tb4	Note: 725'–735' interval has presence of rounded scoria pebbles suggestive of possible thin interlayer of reworked tephra.
735–770	Basaltic sediments—Light gray (N7), pebble gravels with medium to coarse sand, rounded clasts of olivine-phyric basalt indicating fluvial transport and deposition. 735'–750' +10F: broken and subrounded to well rounded clasts of altered olivine-bearing basalt; select well rounded detritus (up to 10 mm) strongly suggest deposits of sedimentary origin. +35F: 99–100% broken to subrounded basalt grains; up to 1% cinders. 750'–770' as above with increasing frequency of subrounded to well-rounded basalt pebbles, granules and grains.	Tb4	

BOREHOLE IDENTIFICATION (ID): R-54	**TECHNICAL AREA (TA):** 54	**PAGE:** 16 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225	**END DATE:**1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl		**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
770–800	Basaltic sediments—Medium gray (N5), pebble gravels with fine to coarse sand and silt, moderately consolidated, poorly sorted. Commonly well rounded detritus of predominately olivine-phyric altered basalt and minor volcanic rocks of intermediate to felsic composition +10F: 95–99% subrounded to well rounded, small pebbles (up to 13 mm) composed of altered basalt; 1–5% fragments of cemented silt (i.e. matrix) to coarse-grained sandstone; trace detrital clasts of rhyolite, andesite, dacite and quartzite. +35F: 85–90% angular chips and rounded grains of basalt; 10–15% clasts/grains of rhyolite, andesite, dacite, basaltic cinders, quartz, microcline plus fragments of clay and fine-grained sandstone.	Tb4	
800–830	Basaltic sediments—Medium gray (N5), pebble gravels with fine to coarse sand and silt, poorly sorted, moderately cemented. Characteristically rounded detritus composed predominantly of basalt with minor abundances of various volcanic rocks and trace quartzite. +10F: 85–80% subrounded to well rounded basalt pebbles (up to 13 mm) and granules, 15–20% subrounded clasts of various volcanic lithologies (dacite, rhyolite and andesite) and trace quartzite with fragments of fine-grained volcaniclastic sandstone. +35F: 80–90% rounded basalt grains; 10–20% grains of diverse lithologies as described for +10F.	Tb4	

BOREHOLE IDENTIFICATION (ID): R-54	**TECHNICAL AREA (TA):** 54	**PAGE:** 17 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225	**END DATE:**1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl		**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence	

Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
830–860	Basaltic sediments—Medium gray (N5), pebble gravel grading to medium-coarse gravels with fine to coarse sand, poorly sorted, moderately indurated. Typically rounded clasts predominantly of basalt with less abundant detritus representing other volcanic lithologies and minor quartzite. +10F: 70–60% broken and subrounded to well rounded basalt clasts (up to 20 mm); 30–40% broken and subrounded clasts of diverse volcanic lithologies (dacite, and andesite), plus minor quartzite and fragments of clay and indurated silty fine-grained sandstone. +35F: 50–60% basalt grains; 40–50% grains of diverse lithologies as described for +10F.	Tb4	Note: Presence of pink clay fragments at 845'–850'. The Tb4-Tpf contact, estimated to be at 860 ft bgs, is based on microscopic and descriptive analysis.
860–872	**PUYE FORMATION:** Clay-rich sediments (claystone)—Very pale orange (10YR 8/2), predominantly claystone with minor clasts composed of basalt and minor dacite. WR/+10F: 95–98% fragments of pale tan clay; 2–5% subangular to subrounded clasts (up to 25 mm) of basalt and minor dacite. +35F: 80–98% claystone fragments; 2–20% angular to subrounded grains of basalt and minor dacite.	Tpf	Puye volcaniclastic sediments (Tpf), intersected from 860 ft to the bottom of the borehole at 944.5 ft bgs, are estimated to be 85.5 ft thick. Note: The interval 860'–870' contains a predominance of pale pinkish tan clay and a relative lack of coarser detritus, suggesting possible lacustrine sediments.
872–875	Claystone/ Volcaniclastic sediments—Very pale orange (10YR 8/2), mixed fragments of pale tan claystone and detritus composed of basalt and dacite. WR: Abundant clay fragments and clay-coated volcanic clasts. +10F: Subangular pebble clasts of dacite and less abundant basalt, minor fragments of indurated sandstone. +35F: 30–40% claystone fragments; 60–70% volcanic grains (dacite and basalt).	Tpf	Note: The interval 870'–875' is a transition zone between claystone deposit and dacite-rich gravels at the top of Tpf. The claystone interval is tentatively assigned as part as of the Puye Formation.

BOREHOLE IDENTIFICATION (ID): R-54	TECHNICAL AREA (TA): 54		PAGE: 18 of 18
DRILLING COMPANY: Boart Longyear Company	**START DATE:** 11/21/2009 **TIME:** 1225		**END DATE:** 1/06/2010 **TIME:** 0855
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR24 HD		**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6679.63 ft amsl			**TOTAL DEPTH:** 944.5 ft
DRILLERS: G. Burton and M. Cross	**SITE GEOLOGISTS:** A. Miller and R. Lawrence		

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
875–885	Volcaniclastic sediments—Varicolored, very pale orange (10YR 8/2) to light gray (N7), fine to medium gravels with fine to coarse sand and silt, unsorted, moderately indurated, basaltic and dacitic detritus. WR/+10F: 90–95% broken and subrounded volcanic clasts (up to 18 mm) predominantly light gray porphyritic hornblende-bearing dacite and less abundant basalt; 5–10% fragments of indurated fine-grained volcanic sandstone. +35F: 70–90% grains of dacite and basalt in varying proportions; 10–30% fragments of claystone and fine-grained sandstone.	Tpf	
885–915	Volcaniclastic sediments—Varicolored light gray (N8) to light brownish gray (5YR 6/1), medium to coarse gravels with fine to coarse sand, unsorted, moderately indurated, predominantly dacitic detritus. +10F/+35F: 98% subrounded to well rounded granules and pebbles (up to 20 mm) predominantly of light gray porphyritic dacite, less abundant reddish to black porphyritic vitrophyre, distinctive white dacite with fine euhedral hornblende, white fine-grained rhyolite; 1–2% fragments of fine-grained volcaniclastic sandstone.	Tpf	
915–944.5	Volcaniclastic sediments—Light brownish gray (5YR 6/1), medium to coarse gravels with fine to coarse sand, very poorly sorted, moderately indurated, predominantly dacitic detritus. 915'-935' +10F/+35F: 99% broken and subangular clasts (up to 20 mm) mostly of light gray and pinkish hornblende-dacites, also less abundant white hornblende-dacite and black to reddish vitrophyre; 1% fragments of indurated fine-grained sandstone. 935'-945' +10F/+35F: medium to fine gravels of similar composition and proportions to those of the 915'–935' interval; coarser clasts up to 10 mm in diameter.	Tpf	Drilling in borehole R-54 was terminated at a total depth of 944.5 ft bgs.

ABBREVIATIONS

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

Qal = Quaternary Alluvium.
Qbo = Otowi Member of Bandelier Tuff.
Qbog = Guaje Pumice Bed.
Qbt = Tshirege Member of the Bandelier Tuff.
Qct = Cerro Toledo Interval.
Tb4 = Cerros del Rio basalt.
Tpf = Puye Formation.

+10F = plus No. 10 sieve sample fraction.

+35F = plus No. 35 sieve sample fraction.

WR = whole rock (unsieved sample).

1mm = 0.039 in.

1 in = 25.4 mm.

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-54

Two groundwater-screening samples were collected at borehole R-54 during drilling within regional saturation: (1) in the Cerros del Rio basaltic sediments at 845.5 ft below ground surface (bgs) and (2) within the Puye Formation at 865.5 ft bgs. Aliquots of the two borehole samples were submitted to external analytical laboratories for analyses of volatile organic compounds (VOCs), high-explosive (HE) compounds, and low-level tritium. The samples were also analyzed at Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14) for cations, anions, and metals.

Additionally, groundwater samples were collected during well development and aquifer testing of the upper screen (830 to 840 ft bgs) and the lower screen (915 to 925 ft bgs) and submitted to EES-14 for total organic carbon (TOC) analyses.

B-1.1 EES-14 Analytical Techniques

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

Groundwater samples were analyzed at EES-14 using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (EPA Method 300, rev. 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limit for perchlorate was 0.002 and 0.005 ppm in the borehole water samples (EPA Method 314.0, rev. 1). Inductively coupled (argon) plasma optical emission spectroscopy (EPA Method 200.7, rev. 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved antimony, arsenic, beryllium, cadmium, cesium, chromium, cobalt, copper, iron, 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, rev. 5.4). The precision limits (analytical error) for major ions and trace elements were generally less than ±7%.

Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques. No groundwater samples were collected for TOC analyses at borehole R-54 before development because of sample matrix and potential presence of drilling fluids. Analyses of TOC were performed on groundwater-screening samples collected during development and aquifer testing following EPA Method 415.1. Charge-balance errors for total cations and anions were -8% and -2% for complete analyses of the above inorganic chemicals in the two borehole water samples, indicating excess anions for the filtered samples.

B-1.2 Field Parameters

Field parameters were measured during well development and aquifer testing at both screens, as described below. Data are summarized in Table B-1.2-1.

Water samples were drawn from the pump discharge line into sealed containers, and field parameters were measured using a YSI multimeter. Results of field parameters, consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during well development at R-54, are presented in Table B-1.2-1. DO was measured in either concentration [milligrams per liter (mg/L)] or percent saturation at well R-54.

B-1.2.1 Initial Development of Upper Screen

During initial development of the upper screen, pH and temperature varied from 7.07 to 7.99 and from 18.22°C to 22.13°C, respectively (Table B-1.2-1). DO ranged from a high of 10.13 mg/L at the beginning of development to a low of 4.12 mg/L at the end.

Corrected Eh values determined from field ORP measurements varied from 467.3 millivolts (mV) near the beginning to 163.5 mV at the end of initial development (Table B-1.2-1). Temperature-dependent correction factors for calculating Eh values from field ORP measurements were based on an Ag/AgCl, KCl-saturated filling solution contained in the ORP electrode. The correction factors are 203.9 and 198.5 mV at 20.0 and 25.0ºC, respectively. Corrected Eh values associated with well R-54 are considered to be reliable and representative of the known relatively oxidizing conditions characteristic of the regional aquifer beneath the Pajarito Plateau; measurable DO concentrations recorded at well R-54 also confirm the upper water-bearing zone is oxidizing.

Specific conductance varied from 83 to 4097 microsiemens per centimeter (µS/cm), and turbidity ranged from 59.8 to 4.7 nephelometric turbidity units (NTU). All turbidity values except one exceeded 5 NTU during development of the upper screen, and the final value was 35.2 NTU.

B-1.2.2 Final Development of Upper Screen

After aquifer testing of the upper screen, development of this zone continued. During the final phase of development, pH ranged from 6.86 to 8.0 and temperature varied from 19.03°C to 20.92°C (Table B-1.2-1). Saturation of DO ranged from 37.3 to 56.8 percent. Concentrations of DO are calculated to range from 2.73 to 4.14 mg/L at 20°C at 6000 ft based on measured percent saturation. The maximum solubility of DO at 100 percent saturation is 7.29 mg/L at 20°C at 6000 ft. Corrected Eh values determined from field ORP measurements decreased from 360.0 to 318.8 mV during continued development of the upper screen (Table B-1.2-1). Specific conductance decreased from 151 to 80 µS/cm, and turbidity varied from 4.7 to 5.4 NTU. The final turbidity value recorded at the end of the final phase of development of the upper screen was 4.8 NTU.

B-1.2.3 Development of Lower Screen

During development of the lower screen at well R-54, pH and temperature ranged from 6.83 to 7.86 and from 19.04°C to 21.57°C, respectively (Table B-1.2-1). Concentrations of DO decreased from 8.73 to 7.60 mg/L during development of the lower screen. Corrected Eh values determined from field ORP measurements decreased from 440.5 to 363.1 mV. Specific conductance varied from 213 to 274 µS/cm, and turbidity decreased from 1.0 to 0.1 NTU (Table B-1.2-1).

B-1.3 Analytical Results for Groundwater-Screening Samples

Analytical results from the offsite laboratories (Table B-1.3-1) and from LANL EES-14 (Tables B-1.3-2 and B-1.3-3) are summarized below.

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

The VOCs 1-butanol, 2-butanol, and 2-hexanone were detected at concentrations of 111, 53, and 1.3 µg/L, respectively, in sample GW54-10-7740. VOCs were not detected in sample GW54-10-7741.

No high explosive compounds were detected in samples GW54-10-7740 and GW54-10-7741. Tritium activity was reported at 1.16 tritium units [3.74 picocuries/liter (pCi/L)] in the borehole sample GW54-10-7740 from approximately 845 ft bgs (Table B-1.3-1), but was not detected in sample GW54-10-7741 from approximately 865 ft bgs.

B-1.3.2 Cations, Anions, Perchlorate, and Metals

EES-14 analytical results for the two borehole screening samples collected at well R-54 during drilling are provided in Table B-1.3-2. The two borehole water samples GW54-10-7740 and GW54-10-7741 consisted of disaggregated colloidal aquifer material, potable water used during drilling, and native groundwater.

Analytical results for the upper borehole water samples show elevated concentrations of dissolved molybdenum (0.329 and 0.013 ppm [329 and 13 µg/L] from GW54-10-7740 and GW54-10-7741, respectively) that are most likely from the drill casing lubricant used during drilling. The maximum background value for molybdenum in the regional aquifer is 0.0043 ppm (4.3 µg/L) (LANL 2007, 095817). Sodium concentrations of 28.51 and 13.03 ppm (GW54-10-7740 and GW54-10-7741, respectively) are most likely the result of dissolution of residual AQF-2 drilling foam, a sodium-based surfactant that was used uphole. Additionally, oxalate, which is also an indicator of the presence of residual drilling foam, was present in the upper borehole screening sample at 0.05 ppm but was not detected in the lower borehole sample. Perchlorate was not detected in either borehole water sample.

B-1.3.3 Total Organic Carbon

TOC concentrations are presented in Table B-1.3-3 by screened interval and in chronological order of collection.

Upper screen

Concentrations of TOC measured in samples collected from the upper screened interval during aquifer testing, development, and final development ranged between 1.5 and 0.5 mgC/L and met the goal of being below 2.0 mg/L at the end of development (Table B-1.3-3).

Lower screen

TOC concentrations from the lower screen ranged from an initial high 12 mg/L to undetected in the final four samples (Table B-1.3-3). With the exception of the initial value, all TOC concentrations were less than 1.0 mg/L and, therefore, met the target goal of being below 2.0 mg/L at the end of development (Table B-1.3-3).

B-1.4 Summary

In summary, groundwater at well R-54 is relatively oxidizing, based on corrected positive Eh values and measured and calculated concentrations of DO. Tritium was detected at a concentration of 3.74 pCi/L in the upper borehole water sample (~845 ft bgs), which suggests that a modern component of groundwater postdating 1943 may be present at that depth. Three VOCs (1-butanol, 2-butanol, and 2- hexanone) and oxalate were detected only in the uppermost borehole water sample GW54-10-7740 (~845 ft bgs), which may be due to residual drilling fluid that was used uphole during drilling.

B-2.0 REFERENCE

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

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

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

Table B-1.2-1
Well-Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-54

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well-Development Composite Water from Both Screens								
1/31/10	n/r[b]; swabbing/bailing						300	300
2/1/10	n/r, swabbing/bailing						740	1040
2/2/10	n/r, swabbing/bailing						550	1590
Well-Development Lower Screen								
2/4/10	n/r, pumping sump						315	1905
2/4/10	n/r, pumping through screen						1925	3830
2/5/10	6.83	19.04	8.73	236.6, 440.5	213	1.0	832	4662
	7.78	21.12	7.82	166.6, 370.5	274	0.3	137	4799
	7.86	21.57	7.60	159.2, 363.1	271	0.1	138	4937
2/5/10	n/r, packer deflated, screens 1 and 2 not isolated						84	5021
Well-Development Upper Screen								
2/5/10	n/r, pumping through screen						2079	7100
2/6/10	7.73	18.34	10.13	217.8, 421.7	3925	6.2	107	7207
	7.98	18.22	9.84	214.9, 418.8	4048	6.0	22	7229
	7.99	18.42	8.31	212.5, 416.4	4097	6.7	26	7255
	7.98	19.00	7.76	220.8, 424.7	4095	4.7	59	7314
	n/r, pumped before shutting off pump						28	7342
2/7/10	7.07	19.18	6.80	263.4, 467.3	147	42.8	202	7544
	7.64	19.62	7.24	225.8, 429.7	143	23.7	95	7639
	7.85	19.20	7.13	191.1, 395.0	142	13.2	222	7861
	7.82	19.32	5.94	176.1, 380.0	149	27.5	18	7879
	7.74	20.21	5.05	139.1, 343.0	156	51.4	35	7914
	7.67	20.91	4.39	90.5, 294.4	157	59.8	34	7948
	7.72	21.00	4.40	46.2, 250.1	158	54.9	33	7981
	7.66	22.13	4.53	25.3, 229.2	159	51.3	34	8015
	7.45	21.61	4.25	16.1, 220.0	83	43.6	52	8067
	7.65	20.92	4.76	−14.3, 189.6	158	38.1	52	8119
	7.72	20.22	4.12	−40.4, 163.5	159	35.2	52	8171
	n/r, pumped before shutting off pump						36	8207

Table B-1.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pumping Test, Upper Screen								
2/10/10	n/r, pumping, mini-test preparation						100	8307
2/11/10	n/r, pumping, mini-test						168	8475
2/14/10 to 2/15/10	7.72	17.77	15.2	261.4, 465.3	158	24.0	128	8603
	7.37	22.46	16.6	247.7, 451.6	173	12.6	54	8657
	7.24	21.90	13.4	224.8, 428.7	172	15.6	34	8691
	7.96	19.06	13.2	213.4, 417.3	171	14.5	213	8904
	7.13	19.45	7.2	189.0, 392.9	169	12.2	23	8927
	7.62	19.53	21.5	177.8, 381.7	162	28.4	22	8949
	6.71	18.79	31.2	184.2, 388.1	164	29.1	23	8972
	7.59	20.80	22.9	160.5, 364.4	163	23.7	22	8994
	7.46	22.70	11.5	150.1, 348.6	167	20.6	21	9015
	7.36	22.80	11.0	145.1, 343.6	167	20.4	21	9036
	7.43	22.57	12.0	141.9, 340.4	169	20.1	21	9057
	7.15	23.61	13.4	165.6, 364.0	166	17.4	67	9124
	7.41	24.62	12.0	168.4, 366.9	166	16.2	22	9146
	7.49	21.62	18.4	177.1, 225.5	165	15.2	41	9187
	n/r, durations of pumping due to pump cavitation						62	9249

Table B-1.2-1 (continued

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pumping Test, Lower Screen								
2/17/10	n/r, pumping, mini-test preparation						520	9769
2/18/10	n/r, pumping, mini-test						1652	11,421
2/20/10 to 2/21/10	7.80	21.06	96.93	131.1, 335.0	121	101.3	555	11,976
	6.59	20.69	97.8	146.7, 350.2	162	0.3	553	12,529
	7.58	21.60	100.6	125.9, 329.8	148	0.9	551	13,080
	7.70	21.40	83.3	123.7, 327.6	148	1.0	550	13,630
	7.71	21.38	80.4	124.9, 328.8	150	0.0	550	14,180
	7.63	21.25	79.5	127.8, 331.7	149	1.2	550	14,730
	7.71	20.96	79.9	125.5, 329.4	152	0.8	586	15,316
	7.69	20.83	80.2	127.4, 331.3	149	1.3	513	15,829
	7.71	21.25	95.6	126.4, 330.3	148	0.3	549	16,378
	7.65	21.24	84.1	132.0, 335.9	148	0.0	551	16,929
	7.77	21.83	88.7	127.3, 331.2	149	0.2	551	17,480
	7.70	21.80	87.7	128.5, 332.4	149	0.3	551	18,031
	7.83	20.26	97.6	142.3, 346.2	149	0.4	3866	21,897
	7.71	21.19	99.1	131.4, 335.3	149	0.7	574	22,471
	7.69	21.43	89.6	132.4, 336.3	149	0.1	533	23,004
	7.72	21.41	88.2	131.7, 335.6	148	0.2	553	23,557
	7.70	21.66	87.6	132.8, 336.7	148	0.1	1106	24,663
	7.64	21.57	99.4	136.3, 340.2	148	0.2	1108	25,771
	7.69	21.75	93.0	134.5, 338.4	148	0.0	1107	26,878
	7.63	20.93	93.5	140.0, 343.9	147	0.3	1107	27,985
	7.70	21.31	83.1	138.5, 342.4	148	0.0	1110	29,095
	7.76	21.34	89.9	138.7, 342.6	148	0.0	2230	31,325
	6.04	19.80	82.8	180.3, 384.2	179	0.3	3906	35,231
	7.76	21.39	95.7	141.3, 345.2	147	0.7	558	35,789
	7.76	20.20	89.6	145.2, 349.1	148	0.3	551	36,340
	7.82	21.13	94.6	142.6, 346.5	147	0.3	558	36,898
	n/r, pumped before shutting off pump						1087	37,985

Table B-1.2-1 (continued

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Final Development of Upper Screen								
2/23/10	n/r						2384	40,369
2/24/10	n/r						2554	42,923
2/25/10	n/r						3287	46,210
2/26/10	6.86	20.31	52.6	156.1, 360.0	151	5.4	2305	48,515
	7.79	20.92	45.6	135.8, 339.7	151	4.7	50	48,565
	7.87	20.42	56.8	133.4, 337.3	150	4.7	68	48,633
	7.89	20.19	40.1	127.7, 331.6	150	4.9	68	48,701
	7.88	20.10	40.9	122.4, 326.3	148	4.7	68	48,769
	8.00	19.03	37.3	114.9, 318.8	080	4.8	68	48,837
	n/r						719	49,556
2/27/10	n/r						3350	52,906

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

[b] n/r = Not recorded.

Table B-1.3-1
Off-site Laboratory Analytical Data

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW54-10-7740	LH3	Tritium	1.16	TU	None
GW54-10-7740	HE	2,4-Diamino-6-nitrotoluene	13	µg/L	U
GW54-10-7740	HE	2,6-Diamino-4-nitrotoluene	13	µg/L	U
GW54-10-7740	HE	3,5-Dinitroaniline	13	µg/L	U
GW54-10-7740	HE	Amino-2,6-dinitrotoluene[4-]	3.25	µg/L	U
GW54-10-7740	HE	Amino-4,6-dinitrotoluene[2-]	3.25	µg/L	U
GW54-10-7740	HE	Dinitrobenzene[1,3-]	3.25	µg/L	U
GW54-10-7740	HE	Dinitrotoluene[2,4-]	3.25	µg/L	U
GW54-10-7740	HE	Dinitrotoluene[2,6-]	3.25	µg/L	U
GW54-10-7740	HE	HMX	3.25	µg/L	U
GW54-10-7740	HE	Nitrobenzene	3.25	µg/L	U
GW54-10-7740	HE	Nitrotoluene[2-]	3.25	µg/L	U
GW54-10-7740	HE	Nitrotoluene[3-]	3.25	µg/L	U
GW54-10-7740	HE	Nitrotoluene[4-]	6.49	µg/L	U
GW54-10-7740	HE	PETN	13	µg/L	U
GW54-10-7740	HE	RDX	3.25	µg/L	U
GW54-10-7740	HE	TATB	13	µg/L	U
GW54-10-7740	HE	Tetryl	6.49	µg/L	U
GW54-10-7740	HE	Trinitrobenzene[1,3,5-]	3.25	µg/L	U
GW54-10-7740	HE	Trinitrotoluene[2,4,6-]	3.25	µg/L	U
GW54-10-7740	HE	Tris (o-cresyl) phosphate	13	µg/L	U
GW54-10-7740	VOC	Acetone	24.5	µg/L	None
GW54-10-7740	VOC	Acetonitrile	25	µg/L	R
GW54-10-7740	VOC	Acrolein	5	µg/L	R
GW54-10-7740	VOC	Acrylonitrile	5	µg/L	U
GW54-10-7740	VOC	Benzene	1	µg/L	U
GW54-10-7740	VOC	Bromobenzene	1	µg/L	UJ
GW54-10-7740	VOC	Bromochloromethane	1	µg/L	U
GW54-10-7740	VOC	Bromodichloromethane	1	µg/L	U
GW54-10-7740	VOC	Bromoform	1	µg/L	U
GW54-10-7740	VOC	Bromomethane	1	µg/L	U
GW54-10-7740	VOC	Butanol[1-]	111	µg/L	J
GW54-10-7740	VOC	Butanone[2-]	53.1	µg/L	None
GW54-10-7740	VOC	Butylbenzene[n-]	1	µg/L	U
GW54-10-7740	VOC	Butylbenzene[sec-]	1	µg/L	U
GW54-10-7740	VOC	Butylbenzene[tert-]	1	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW54-10-7740	VOC	Carbon Disulfide	5	µg/L	U
GW54-10-7740	VOC	Carbon Tetrachloride	1	µg/L	U
GW54-10-7740	VOC	Chloro-1,3-butadiene[2-]	1	µg/L	U
GW54-10-7740	VOC	Chloro-1-propene[3-]	5	µg/L	U
GW54-10-7740	VOC	Chlorobenzene	1	µg/L	U
GW54-10-7740	VOC	Chlorodibromomethane	1	µg/L	U
GW54-10-7740	VOC	Chloroethane	1	µg/L	U
GW54-10-7740	VOC	Chloroform	1	µg/L	U
GW54-10-7740	VOC	Chloromethane	1	µg/L	U
GW54-10-7740	VOC	Chlorotoluene[2-]	1	µg/L	U
GW54-10-7740	VOC	Chlorotoluene[4-]	1	µg/L	U
GW54-10-7740	VOC	Dibromo-3-Chloropropane[1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dibromoethane[1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dibromomethane	1	µg/L	U
GW54-10-7740	VOC	Dichlorobenzene[1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dichlorobenzene[1,3-]	1	µg/L	U
GW54-10-7740	VOC	Dichlorobenzene[1,4-]	1	µg/L	U
GW54-10-7740	VOC	Dichlorodifluoromethane	1	µg/L	UJ
GW54-10-7740	VOC	Dichloroethane[1,1-]	1	µg/L	U
GW54-10-7740	VOC	Dichloroethane[1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dichloroethene[1,1-]	1	µg/L	U
GW54-10-7740	VOC	Dichloroethene[cis-1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dichloroethene[trans-1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dichloropropane[1,2-]	1	µg/L	U
GW54-10-7740	VOC	Dichloropropane[1,3-]	1	µg/L	U
GW54-10-7740	VOC	Dichloropropane[2,2-]	1	µg/L	U
GW54-10-7740	VOC	Dichloropropene[1,1-]	1	µg/L	U
GW54-10-7740	VOC	Dichloropropene[cis-1,3-]	1	µg/L	U
GW54-10-7740	VOC	Dichloropropene[trans-1,3-]	1	µg/L	U
GW54-10-7740	VOC	Diethyl Ether	1	µg/L	UJ
GW54-10-7740	VOC	Ethyl Methacrylate	5	µg/L	U
GW54-10-7740	VOC	Ethylbenzene	1	µg/L	U
GW54-10-7740	VOC	Hexachlorobutadiene	1	µg/L	U
GW54-10-7740	VOC	Hexanone[2-]	1.3	µg/L	J
GW54-10-7740	VOC	Iodomethane	5	µg/L	U
GW54-10-7740	VOC	Isobutyl alcohol	50	µg/L	R
GW54-10-7740	VOC	Isopropylbenzene	1	µg/L	UJ
GW54-10-7740	VOC	Isopropyltoluene[4-]	1	µg/L	U
GW54-10-7740	VOC	Methacrylonitrile	5	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW54-10-7740	VOC	Methyl Methacrylate	5	µg/L	U
GW54-10-7740	VOC	Methyl tert-Butyl Ether	1	µg/L	U
GW54-10-7740	VOC	Methyl-2-pentanone[4-]	5	µg/L	U
GW54-10-7740	VOC	Methylene Chloride	10	µg/L	UJ
GW54-10-7740	VOC	Naphthalene	1	µg/L	U
GW54-10-7740	VOC	Propionitrile	5	µg/L	R
GW54-10-7740	VOC	Propylbenzene[1-]	1	µg/L	U
GW54-10-7740	VOC	Styrene	1	µg/L	U
GW54-10-7740	VOC	Tetrachloroethane[1,1,1,2-]	1	µg/L	U
GW54-10-7740	VOC	Tetrachloroethane[1,1,2,2-]	1	µg/L	U
GW54-10-7740	VOC	Tetrachloroethene	1	µg/L	U
GW54-10-7740	VOC	Toluene	1	µg/L	U
GW54-10-7740	VOC	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	µg/L	U
GW54-10-7740	VOC	Trichlorobenzene[1,2,3-]	1	µg/L	U
GW54-10-7740	VOC	Trichlorobenzene[1,2,4-]	1	µg/L	U
GW54-10-7740	VOC	Trichloroethane[1,1,1-]	1	µg/L	U
GW54-10-7740	VOC	Trichloroethane[1,1,2-]	1	µg/L	U
GW54-10-7740	VOC	Trichloroethene	1	µg/L	U
GW54-10-7740	VOC	Trichlorofluoromethane	1	µg/L	U
GW54-10-7740	VOC	Trichloropropane[1,2,3-]	1	µg/L	U
GW54-10-7740	VOC	Trimethylbenzene[1,2,4-]	1	µg/L	UJ
GW54-10-7740	VOC	Trimethylbenzene[1,3,5-]	1	µg/L	U
GW54-10-7740	VOC	Vinyl acetate	5	µg/L	U
GW54-10-7740	VOC	Vinyl chloride	1	µg/L	U
GW54-10-7740	VOC	Xylene[1,2-]	1	µg/L	U
GW54-10-7740	VOC	Xylene[1,3-]+Xylene[1,4-]	2	µg/L	U
GW54-10-7741	LH3	Tritium	0.59	TU	U
GW54-10-7741	HE	2,4-Diamino-6-nitrotoluene	1.3	µg/L	U
GW54-10-7741	HE	2,6-Diamino-4-nitrotoluene	1.3	µg/L	U
GW54-10-7741	HE	3,5-Dinitroaniline	1.3	µg/L	U
GW54-10-7741	HE	Amino-2,6-dinitrotoluene[4-]	0.325	µg/L	U
GW54-10-7741	HE	Amino-4,6-dinitrotoluene[2-]	0.325	µg/L	U
GW54-10-7741	HE	Dinitrobenzene[1,3-]	0.325	µg/L	U
GW54-10-7741	HE	Dinitrotoluene[2,4-]	0.325	µg/L	U
GW54-10-7741	HE	Dinitrotoluene[2,6-]	0.325	µg/L	U
GW54-10-7741	HE	HMX	0.325	µg/L	U
GW54-10-7741	HE	Nitrobenzene	0.325	µg/L	U
GW54-10-7741	HE	Nitrotoluene[2-]	0.325	µg/L	U
GW54-10-7741	HE	Nitrotoluene[3-]	0.325	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW54-10-7741	HE	Nitrotoluene[4-]	0.649	µg/L	U
GW54-10-7741	HE	PETN	1.3	µg/L	U
GW54-10-7741	HE	RDX	0.325	µg/L	U
GW54-10-7741	HE	TATB	1.3	µg/L	U
GW54-10-7741	HE	Tetryl	0.649	µg/L	U
GW54-10-7741	HE	Trinitrobenzene[1,3,5-]	0.325	µg/L	U
GW54-10-7741	HE	Trinitrotoluene[2,4,6-]	0.325	µg/L	U
GW54-10-7741	HE	Tris (o-cresyl) phosphate	1.3	µg/L	U
GW54-10-7741	VOC	Acetone	10	µg/L	U
GW54-10-7741	VOC	Acetonitrile	25	µg/L	R
GW54-10-7741	VOC	Acrolein	5	µg/L	R
GW54-10-7741	VOC	Acrylonitrile	5	µg/L	U
GW54-10-7741	VOC	Benzene	1	µg/L	U
GW54-10-7741	VOC	Bromobenzene	1	µg/L	UJ
GW54-10-7741	VOC	Bromochloromethane	1	µg/L	U
GW54-10-7741	VOC	Bromodichloromethane	1	µg/L	U
GW54-10-7741	VOC	Bromoform	1	µg/L	U
GW54-10-7741	VOC	Bromomethane	1	µg/L	U
GW54-10-7741	VOC	Butanol[1-]	50	µg/L	R
GW54-10-7741	VOC	Butanone[2-]	5	µg/L	U
GW54-10-7741	VOC	Butylbenzene[n-]	1	µg/L	U
GW54-10-7741	VOC	Butylbenzene[sec-]	1	µg/L	U
GW54-10-7741	VOC	Butylbenzene[tert-]	1	µg/L	U
GW54-10-7741	VOC	Carbon Disulfide	5	µg/L	U
GW54-10-7741	VOC	Carbon Tetrachloride	1	µg/L	U
GW54-10-7741	VOC	Chloro-1,3-butadiene[2-]	1	µg/L	U
GW54-10-7741	VOC	Chloro-1-propene[3-]	5	µg/L	U
GW54-10-7741	VOC	Chlorobenzene	1	µg/L	U
GW54-10-7741	VOC	Chlorodibromomethane	1	µg/L	U
GW54-10-7741	VOC	Chloroethane	1	µg/L	U
GW54-10-7741	VOC	Chloroform	1	µg/L	U
GW54-10-7741	VOC	Chloromethane	1	µg/L	U
GW54-10-7741	VOC	Chlorotoluene[2-]	1	µg/L	U
GW54-10-7741	VOC	Chlorotoluene[4-]	1	µg/L	U
GW54-10-7741	VOC	Dibromo-3-Chloropropane[1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dibromoethane[1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dibromomethane	1	µg/L	U
GW54-10-7741	VOC	Dichlorobenzene[1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dichlorobenzene[1,3-]	1	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW54-10-7741	VOC	Dichlorobenzene[1,4-]	1	µg/L	U
GW54-10-7741	VOC	Dichlorodifluoromethane	1	µg/L	UJ
GW54-10-7741	VOC	Dichloroethane[1,1-]	1	µg/L	U
GW54-10-7741	VOC	Dichloroethane[1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dichloroethene[1,1-]	1	µg/L	U
GW54-10-7741	VOC	Dichloroethene[cis-1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dichloroethene[trans-1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dichloropropane[1,2-]	1	µg/L	U
GW54-10-7741	VOC	Dichloropropane[1,3-]	1	µg/L	U
GW54-10-7741	VOC	Dichloropropane[2,2-]	1	µg/L	U
GW54-10-7741	VOC	Dichloropropene[1,1-]	1	µg/L	U
GW54-10-7741	VOC	Dichloropropene[cis-1,3-]	1	µg/L	U
GW54-10-7741	VOC	Dichloropropene[trans-1,3-]	1	µg/L	U
GW54-10-7741	VOC	Diethyl Ether	1	µg/L	UJ
GW54-10-7741	VOC	Ethyl Methacrylate	5	µg/L	U
GW54-10-7741	VOC	Ethylbenzene	1	µg/L	U
GW54-10-7741	VOC	Hexachlorobutadiene	1	µg/L	U
GW54-10-7741	VOC	Hexanone[2-]	5	µg/L	UJ
GW54-10-7741	VOC	Iodomethane	5	µg/L	U
GW54-10-7741	VOC	Isobutyl alcohol	50	µg/L	R
GW54-10-7741	VOC	Isopropylbenzene	1	µg/L	UJ
GW54-10-7741	VOC	Isopropyltoluene[4-]	1	µg/L	U
GW54-10-7741	VOC	Methacrylonitrile	5	µg/L	U
GW54-10-7741	VOC	Methyl Methacrylate	5	µg/L	U
GW54-10-7741	VOC	Methyl tert-Butyl Ether	1	µg/L	U
GW54-10-7741	VOC	Methyl-2-pentanone[4-]	5	µg/L	U
GW54-10-7741	VOC	Methylene Chloride	10	µg/L	UJ
GW54-10-7741	VOC	Naphthalene	1	µg/L	U
GW54-10-7741	VOC	Propionitrile	5	µg/L	R
GW54-10-7741	VOC	Propylbenzene[1-]	1	µg/L	U
GW54-10-7741	VOC	Styrene	1	µg/L	U
GW54-10-7741	VOC	Tetrachloroethane[1,1,1,2-]	1	µg/L	U
GW54-10-7741	VOC	Tetrachloroethane[1,1,2,2-]	1	µg/L	U
GW54-10-7741	VOC	Tetrachloroethene	1	µg/L	U
GW54-10-7741	VOC	Toluene	1	µg/L	U
GW54-10-7741	VOC	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	µg/L	U
GW54-10-7741	VOC	Trichlorobenzene[1,2,3-]	1	µg/L	U
GW54-10-7741	VOC	Trichlorobenzene[1,2,4-]	1	µg/L	U
GW54-10-7741	VOC	Trichloroethane[1,1,1-]	1	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW54-10-7741	VOC	Trichloroethane[1,1,2-]	1	µg/L	U
GW54-10-7741	VOC	Trichloroethene	1	µg/L	U
GW54-10-7741	VOC	Trichlorofluoromethane	1	µg/L	U
GW54-10-7741	VOC	Trichloropropane[1,2,3-]	1	µg/L	U
GW54-10-7741	VOC	Trimethylbenzene[1,2,4-]	1	µg/L	UJ
GW54-10-7741	VOC	Trimethylbenzene[1,3,5-]	1	µg/L	U
GW54-10-7741	VOC	Vinyl acetate	5	µg/L	U
GW54-10-7741	VOC	Vinyl chloride	1	µg/L	U
GW54-10-7741	VOC	Xylene[1,2-]	1	µg/L	U
GW54-10-7741	VOC	Xylene[1,3-]+Xylene[1,4-]	2	µg/L	U

U = undetected.
J = estimated value.
R = rejected value.
HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
PETN = pentaerythritol tetranitrate.
RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine.
TATB= triaminotrinitrobenzene.
TU = tritium unit.

Table B-1.3-2
EES-14 Analytical Results

Sample ID	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	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)
GW54-10-7740	0	U	0.486	0.001	0.0009	0.0000	0.111	0.001	0.370	0.001	0	U	0.04	20.70	0	0	U	9.34	0.01	U	0	U	0.8	U	0.001	0.000	0	U	0.001	U
GW54-10-7741	0	U	0.024	0.000	0.0024	0.0000	0.115	0.002	0.437	0.003	0	U	0.05	13.32	0	0	U	3.88	0	U	0	U	0.8	U	0.003	0.000	0	U	0.001	U

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)	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)	pH	PO4(-3) rslt (ppm)
0.63	0.17	0.00	149	0.00021	0.00001	4.35	0.04	0.028	0.000	5.94	0.05	0.160	0.002	0.329	0.016	28.51	0	0.002	0.000	0.010	0.003	U	0.050	0.011	0.05	0.01	0.0002	U	7.73	0.57
0.41	0.15	0.00	89	0.00009	0.00001	1.62	0.01	0.022	0.000	3.99	0.03	0.077	0.001	0.013	0.000	13.03	0	0.002	0.000	0.010	0.003	U	0.060	0.014	0.01	U	0.0002	U	7.33	0.01

PO4(-3)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)	S rslt (ppm)	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
0.05	0.001	0.000	0.001	U	0.001	U	16.64	35.61	3.6	0.001	U	6.93	0.088	0.000	0.001	U	0.029	0.000	0.001	U	0.0002	U	0.002	0.000	0.115	0.001	297	2.89	3.39	-0.08
U	0.004	0.000	0.001	U	0.001	U	25.97	55.58	5.6	0.001	U	2.36	0.056	0.000	0.001	U	0.004	0.000	0.001	U	0.0008	0.0000	0.013	0.000	0.063	0.000	185	1.62	1.68	-0.02

Notes: NA = not analyzed and U = undetected at analytical detection.

Table B-1.3-3
Total Organic Carbon Results

Sample ID	Date Collected	Sample Type	Depth (ft)	TOC concentration (mg/L)
Upper Screen				
GW54-10-7751	2/6/2010	Development	830.0-840.0	0.30
GW54-10-7752	2/7/2010	Development	830.0-840.0	0.70
GW54-10-7753	2/7/2010	Development	830.0-840.0	0.50
GW54-10-7754	2/14/2010	Aquifer Testing	830.0-840.0	1.50
GW54-10-7755	2/14/2010	Aquifer Testing	830.0-840.0	0.50
GW54-10-7756	2/14/2010	Aquifer Testing	830.0-840.0	0.50
GW54-10-7757	2/15/2010	Aquifer Testing	830.0-840.0	0.50
GW54-10-7764	2/23/2010	Continued development	830.0-840.0	0.47
GW54-10-7765	2/24/2010	Continued development	830.0-840.0	0.40
GW54-10-7766	2/25/2010	Continued development	830.0-840.0	0.38
GW54-10-7767	2/26/2010	Continued development	830.0-840.0	0.64
GW54-10-7768	2/27/2010	Continued development	830.0-840.0	0.50
Lower Screen				
GW54-10-7749	2/5/2010	Development	915.0-925.0	12.0
GW54-10-7750	2/5/2010	Development	915.0-925.0	0.60
GW54-10-7758	2/20/2010	Aquifer Testing	915.0-925.0	0.18 U
GW54-10-7759	2/20/2010	Aquifer Testing	915.0-925.0	0.30
GW54-10-7760	2/20/2010	Aquifer Testing	915.0-925.0	0.18 U
GW54-10-7761	2/20/2010	Aquifer Testing	915.0-925.0	0.16 U
GW54-10-7762	2/21/2010	Aquifer Testing	915.0-925.0	0.17 U
GW54-10-7763	2/21/2010	Aquifer Testing	915.0-925.0	0.19 U

Note: NA means not analyzed and U means less than analytical detection.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted during February 2010 at R-54, a dual-screen regional aquifer well located in Pajarito Canyon downgradient of Material Disposal Area L (MDA L). The tests on R-54 were conducted to quantify the hydraulic properties of the two zones in which the well is screened and evaluate the hydraulic interconnection of the zones.

Testing planned for each screen interval consisted of brief trial pumping, background water-level data collection, and a 24-h constant-rate pumping test. However, aerated water in the upper screen zone (described below) interfered with successful pump operation and made it impossible to pump water continuously for 24 h. Therefore, in lieu of the planned 24-h pumping test for screen 1, several short tests were performed instead.

Water levels were monitored in both zones during each of the pumping tests in each screen. As with most of the R-well pumping tests conducted on the Pajarito Plateau (the Plateau), an inflatable packer system was used in R-54 to both hydraulically isolate the screen zones and try to eliminate casing storage effects on the test data. Storage effects were eliminated successfully from the screen 2 tests but were present in the screen 1 tests. There were two possible reasons for the screen 1 storage phenomena observed in the tests. First, it was possible that air from the drilling operation was trapped in the formation pores. This air would expand and contract in response to pumping and recovery, causing a storage-like effect. Alternatively, previous well-development operations may have pulled the pumping water level into screen 1. Had this occurred, the filter pack behind the blank casing above screen 1 would have drained and filled with air. This air would have remained trapped, expanding and contracting in response to pumping and recovery, causing a storage-like effect.

C-1.1 Conceptual Hydrogeology

Well R-54 is screened within sands and gravels in basaltic sediments near the base of the Cerros del Rio basalt and in the upper portion of the Puye Formation. Screen 1 is 10 ft long, extending from 830 to 840 ft below ground surface (bgs). Screen 2 is 10 ft long as well, extending from 915 to 925 ft bgs. Most of the interval between the well screens, from 845 to 900 ft, is clay rich including 10 ft of particularly tight clay-rich silt from 860 to 870 ft. The clayey sediments were expected to serve as an aquitard separating the permeable screen zones.

The composite static water level measured on February 7, 2010, was 815.47 ft bgs. The surveyed ground-level elevation at the well was 6679.63 ft above mean sea level (amsl), making the composite water-level elevation 5864.16 ft amsl.

When the screen zones were isolated with an inflatable packer, the water level in screen 1 *declined* 1.59 ft to 817.06 ft bgs, to an elevation of 5862.57 ft amsl. Simultaneously, the head in screen *2 rose* 0.18 ft to a depth of 815.29 ft bgs, to an elevation of 5864.34 ft amsl—1.77 ft higher than the screen 1 water level. Thus, the water levels showed an *upward* hydraulic gradient across the tight, clay-rich materials between 845 and 900 ft. This result was unusual and opposite of most observations at the Laboratory. With few exceptions, multiple-screen wells at the Laboratory show downward, rather than upward, gradients. This is especially true of wells set back a great distance from the Rio Grande River such as R-54.

The upper aquifer was considered to be unconfined and 27.94 ft thick, extending from the measured static water level of 817.06 ft to the top of the clay-rich sediments at 845 ft. The lower aquifer was confined and of unknown saturated thickness, extending from the bottom of the clay-rich zone at 900 ft to an unknown depth beneath screen 2.

C-1.2 R-54 Screen 1 Testing

Well R-54 screen 1 was tested from February 10 to 16, 2010. After filling the drop pipe on February 10, testing began with brief trial pumping on February 11, background data collection, and an attempted start of a 24-h constant-rate pumping test on February 13.

Two trial tests were conducted on February 11. Trial 1 was conducted for 60 min at a discharge rate of 0.87 gallons per minute (gpm) from 8:00 until 9:00 a.m. and was followed by 60 min of recovery until 10:00 a.m. Trial 2 was conducted for 120 min at 0.89 gpm from 10:00 a.m. until 12:00 p.m. and was followed by 2640 min of recovery until 8:00 a.m. on February 13.

On February 13, an attempt was made to begin the 24-h pumping test. Unfortunately, the pump bowl used for the testing failed and had to be pulled and replaced.

The attempted 24-h test was restarted the following day, February 14, at 8:00 a.m. The initial discharge rate was 2.1 gpm. However, after 75 min of pumping, the discharge rate began to decline. An hour later, the rate had declined to just 0.4 gpm and the pump had to be shut down to avoid overheating the pump motor. Pump shutoff occurred at 10:15 a.m. The data from this 135-min pumping event were retained as trial 3.

It was surmised that aerated groundwater had interfered with pumping. To try to minimize this effect, subsequent pumping was performed at a reduced discharge rate. The next pumping event began at 1:30 p.m. on February 14 at a rate of 0.77 gpm. At this discharge rate, production was maintained for 405 min until 8:15 p.m. before air entrainment affected the pump operation. At that time, the pumping rate declined about 12% and held there for 80 min until 9:35 p.m. Then, the flow rate declined rapidly, forcing shutdown 11 min later at 9:46 p.m. Data from this pumping event were retained as trial 4.

After several hours of recovery/re-equilibration, a final pumping event, trial 5, was performed for 250 min at 0.8 gpm from 3:50 a.m. until 8:00 a.m. on February 15. This pumping event was compromised by failure of the electric generator, which stalled and had to be restarted several times during the test. Following shutdown of trial 5, recovery data were collected for 1460 min until 8:20 a.m. on February 16.

C-1.2.1 Aerated Water

In all likelihood, trapped and/or dissolved air in the formation that was released via pressure reduction when screen 1 was pumped interfered with pump operation by causing cavitation and reducing the pump bowl efficiency. The water pumped from screen 1 during the initial tests was exceedingly aerated, having the appearance of a carbonated beverage. It is possible that compressed air introduced into the formation during drilling was retained in the formation pores and/or dissolved in the groundwater, only to be released subsequently during pumping.

It was clear that the submersible pump underperformed when pumping from the upper screen in R-54. The pumps used for testing screen 1 had a capacity of about 12 gpm and, when pumping from both screens (with the packer deflated), produced at this level. The observed specific capacity and available drawdown in screen 1 implied a yield potential for that zone of around 6 gpm. Nevertheless, during final development purging of screen 1, the pump could produce only about 1.7 gpm continuously. Subsequently, as described above, test pumping showed that yields dropped to a fraction of a gpm after extended pumping. Given the yield capacity of the pumps that were used and the hydraulic characteristics of the screen 1 zone, the only explanation for the inability to pump more water was a decline in pump bowl efficiency attributable to high gas content in the water.

As testing of screen 1 continued from trial 1 through trial 5, the observed air content in the pumped water declined steadily and appeared substantially lower at the conclusion of the test pumping effort. Indeed, following test pumping, several days of additional purge development were performed on screen 1 employing the same pump that was used for testing. During this activity, the submersible pump delivered 4 to 5 gpm continuously for 8 to 10 h per day against significant back pressure (a partially closed valve). Achieving this rate of pumping using the same well pump suggested more efficient pump bowl operation, consistent with lower gas content in the pumped water at that time.

C-1.3 R-54 Screen 2 Testing

Well R-54 screen 2 was tested from February 17 to 22, 2010. After filling the drop pipe on February 17, testing began with brief trial pumping on February 18, background data collection, and a 24-h constant-rate pumping test that was begun on February 20.

Two trial tests were conducted on February 18. Trial 1 was conducted at a discharge rate of 18.4 gpm for 30 min from 12:00 to 12:30 p.m. and was followed by 30 min of recovery until 1:00 p.m.

Trial 2 was conducted for 60 minutes from 1:00 to 2:00 p.m. at a rate of 18.4 gpm. Following shutdown, recovery/background data were recorded for 2520 minutes until 8:00 a.m. on February 20.

At 8:00 a.m. on February 20, the 24-h pumping test was begun at a rate of 18.6 gpm. Pumping continued for 1440 min until 8:00 a.m. on February 21. Following shutdown, recovery measurements were recorded for 1440 min until 8:00 a.m. on February 22, when the pump was tripped out of the well.

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 with barometric pressure data from the area to determine if a correlation existed.

Previous pumping tests on the Plateau have demonstrated a barometric efficiency for most wells of between 90% and 100%. Barometric efficiency is defined as the ratio of water-level change divided by barometric pressure change, expressed as a percentage. In the initial pumping tests conducted on the early R-wells, downhole pressure was monitored using a vented pressure transducer. This equipment measured 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-54, have used nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency, and in the same direction as the barometric pressure change rather than in the opposite direction.

Barometric pressure data were obtained from the 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 6679.63 ft amsl. The static water level in R-54 was 815.47 ft below land surface, making the calculated water-table elevation 5864.16 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-54.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R-54} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-54}}{T_{WELL}}\right)\right], \qquad \textbf{Equation C-1}$$

where P_{WT} = barometric pressure at the water table inside R-54,

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

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

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

E_{R-54} = land-surface elevation at R-54 site, in feet (6679.16 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-54, in feet (5864.16 ft),

T_{TA54} = air temperature near TA-54, in degrees kelvin (assigned a value of 30.0 degrees Fahrenheit, [ºF] or 272.0 degrees kelvin), and

T_{WELL} = air temperature inside R-54, in degrees Kelvin (assigned a value of 67.0ºF, or 292.6 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 to the water-level hydrograph to discern the correlation between the two.

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 that 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, and

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, there can be an additional storage contribution 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, and

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. (As proof, note that the left-hand term within the brackets is directly proportional to the annular area [and volume] between the casing and drop pipe while the right-hand term is proportional to the area [and volume] between the borehole and the casing, corrected for the drainable porosity of the filter pack. Thus, the summed term within the brackets accounts for all of the volume [casing water and drained filter-pack water] appropriately.)

In some instances, it is possible to eliminate casing-storage effects by setting an inflatable packer above the tested screen interval before conducting the test. This proved effective for the screen 2 tests but did not eliminate storage-like effects from the screen 1 tests, likely because of trapped air in either the filter packer above screen 1 or the formation pores.

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

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

and where s = drawdown, in feet,

Q = discharge rate, in gallons per minute,

T = transmissivity, in gallons per day per foot (gpd/ft),

S = storage coefficient (dimensionless),

t = pumping time, in days, and

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, and

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.

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, and

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, and

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.

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 unknown, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

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

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

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

Equation C-14

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

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right).$$

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. Unconfined conditions were assumed for R-54 screen 1, while confined conditions were applicable to screen 2. Storage-coefficient values for unconfined conditions can be expected to range from about 0.01 to 0.25, while those for unconfined aquifers tend to range from 10^{-5} to 10^{-3} (Driscoll 1986, 104226). Values ranging from 0.01 to 0.10 were used for the R-54 screen 1 calculations while a value of 2×10^{-4} was used for the screen 2 calculations. The calculation result is not particularly sensitive to the choice of storage-coefficient value, so a rough estimate of the storage coefficient is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. Screen 1 was assigned a saturated thickness value of 29.53 ft, based on the understanding of the clay content of the sediments beneath the screen. For the purposes of this exercise, the saturated thickness for the screen 2 zone was arbitrarily assigned a value of 50 ft. The calculations are not particularly sensitive to the choice of aquifer thickness because sediments far above or below the screen typically contribute little flow.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-54 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-54 screen 1 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-54 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-54 pumping tests are included on the figure for reference.

There were a couple notable observations regarding the apparent hydrograph. First, the apparent hydrograph data trace did not reflect the changes in barometric pressure. This suggested a barometric efficiency near 100%.

Second, the screen 1 hydrograph did not show any drawdown in response to the screen 2 pumping test, implying a tight aquitard separating the two screen zones, consistent with the geologic observations. On the contrary, the measured pressure in screen 1 actually rose slightly (one or two hundredths of a foot) during the 24-h pumping test on screen 2. This could be an indication of reverse water-level fluctuations, also called the Noordbergum effect (Wolff 1970, 098242; Rodrigues 1983, 098239; Heish 1996, 098238). This effect is seen occasionally in observation wells completed within aquitards or within aquifers adjacent to the pumped aquifer and separated from it by an aquitard. Reverse water-level fluctuations are brought about by poroelastic effects and corresponding pore-pressure changes. When an aquifer is pumped, it undergoes elastic deformation in response to the change in pore water pressures, as well as the downthrust on the land surface at the wellhead associated with operating the pump. When the pumped aquifer becomes distorted, adjacent layers of aquitards and aquifers also are distorted. This creates transient pore-pressure changes within these units. At some locations, the pressures decline, while at other locations they rise (reverse water-level fluctuations). As time goes on, these pressure changes are relieved as water moves from high-pressure areas to low-pressure areas.

Alternatively, the slight rise in pressure in screen 1 could have been attributable to other causes including (1) physical stretching/movement of the drop pipe and packer in response to the vertical tensile stresses induced by pumping screen 2, (2) temperature increase associated with the electric motor heating the water, or (3) vibration and/or electrical disturbance associated with operating the submersible pump.

Figure C-7.0-2 shows the comparison of barometric pressure and the apparent hydrograph from R-54 screen 2. The data showed an approximate correlation between barometric and aquifer pressure, suggesting an unusually low barometric efficiency for screen 2. Most wells on the Plateau exhibit high barometric efficiencies, particularly those that are deep and set back far from the Rio Grande, so this result was not expected. Even more perplexing, close examination of the curves on Figure C-7.0-2 (on an expanded scale, not shown here) revealed that changes in aquifer pressure *preceded* changes in barometric pressure by a couple of hours. Usually, changes in aquifer pressure lag those in barometric pressure, so this result was not readily explainable. It will be interesting to track water levels long-term in screen 2 to further assess the barometric efficiency.

C-8.0 WELL R-54 SCREEN 1 DATA ANALYSIS

This section presents the data obtained from the R-54 screen 1 pumping tests and the results of the analytical interpretations. Data are presented for trials 1 through 5.

C-8.1 Well R-54 Screen 1, Trial 1

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from trial 1 at a discharge rate of 0.87 gpm. As indicated on the graph, the early drawdown was exaggerated slightly, likely a result of antecedent drainage of a tiny portion of the drop pipe beneath one of the check valves. This allowed the pump to operate against reduced head briefly (a few seconds) until the drop pipe was refilled and full head conditions were restored. (The drop pipe used in recent testing has included a blend of both the old 1 ½-in. stainless steel LANL pipe that has shown leaky threads before, and newer 2-in. stainless-steel material. There is an intention to purchase additional footage of 2-in. pipe that may allow testing to proceed without having to use the 1 ½-in. material.)

Figure C-8.1-2 shows an expanded-scale graph of the drawdown data. The early steep slope showed storage effects, yielding an unrealistically low transmissivity value. Several minutes into the test, the curve flattened briefly, perhaps an indication of delayed yield response associated with unconfined aquifers. The subsequent data yielded a computed transmissivity of 3410 gpd/ft. As discussed below, these drawdown data probably were still affected by delayed yield, making this value an overestimate of transmissivity.

Figure C-8.1-3 shows the recovery data collected following shutdown of the trial 1 pumping test. As with the pumping data, the steep portion of the data trace was storage affected and produced an unrealistic transmissivity value.

Following storage effects, the data transitioned steadily to full recovery in a short time, as shown on the expanded-scale graph on Figure C-8.1-4. None of the recovery data showed a valid slope supporting calculation of transmissivity. The premature water-level recovery may have been an indication of hysteretic effects. In unconfined aquifers, rate of recovery can be more rapid than that of drawdown because of a smaller effective storage coefficient during recovery. During pumping the capillary fringe above the water table increases in thickness, while during recovery it gets thinner (Bevan et al. 2005, 105186). If the rate of thinning during recovery exceeds the rate of growth during pumping, the effective storage coefficient during recovery will be less than that during pumping, resulting in a more rapid recovery rate than drawdown rate. Additionally, as the water table rebounds during recovery, it can trap air in the previously dewatered pore spaces, further decreasing the effective recovery storage coefficient.

C-8.2 Well R-54 Screen 1, Trial 2

Figure C-8.2-1 shows a semilog plot of the drawdown data collected from trial 2 at a discharge rate of 0.89 gpm. As indicated on the graph, the early drawdown was exaggerated slightly, again the result of antecedent drainage of a tiny portion of the drop pipe beneath one of the check valves.

Figure C-8.2-2 shows an expanded-scale graph of the drawdown data. The early steep slope showed storage effects, yielding an unrealistically low transmissivity value. Several minutes into the test, the curve flattened briefly, again a likely indication of delayed yield response associated with unconfined aquifers. The subsequent data yielded a computed transmissivity of 2270 gpd/ft. This result was smaller than the transmissivity value computed from trial 1, probably because the longer pumping time in trial 2 allowed greater departure from the delayed yield portion of the curve. Nevertheless, as discussed below, the drawdown data probably were still affected by delayed yield, making this value an overestimate of transmissivity as well.

Figure C-8.2-3 shows the recovery data collected following shutdown of the trial 2 pumping test. As with the pumping data, the steep portion of the data trace was storage affected and produced an unrealistic transmissivity value.

As shown on the expanded-scale plot in Figure C-8.2-4, following storage effects, the data transitioned steadily to full recovery in just a few minutes, precluding a valid analysis of the data.

C-8.3 Well R-54 Screen 1, Trial 3

Figure C-8.3-1 shows a semilog plot of the drawdown data collected from trial 3—the intended 24-h test. As indicated on the graph, the early drawdown was exaggerated slightly, again the result of antecedent drainage of a small portion of the drop pipe beneath one of the check valves. The discharge rate was approximately 2.1 gpm, with some variation caused by varying gas content in the pumped water.

After 75 min of pumping, the pumping rate began declining rapidly. Either the gas content in the water increased substantially or, more likely, buildup of trapped air beneath the upper packer had displaced the pumping water-level downward, finally reaching the pump intake. After 135 min of pumping, the rate reached 0.4 gpm, forcing shutdown of the pump to avoid overheating the motor. The chaotic discharge rate variation precluded analysis of the trial 3 data.

C-8.4 Well R-54 Screen 1, Trial 4

Figure C-8.4-1 shows a semilog plot of the drawdown data collected from trial 4 at 0.77 gpm. In this test, the data collection frequency was insufficient to capture the leaky drop pipe effect seen in the previous tests. The exaggerated drawdown observed in the first few minutes of the test was a result of the initial pumping rate being greater than 0.77 gpm. On startup, the initial discharge valve setting was unchanged from trial 3 and it took a few minutes to adjust the rate to the desired level.

The reduced discharge rate was selected in an attempt to minimize the release of dissolved/trapped gas from the groundwater in hopes of extending the duration of steady pumping. The change was somewhat successful in that a reasonably steady discharge rate was maintained for 405 min before air entrainment in the water degraded the pump efficiency and reduced the rate.

Figure C-8.4-2 shows an expanded-scale plot of the trial 4 drawdown data. The greater pumping period, compared with trials 1 and 2, was sufficient to exceed the duration of delayed yield effects and achieve a stable, representative drawdown slope. The transmissivity computed from the line of fit shown on the graph was 1010 gpd/ft. Based on a saturated thickness of about 28 ft, the computed hydraulic conductivity was 36.1 gpd/ft^2, or 4.8 ft/d.

C-8.5 Well R-54 Screen 1, Trial 5

Figure C-8.5-1 shows a semilog plot of the drawdown data collected from trial 5 at 0.85 gpm. Attempts at controlling the pumping rate by periodically adjusting the discharge valve were largely unsuccessful in the middle portion of the test. Later on, there were several generator failures (shutdowns) that created “noise” in the data plot. The data set was not readily analyzable.

Figure C-8.5-2 shows a semilog plot of the recovery data collected following trial 5. As with other recovery data sets from screen 1, nearly complete recovery was achieved in just a few minutes because of hysteretic effects. Prior data were storage affected and not analyzable.

One oddity visible on the graph was an inflection pattern at a t/t' value of 200 (about 1.25 min after pump shutoff). There was no explanation for this unusual feature although it may have been a trapped-gas effect of some sort.

C-8.6 Well R-54 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-54 screen 1. This was done to provide a frame of reference for evaluating the foregoing analyses.

During the trial 4 pumping test, the discharge rate remained constant at 0.77 gpm for 405 min. The corresponding drawdown was 1.66 ft. In addition to specific capacity and pumping time, other input values used in the calculations included storage coefficient values ranging from 0.01 to 0.10 and a borehole radius of 0.51 ft.

Applying the Brons and Marting method to these inputs for fully penetrating conditions yielded lower-bound transmissivity values from around 900 to 1000 gpd/ft, as shown in Figure C-8.6-1. These estimates provided good corroboration of the value of 1010 gpd/ft obtained from the pumping test data analysis.

C-9.0 WELL R-54 SCREEN 2 DATA ANALYSIS

This section presents the data obtained from the R-54 screen 2 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery data from trials 1 and 2 as well as the 24-h constant-rate test.

C-9.1 Well R-54 Screen 2, Trial 1

Figure C-9.1-1 shows a semilog plot of the drawdown data collected from trial 1 in screen 2 at a discharge rate of 18.4 gpm. The data showed three distinct slopes. The first slope persisted for just a few seconds and was interpreted as reflecting the transmissivity of the 10 ft of formation immediately adjacent to screen 2.

The second slope likely reflected the transmissivity of a similar thickness of sediments but averaged the properties of a larger volume of material through a greater distance from the borehole. Finally, the third slope was considered representative of the contiguous aquifer (of unknown thickness) in which screen 2 is placed.

The initial slope supported a transmissivity calculation of 6230 gpd/ft. Dividing this by the screen length of 10 ft yielded a hydraulic conductivity of 623 gpd/ft^2, or 83.3 ft/d. Again, this was probably representative of the properties of the sediments immediately around the borehole.

The second slope showed a transmissivity of 4620 gpd/ft, presumably the effective average transmissivity of a larger block of material around the well, although still approximately 10 ft thick. The corresponding hydraulic conductivity was 462 gpd/ft^2, or 61.8 ft/d.

The final slope showed a transmissivity of 11,500 gpd/ft, interpreted as the total transmissivity of the hydraulically contiguous aquifer penetrated by screen 2.

Figure C-9.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. The three slopes shown on the drawdown graph were reproduced on the recovery graph showing transmissivities of 5290, 4140 and 11,400 gpd/ft, respectively. The corresponding hydraulic conductivity values computed for the 10-ft-thick screened interval were 529 gpd/ft^2 (70.7 ft/d) near the borehole and 414 gpd/ft^2 (55.3 ft/d) over a greater area around the well.

C-9.2 Well R-54 Screen 2, Trial 2

Figure C-9.2-1 shows a semilog plot of the drawdown data collected from trial 2 in screen 2 at a discharge rate of 18.4 gpm. The plot suggested transmissivity values of 6500 gpd/ft at the borehole (a = 650 gpd/ft^2, or 86.9 ft/d), 4340 gpd/ft in a greater area around the well (K = 434 gpd/ft^2, or 58.0 ft/d), and 12,000 gpd/ft through a greater thickness of sediments.

Figure C-9.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. As indicated on the graph, the corresponding transmissivity values obtained from the recovery data were 5780, 4370, and 11,700 gpd/ft.

The very late recovery data were dominated by barometric pressure effects but suggested further overall flattening of the curve and an even greater transmissivity value. This likely reflected continued vertical growth of the cone of depression and/or lateral increases in conductivity and transmissivity of the aquifer some distance away from the well. Because of the large barometric pressure effects and the inexplicable relationship between barometric and aquifer pressure, no attempt was made to correct and analyze the late data.

Note that the very early data in the recovery data plot deviated from the straight line pattern, likely showing a subtle inertial effect, not uncommon in highly permeable environments.

C-9.3 Well R-54 Screen 2 24-h Constant-Rate Pumping Test

Figure C-9.3-1 shows a semilog plot of the screen 2 drawdown data collected during the 24-hr pumping test at a discharge rate of 18.6 gpm. The earliest data on the graph showed a deviation from the line of fit, indicating the possibility that a trivial quantity of water had drained from the drop pipe overnight.

The drawdown plot suggested transmissivity values of 7370 gpd/ft at the borehole (K = 737 gpd/ft^2, or 98.5 ft/d), 3930 gpd/ft throughout a greater area around the well (K = 393 gpd/ft^2, or 52.5 ft/d), and 11,700 gpd/ft through a greater thickness of sediments.

The late data from the 24-h test appeared to show a flat aspect similar to the late recovery data from trial 2. This may have been an indication of continued vertical growth of the cone of depression and/or a lateral increase in conductivity and transmissivity showing an even greater overall transmissivity than suggested by the calculations on the graph. Some of the flattening may have been an artifact of barometric pressure changes, which showed a significant rise during most of the pumping period (Figure C-7.0-2). Again, because of the unusual and inexplicable relationship between barometric and aquifer pressure, no attempt was made to correct the water-level measurements for barometric pressure effects.

Figure C-9.3-2 shows the recovery data collected following shutdown of the 24-h pumping test. As indicated on the graph, the corresponding transmissivity values obtained from the recovery data were 6550, 4370, and 10,600 gpd/ft, respectively. Again, the very late data showed possible continuing flattening of the recovery curve, although the observed trend was altered and obscured by ongoing barometric fluctuations.

The inertial effect seen earlier was visible in the early portion of the recovery plot.

The transmissivity values obtained from the trial tests and 24-h test on R-54 screen 2 are summarized in Table C-9.3-1. The average of the near-well transmissivity values was 6290 gpd/ft, suggesting a near-well hydraulic conductivity of 629 gpd/ft^2, or 84.1 ft/d.

The average transmissivity representing a greater area of sediments around the well was 4300 gpd/ft, suggesting an average hydraulic conductivity of 430 gpd/ft^2, or 57.5 ft/d.

Finally, the late-time transmissivity values indicative of properties of a greater, but unknown, thickness of sediments averaged 11,500 gpd/ft.

During the R-54 pumping tests, water levels were monitored in the existing nearby R-wells including R-20 screens 1 and 2, R-32 screen 1, and R-40 screen 2. Figures C-9.3-3 through C-9.3-6 show the hydrographs obtained from these wells. The barometric pressure curve and the times of the R-54 pumping tests are shown on the graphs for reference. 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 by accounting for current and antecedent barometric pressure effects.

Figure C-9.3-3 shows the hydrograph for R-20 screen 1 along with the BETCO correction. R-20 screen 1 is located 50 ft lower than the bottom of R-54 screen 1 and about 15 ft above the top of R-54 screen 2. The BETCO corrected hydrograph showed a steady decline in water level that began late on February 16 or early on February 17, continuing for about three days. The data showed no discernable response to pumping R-54 screen 1 but did show a significant response to pumping screen 2─both on February 18 when the trial tests were conducted and on February 20 and 21 during the 24-h test. The estimated drawdown observed in R-20 screen 1 during the 24-h test on R-54 screen 2 was 0.4 ft. A rough estimate of the magnitude of the three-day water-level decline preceding the R-54 screen 2 pumping test was 0.2 ft.

Figure C-9.3-4 shows the corresponding data from R-20 screen 2. The data clearly showed a decline in water level on February 17, 18, and 19 followed by a rebound over the next several days; the timing of the water-level decline does not correlate with documented pumping of nearby supply wells. The estimated magnitude of the water-level decline was 0.9 ft. Unlike R-20 screen 1, R-20 screen 2 did not show a clear-cut drawdown response to pumping R-54 screen 2. However, subtle "ripples" on the corrected hydrograph at the start of pumping R-54 screen 2, and again at the start of recovery, suggested the possibility of hydraulic connection and a small response─perhaps on the order of a hundredth of a foot. R-20 screen 2 is set approximately 240 ft deeper than R-20 screen 1 and is about 200 ft lower than R-54 screen 2. It is likely that resistive sediments between the screens help isolate the two screens hydraulically. While R-20 screen 1 is in good hydraulic communication with R-54 screen 2, R-20 screen 2 is somewhat hydraulically isolated from it. On the other hand, R-20 screen 2 showed a greater water-level change than did screen 1 during February 17, 18, and 19. The observed decline in water levels during this period was believed to be caused by operation of Los Alamos County well PM-4. A review of County pumping records showed only 6 h of pump operation (on February 19) at PM-4 during this period, but the R-20 water-level data suggested otherwise. (The other production well in the area is PM-2, which could have had a similar effect on local water levels. However, PM-2 reportedly has been offline for some time.)

Figure C-9.3-5 shows the hydrograph data from R-32 screen 1. There was no identifiable response to pumping R-54. The data showed a slight and gradual decline in head beginning around February 19 with no apparent rebound during the monitoring period. This could have been an artifact of barometric pressure changes not fully removed by the BETCO algorithm or may have been a delayed and muted response to the presumed operation of PM-4.

Figure C-9.3-6 shows the hydrograph data from R-40 screen 2, located slightly higher than R-54 screen 1. There was a clear response to pumping R-54 screen 2─both on February 18 when the trial tests were conducted and on February 20 and 21 during the 24-h test. The observed drawdown during the R-54 screen 2 24-h test was estimated at about 0.2 ft. R-40 screen 2 also showed the three-day water-level decline in response to the presumed operation of PM-4. The magnitude of this water-level change was about 0.2 ft. Of note was that there was no response in R-40 screen 2 to pumping R-54 screen 1 even though the screens are at similar elevations. This may have indicated a lack of hydraulic connection between the two screens or be an artifact of the low flow rates and short pumping periods in R-54 screen 1.

Figure C-9.3-7 shows the hydrograph for Los Alamos County well PM-5 for the same time period shown on the previous hydrographs. (Note that the graphical scale for the PM-5 water-level data was compressed by a factor of five to accommodate the relatively large magnitude of the water-level changes.) PM-5 was in operation for most of the period but, fortuitously, was shut off from early February 16 until late February 20. As shown on the figure, during the three-day period from the evening of February 16 to the evening of February 19, the water level in PM-5 declined about 2.5 ft─obviously a response to pumping in the regional aquifer. This helped to reinforce the conclusion that PM-4 may have operated during this period. There was no apparent response to pumping R-54 at PM-5.

Table C-9.3-2 summarizes the water-level changes in R-20 and R-40 on February 17 through 20 attributable to the probable operation of PM-4. The shallowest screens (R-20 screen 1 and R-40 screen 2) showed the least water-level response, being more hydraulically isolated from the deep screen in PM-4. As expected, the deepest screen (R-20 screen 2) showed the greatest response.

Table C-9.3-2 also shows the drawdown observed on February 20 and 21 caused by pumping R-54 screen 2. As an exercise, the drawdown values observed in the shallow screens (R-20 screen 1 and R-40 screen 2) were plotted on the distance-drawdown graph shown in Figure C-9.3-8. Theis curve matching was used to estimate aquifer parameters. It must be pointed out that this analysis is valid only if R-54 screen 2 and the two observation well screens are located in the same hydrogeologic unit. As shown on the figure, the analysis produced a transmissivity estimate of 19,700 gpd/ft and a storage coefficient of 1.7×10^{-4}. It was not known if all three screens fell in the same hydraulic unit or not and, therefore, the representativeness of these calculations could not be evaluated. Of note is the fact that screen 2 in R-40 straddles the static water level of the regional aquifer at that location, suggesting unconfined conditions. The low storage coefficient value computed using the Theis analysis seems to conflict with this and could mean that the computations are not valid. In all likelihood the actual hydrologic regime is highly complex, consisting of several tilted, anisotropic, discrete, yet interconnected, aquifer zones.

C-9.4 Well R-54 Screen 2 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-54 screen 2. This was done to provide a frame of reference for evaluating the foregoing analyses.

During the 24-h constant-rate pumping test, the discharge rate remained constant at 18.6 gpm for 1440 min. The corresponding drawdown was 5.6 ft. In addition to specific capacity and pumping time, other input values used in the calculations included a storage coefficient value of 2×10^{-4}, a borehole radius of 0.51 ft, and an arbitrary aquifer thickness of 50 ft.

Applying the Brons and Marting method to these inputs yielded a lower-bound hydraulic conductivity value of 303 gpd/ft^2, or 40.5 ft/d. This estimate was consistent with the area-wide conductivity value of 430 gpd/ft^2 (57.5 ft/d) obtained from the pumping test analyses.

C-10.0 SUMMARY

Constant-rate pumping tests were conducted on R-54 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.

The static water level observed in screen 1 was 1.77 ft lower than that in screen 2, showing an upward hydraulic gradient—unusual for multiple-screen wells at the Laboratory.

A comparison of barometric pressure and R-54 screen 1 water-level data showed a high barometric efficiency, perhaps near 100%. The data for screen 2, on the other hand, suggested a low barometric efficiency for that zone (unusual for deep wells at the Laboratory) and inexplicably showed the water-level response leading the barometric pressure changes by a couple of hours.

Tight, clay-rich materials dominated the sediments between the well screens, effectively hydraulically isolating the screen zones.

Consistent with this, pumping either zone did not induce drawdown in the other. When screen 2 was pumped, the screen 1 water level appeared to actually rise one or two hundredths of a foot. This could have been an indication of reverse water-level fluctuations associated with deformation of the hydrologic units or simply elastic deformation of the drop pipe used to hang the pump.

Pumping screen 1 proved difficult because of air entrainment in the groundwater, which affected the hydraulic efficiency of the submersible pump. Because extended pumping could not be sustained, several short tests were conducted on screen 1 in lieu of a 24-h test.

Analysis of the screen 1 pumping tests suggested a transmissivity of 1010 gpd/ft and a hydraulic conductivity of 36.1 gpd/ft^2, or 4.8 ft/d.

Screen 1 produced 0.77 gpm for 405 min with 1.66 ft of drawdown for a specific capacity of 0.46 gpm/ft. The lower-bound transmissivity computed from this information fell between about 900 and 1000 gpd/ft, consistent with the pumping test values.

Analysis of the screen 2 pumping tests suggested an area-wide hydraulic conductivity of 430 gpd/ft^2 (57.5 ft/d) for the 10-ft-thick screened interval and a slightly greater conductivity immediately adjacent to the borehole of 629 gpd/ft^2, or 84.1 ft/d.

Screen 2 produced 18.6 gpm for 1440 min with 5.6 ft of drawdown for a specific capacity of 3.3 gpm/ft. The lower-bound transmissivity computed from this information was 303 gpd/ft^2, or 40.5 ft/d, consistent with the pumping test values.

Pumping R-54 screen 2 created observable drawdown responses in R-20 and R-40 at distances of 932 and 2435 ft, respectively.

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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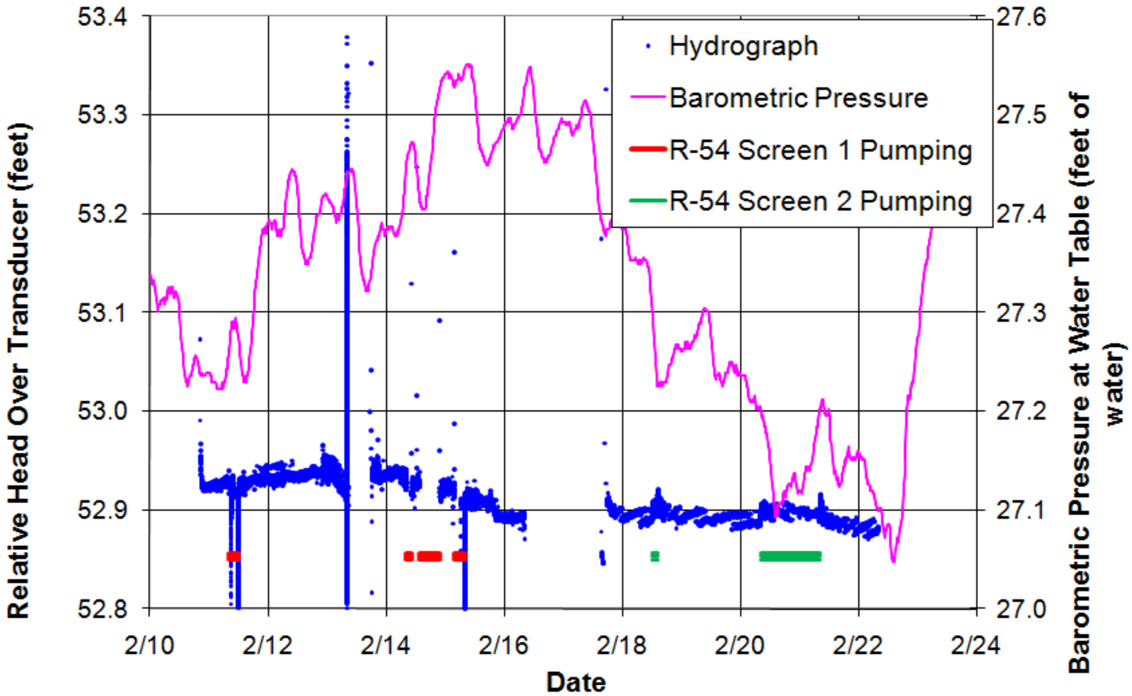

Figure C-7.0-1 Well R-54 screen 1 apparent hydrograph

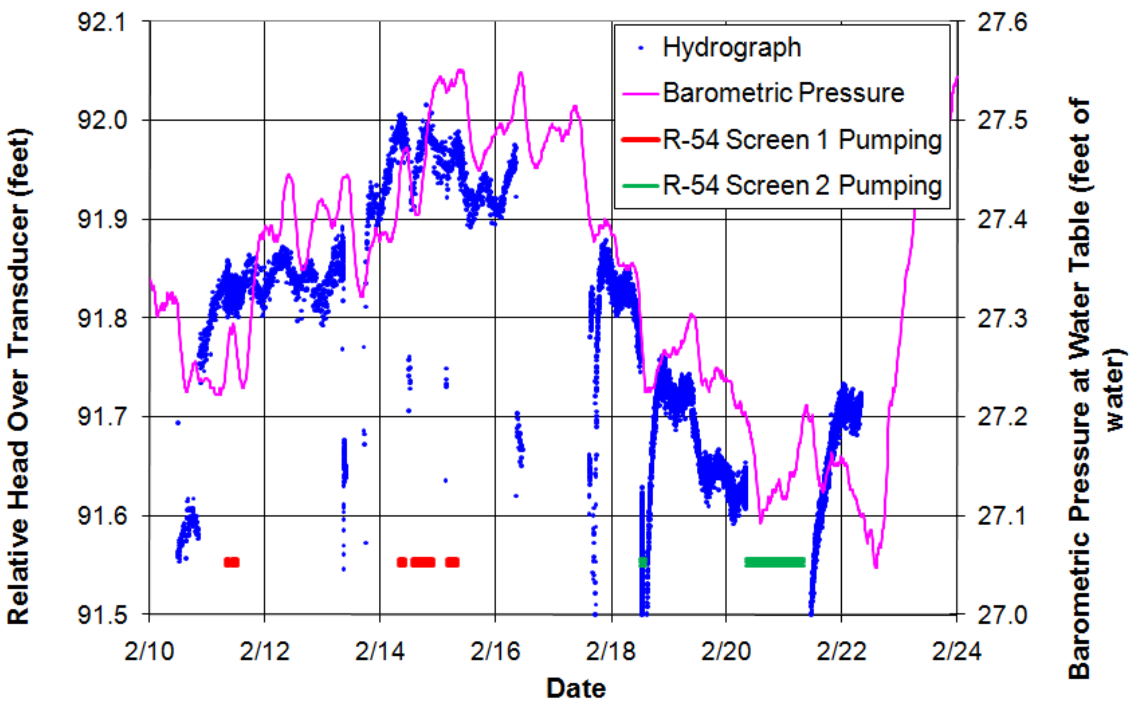

Figure C-7.0-2 Well R-54 screen 2 apparent hydrograph

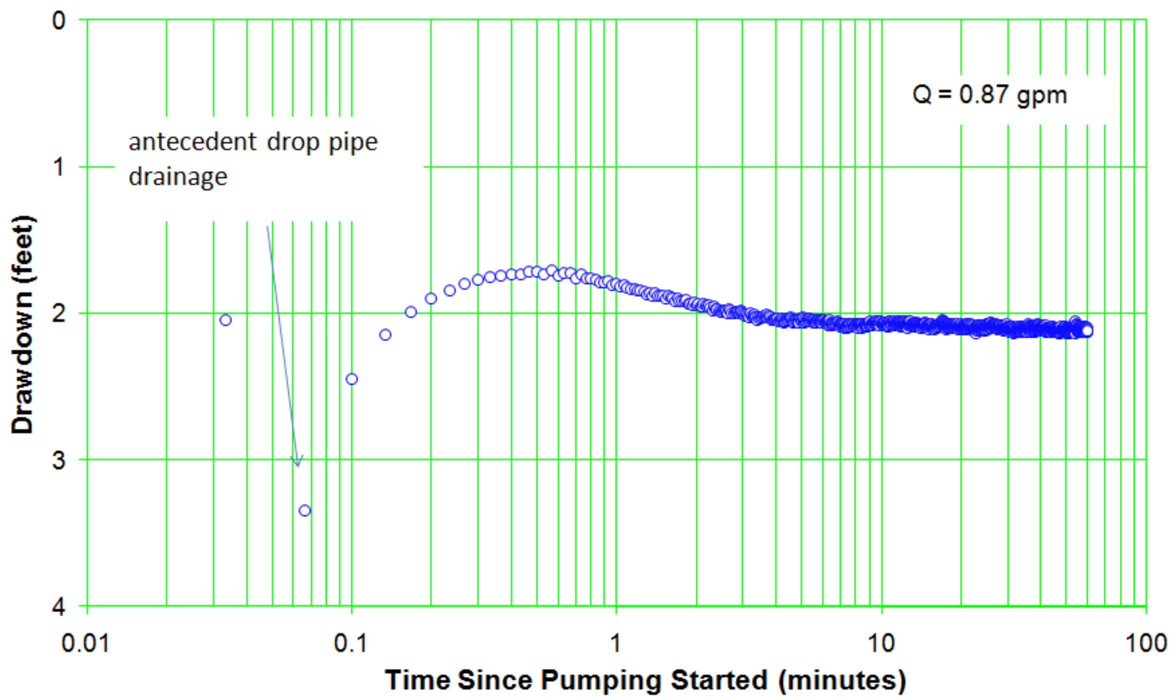

Figure C-8.1-1 Well R-54 screen 1, trial 1 drawdown

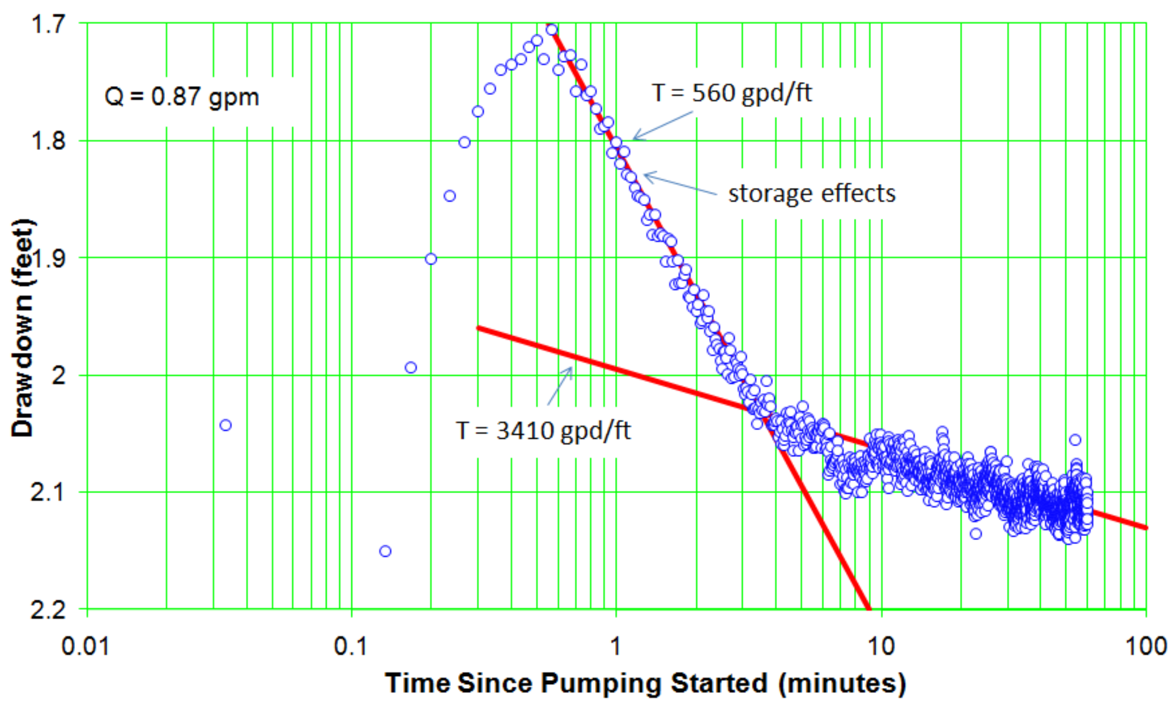

Figure C-8.1-2 Well R-54 screen 1, trial 1 drawdown – expanded scale

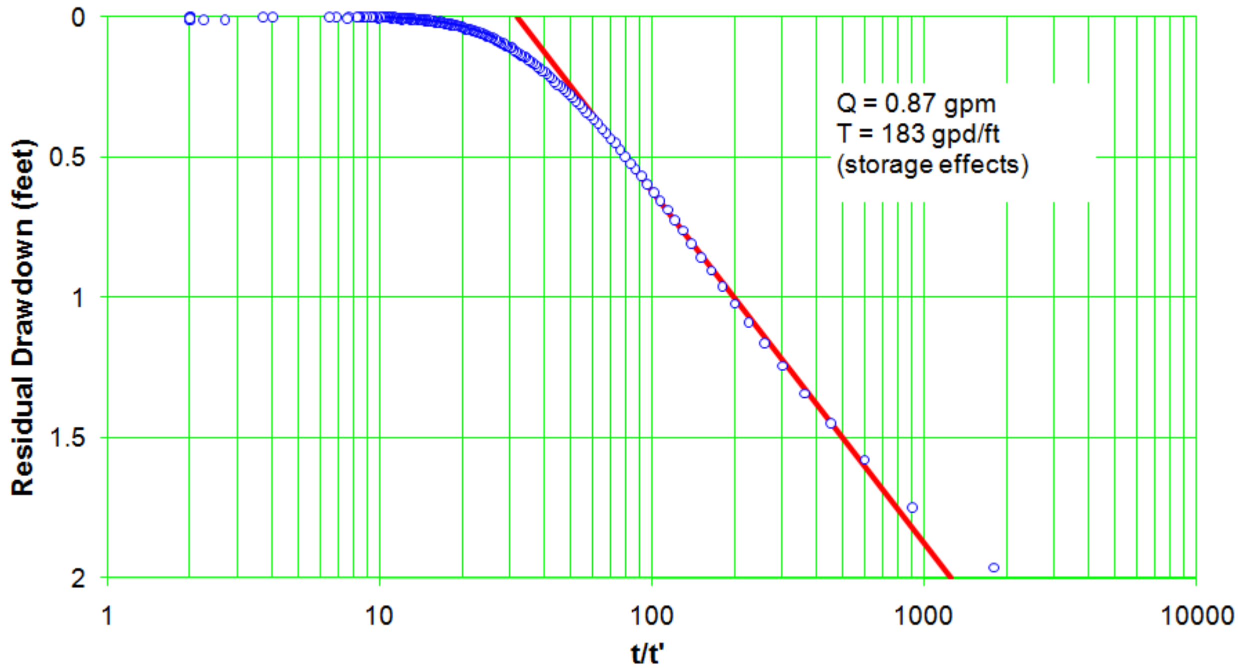

Figure C-8.1-3 Well R-54 screen 1, trial 1 recovery

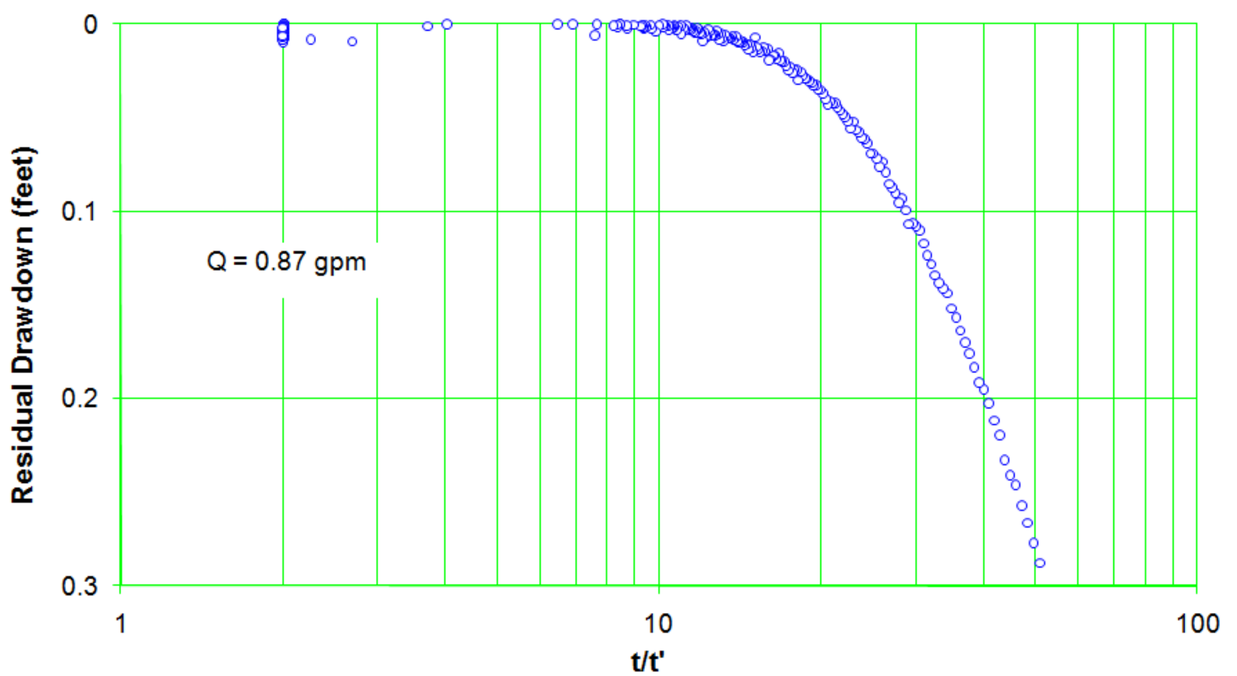

Figure C-8.1-4 Well R-54 screen 1, trial 1 recovery – expanded scale

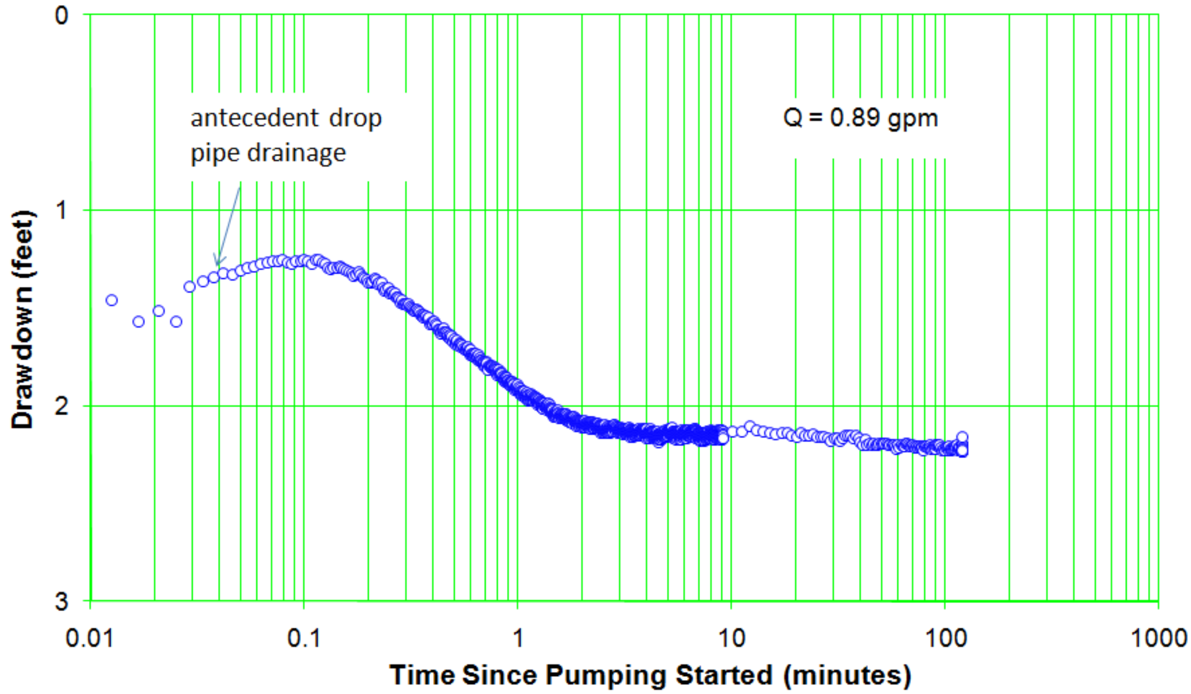

Figure C-8.2-1 Well R-54 screen 1, trial 2 drawdown

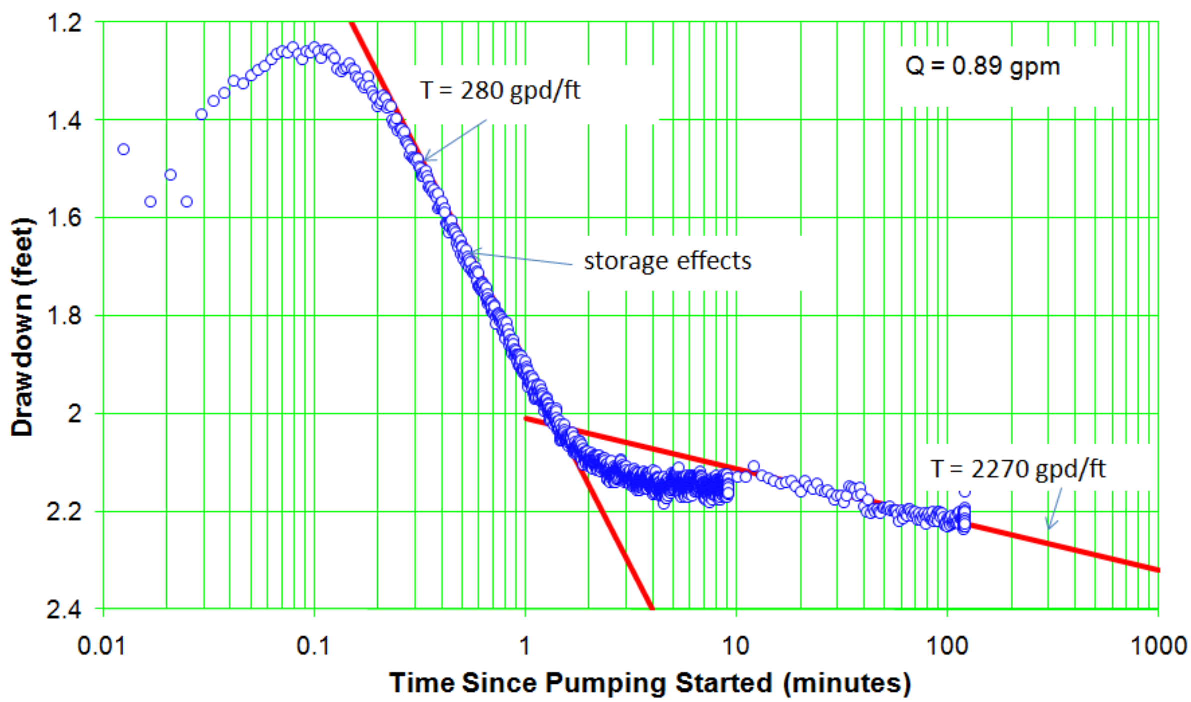

Figure C-8.2-2 Well R-54 screen 1, trial 2 drawdown – expanded scale

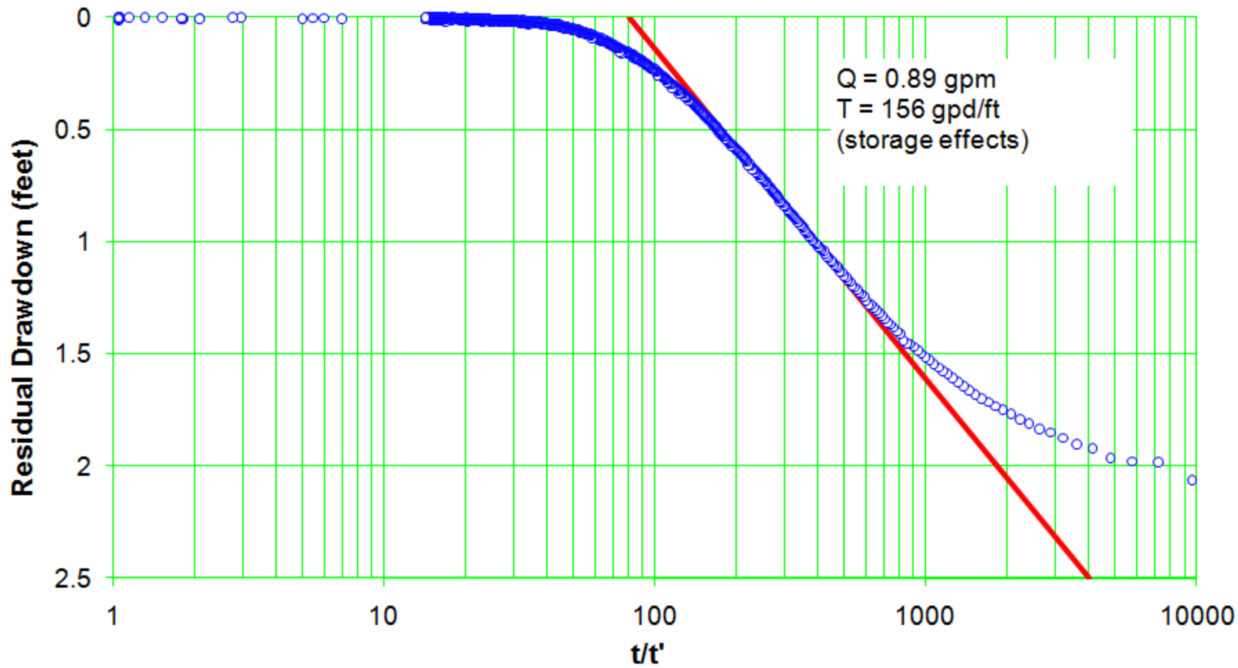

Figure C-8.2-3 Well R-54 screen 1, trial 2 recovery

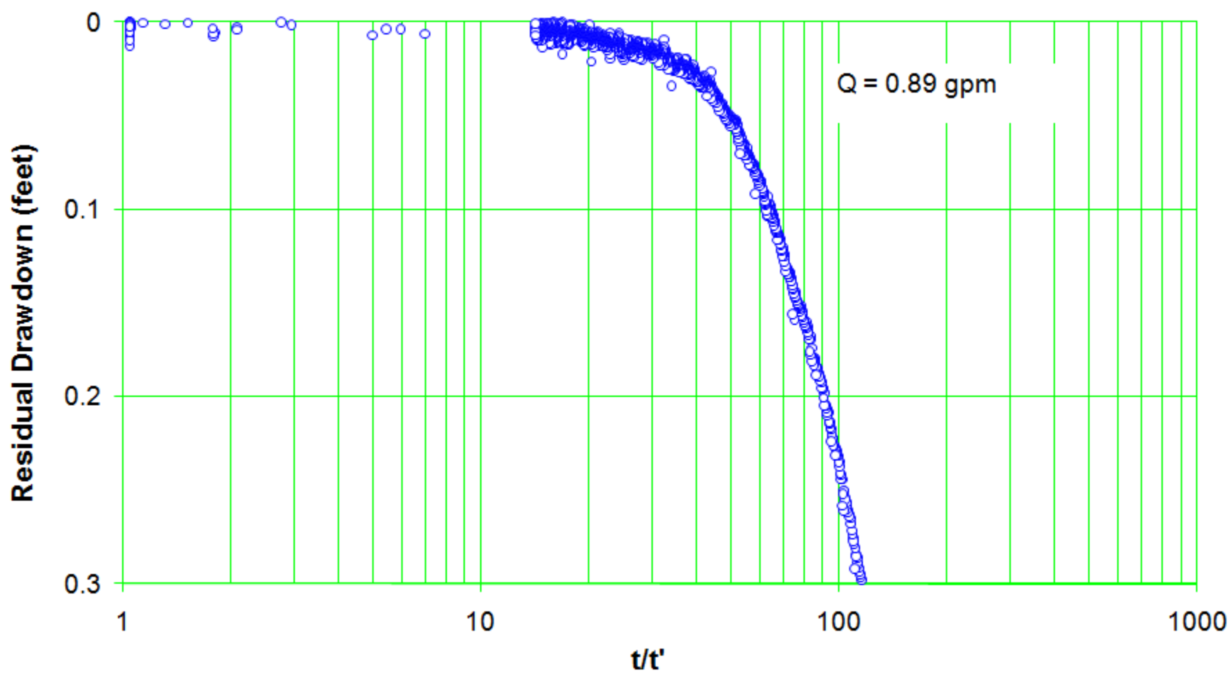

Figure C-8.2-4 Well R-54 screen 1, trial 2 recovery – expanded scale

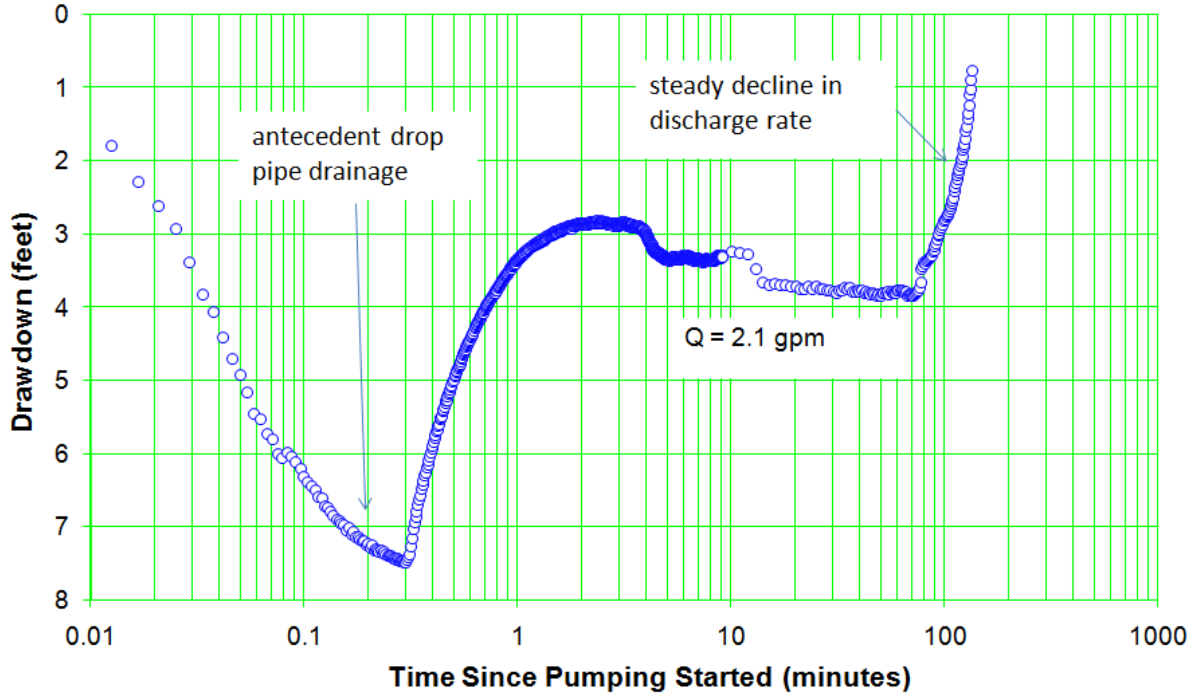

Figure C-8.3-1 Well R-54 screen 1, trial 3 drawdown

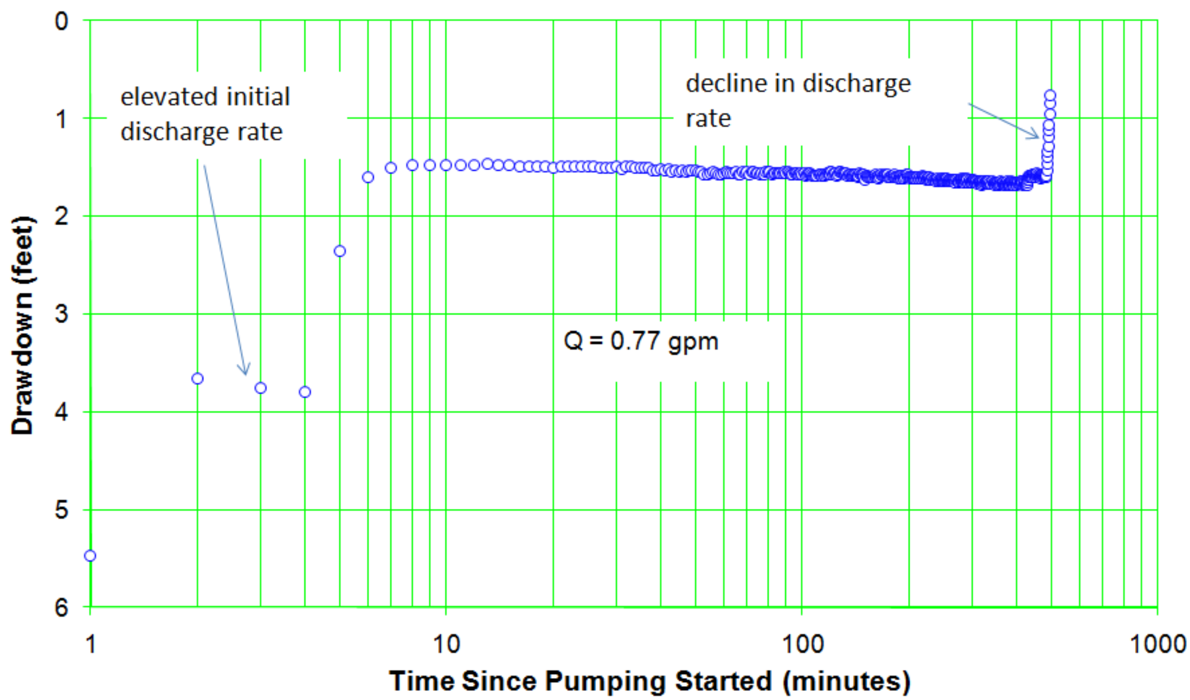

Figure C-8.4-1 Well R-54 screen 1, trial 4 drawdown

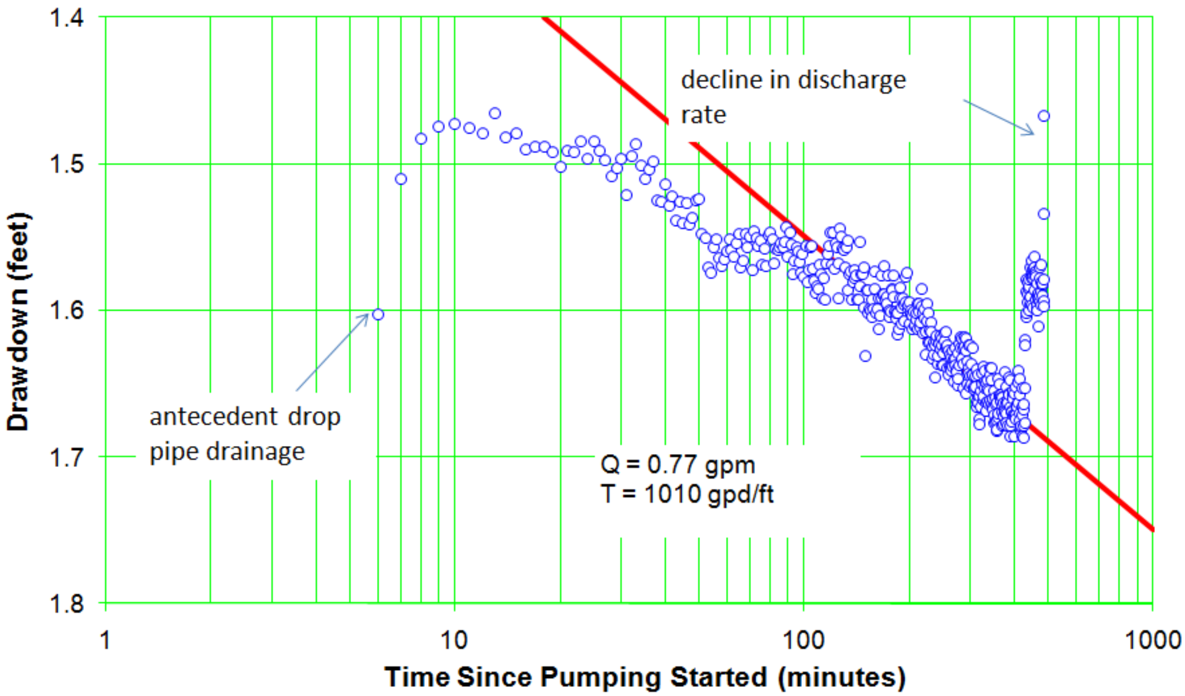

Figure C-8.4-2 Well R-54 screen 1, trial 4 drawdown – expanded scale

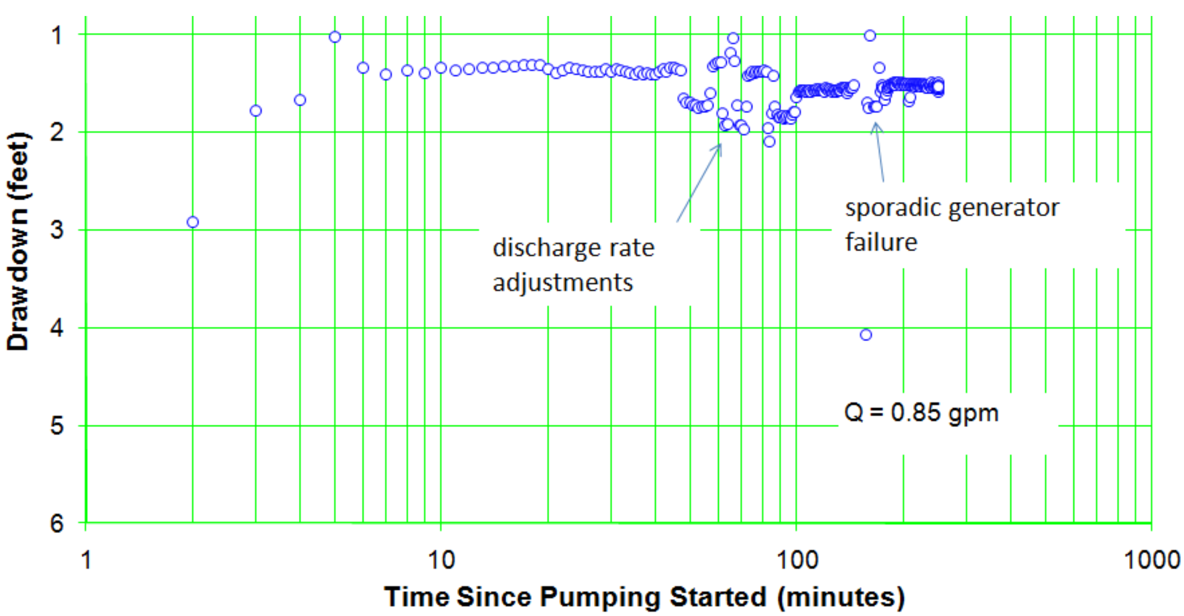

Figure C-8.5-1 Well R-54 screen 1, trial 5 drawdown

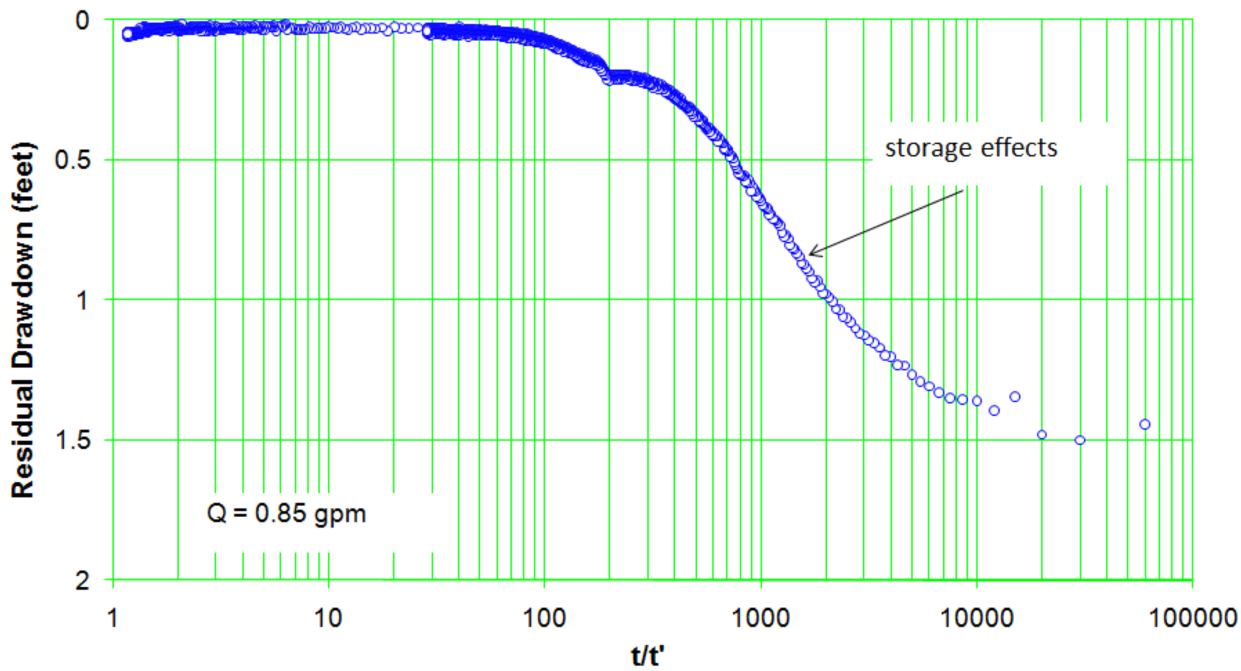

Figure C-8.5-2 Well R-54 screen 1, trial 5 recovery

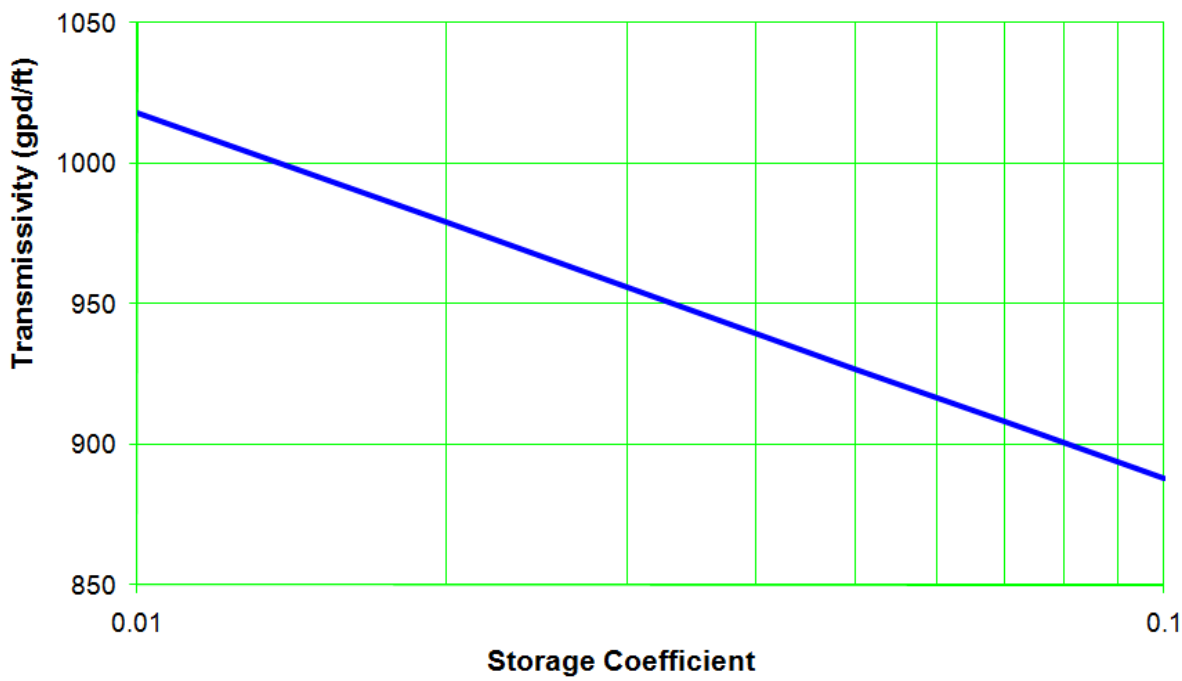

Figure C-8.6-1 Well R-54 screen 1 lower-bound transmissivity

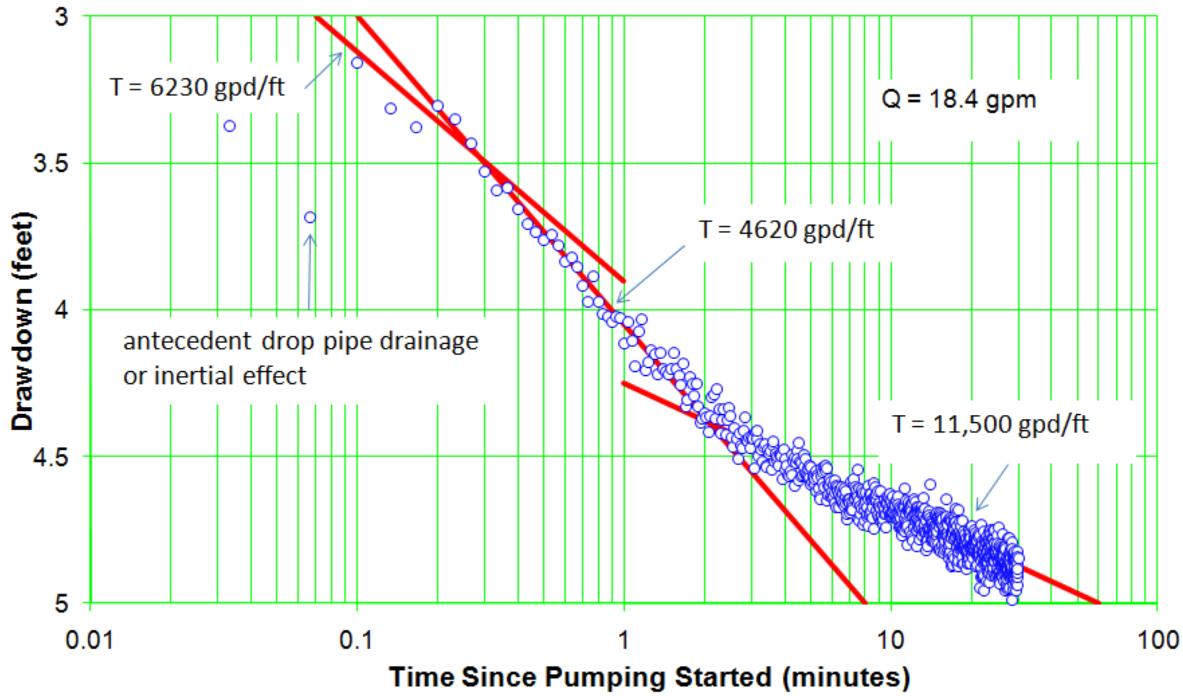

Figure C-9.1-1 Well R-54 screen 2, trial 1 drawdown

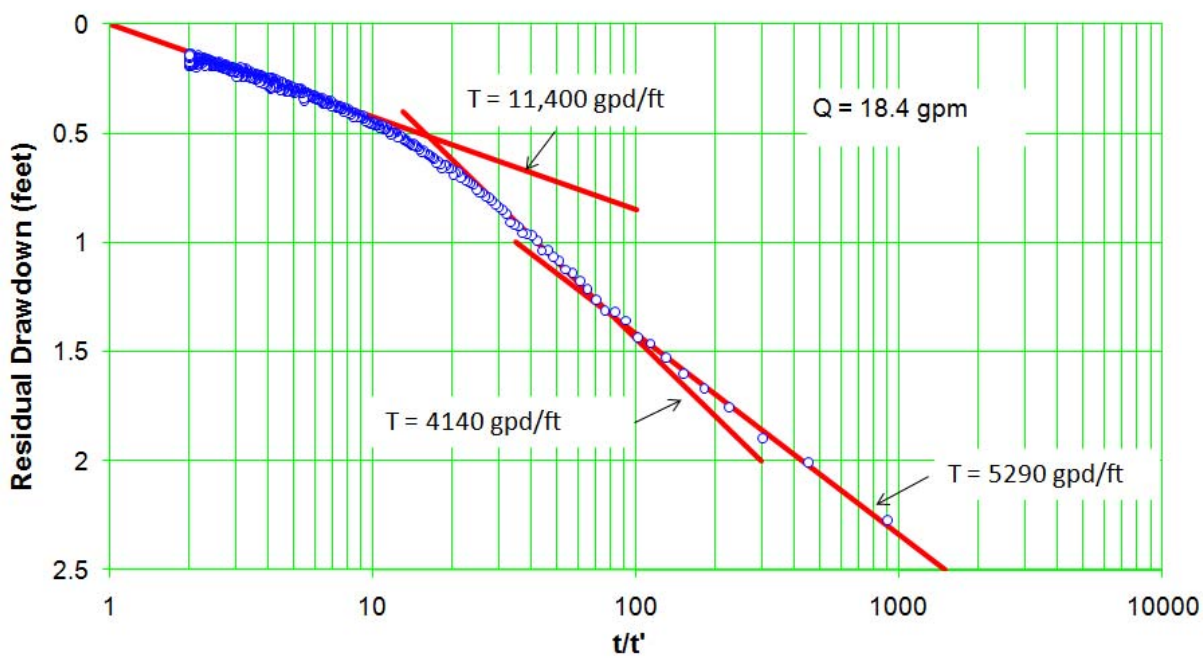

Figure C-9.1-2 Well R-54 screen 2, trial 1 recovery

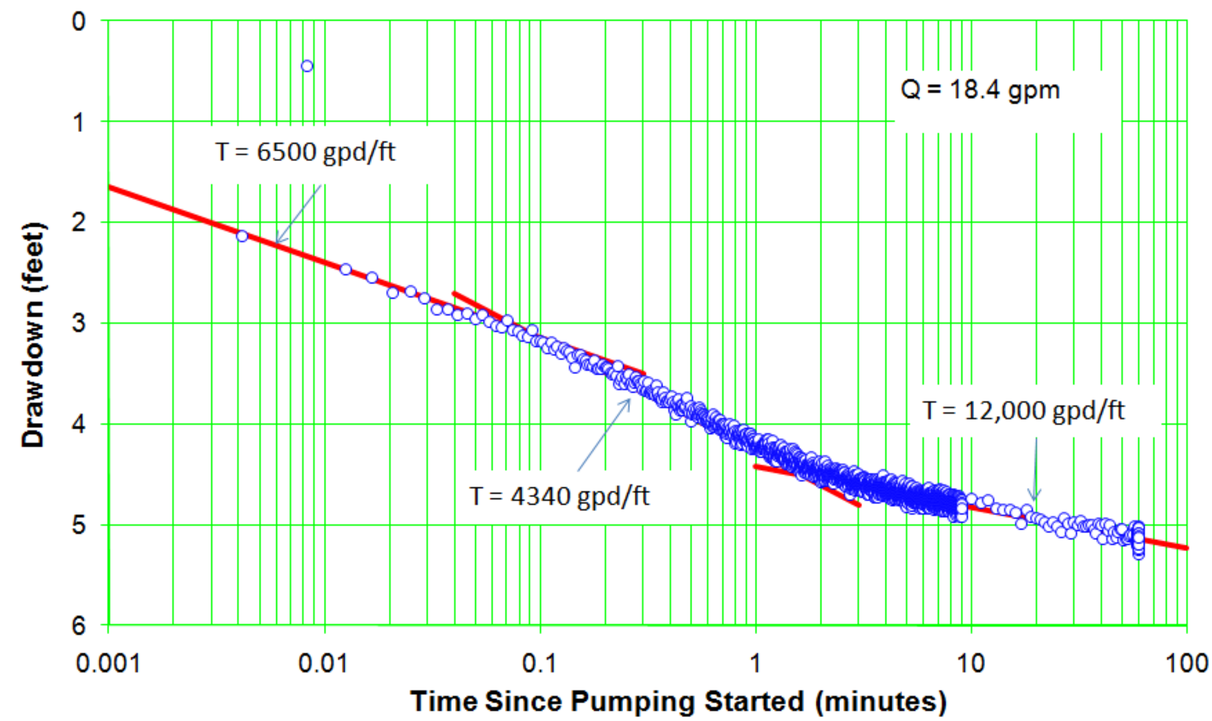

Figure C-9.2-1 Well R-54 screen 2, trial 2 drawdown

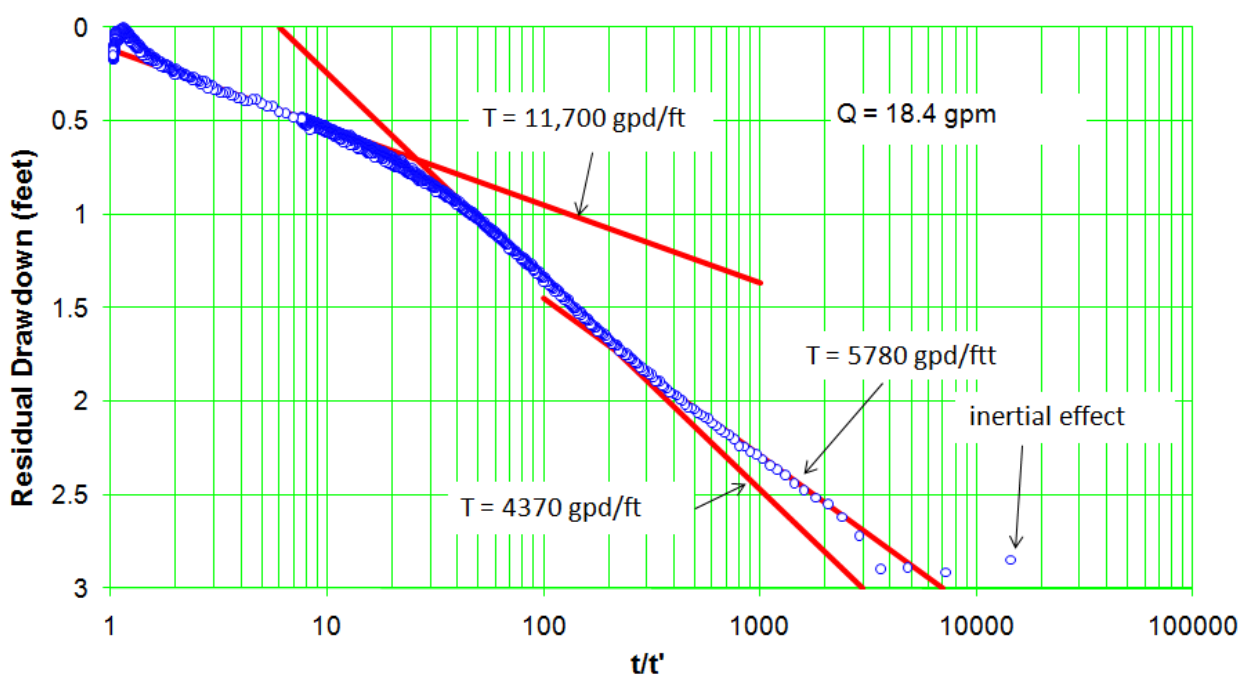

Figure C-9.2-2 Well R-54 screen 2, trial 2 recovery

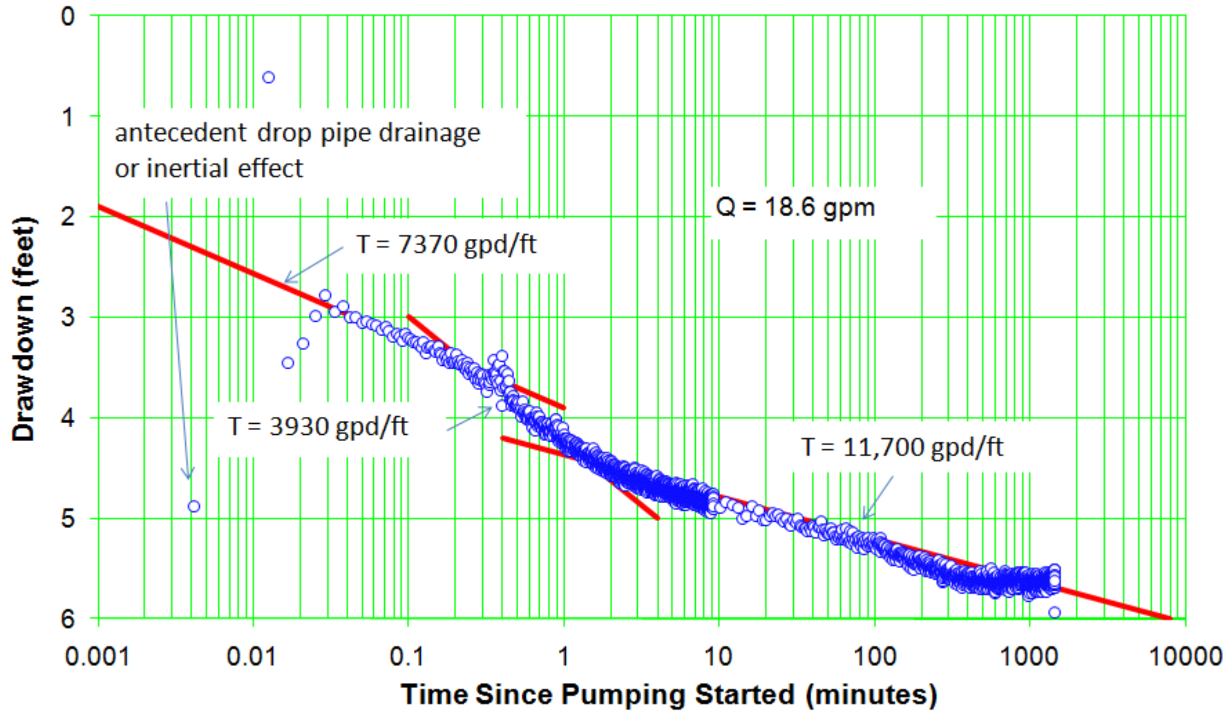

Figure C-9.3-1 Well R-54 screen 2 drawdown

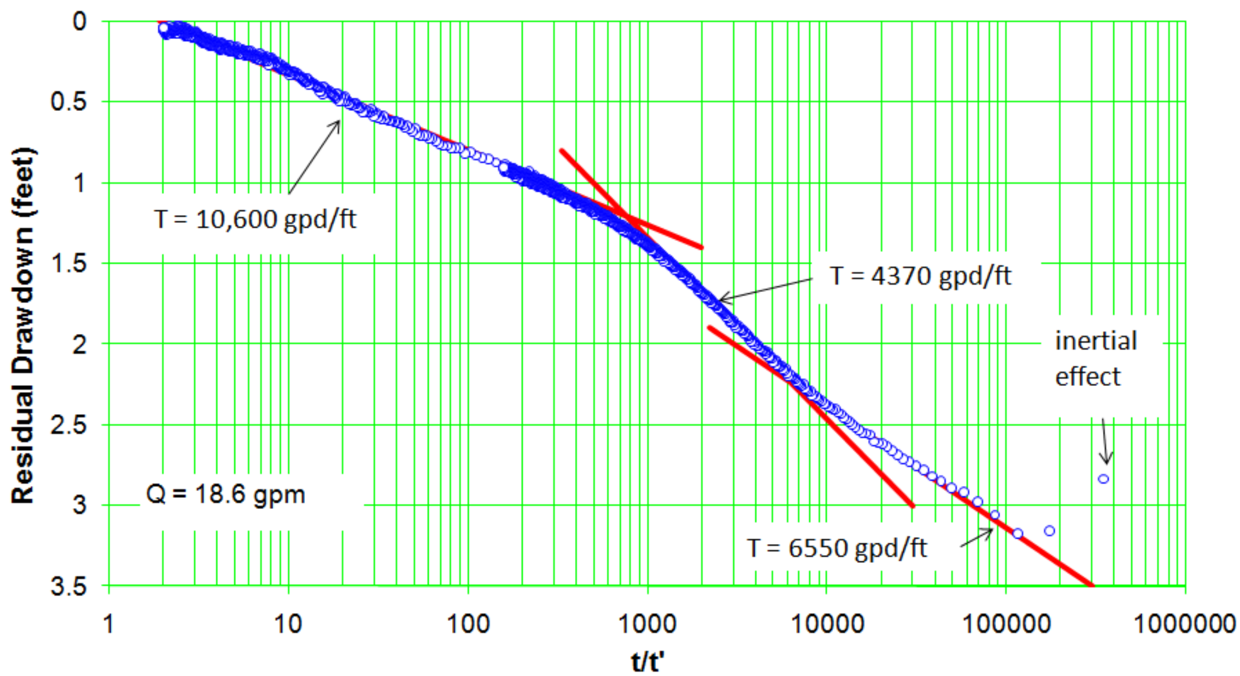

Figure C-9.3-2 Well R-54 screen 2 recovery

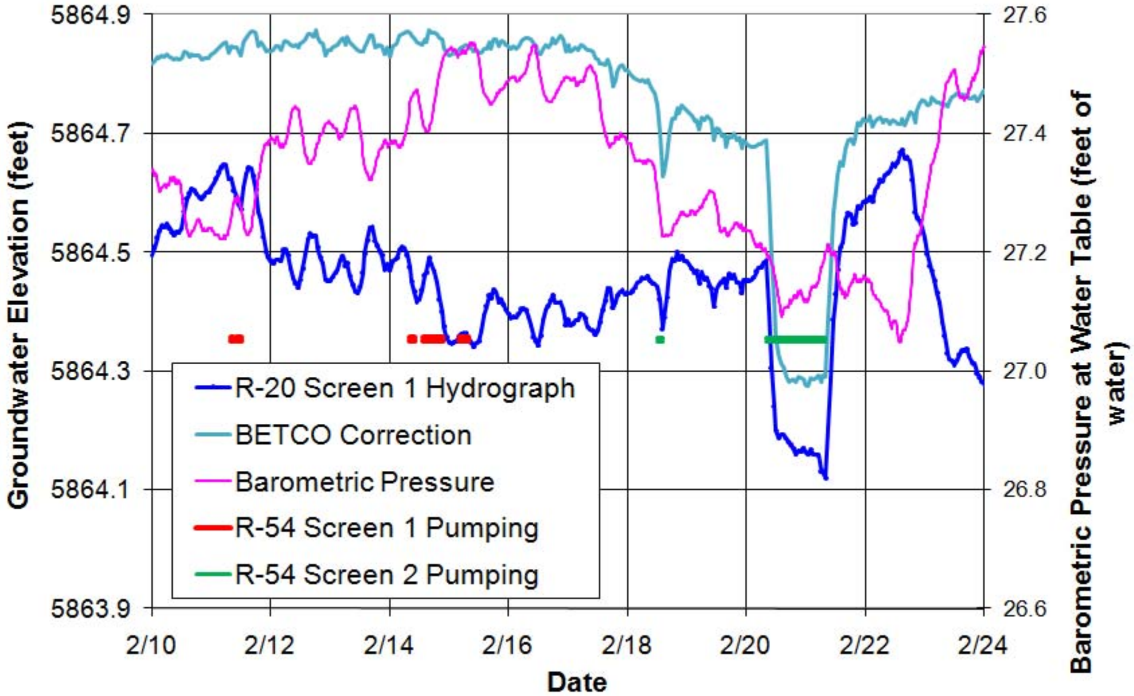

Figure C-9.3-3 Well R-20 screen 1 hydrograph

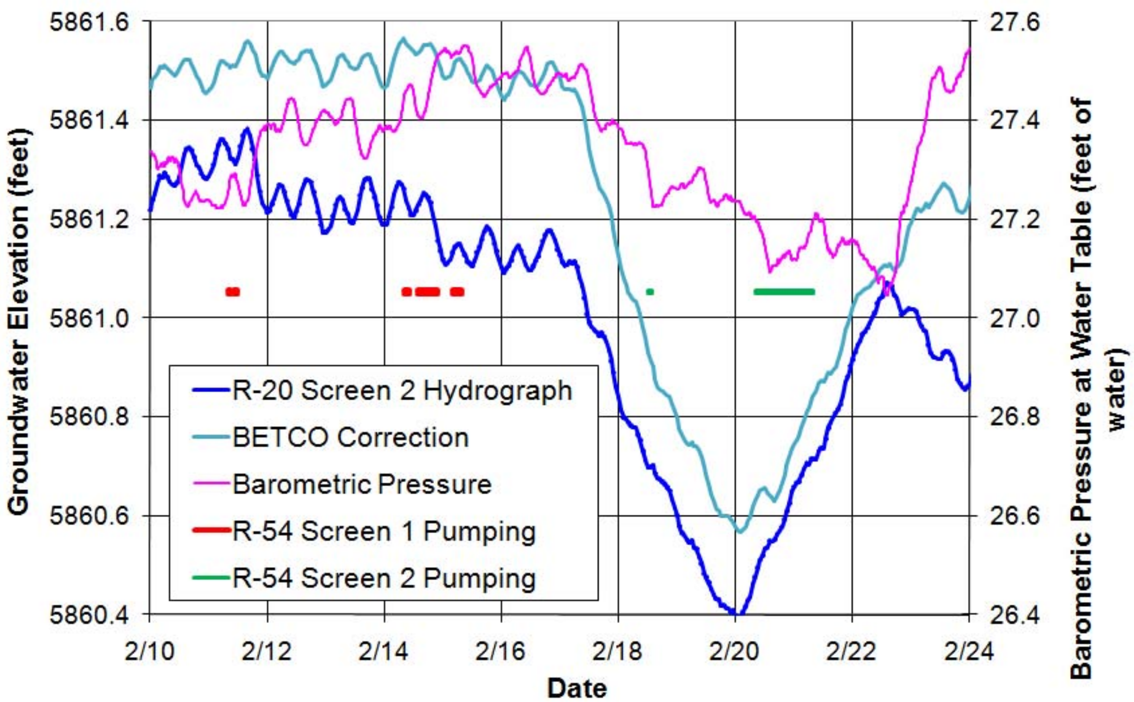

Figure C-9.3-4 Well R-20 screen 2 hydrograph

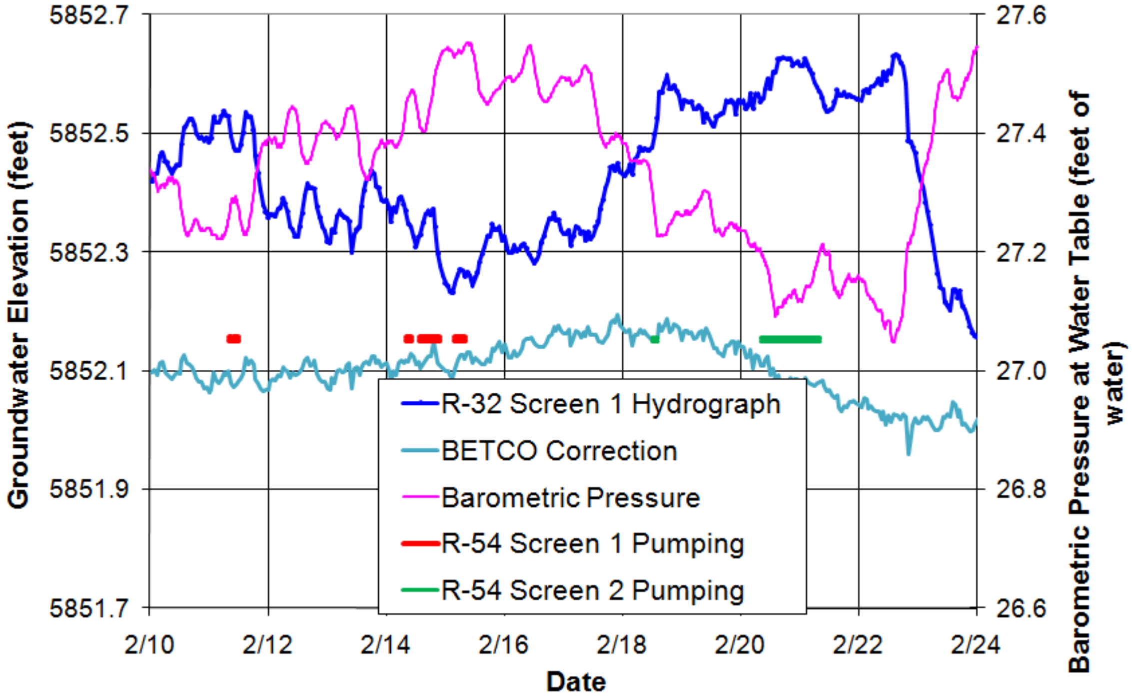

Figure C-9.3-5 Well R-32 screen 1 hydrograph

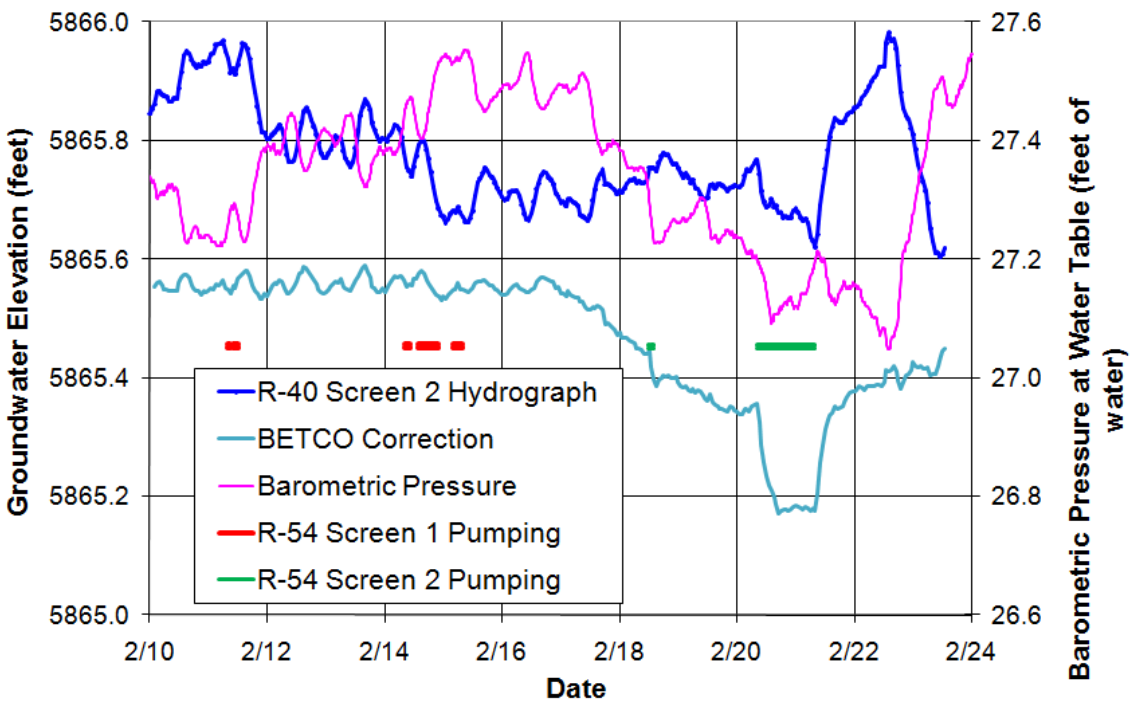

Figure C-9.3-6 Well R-40 screen 2 hydrograph

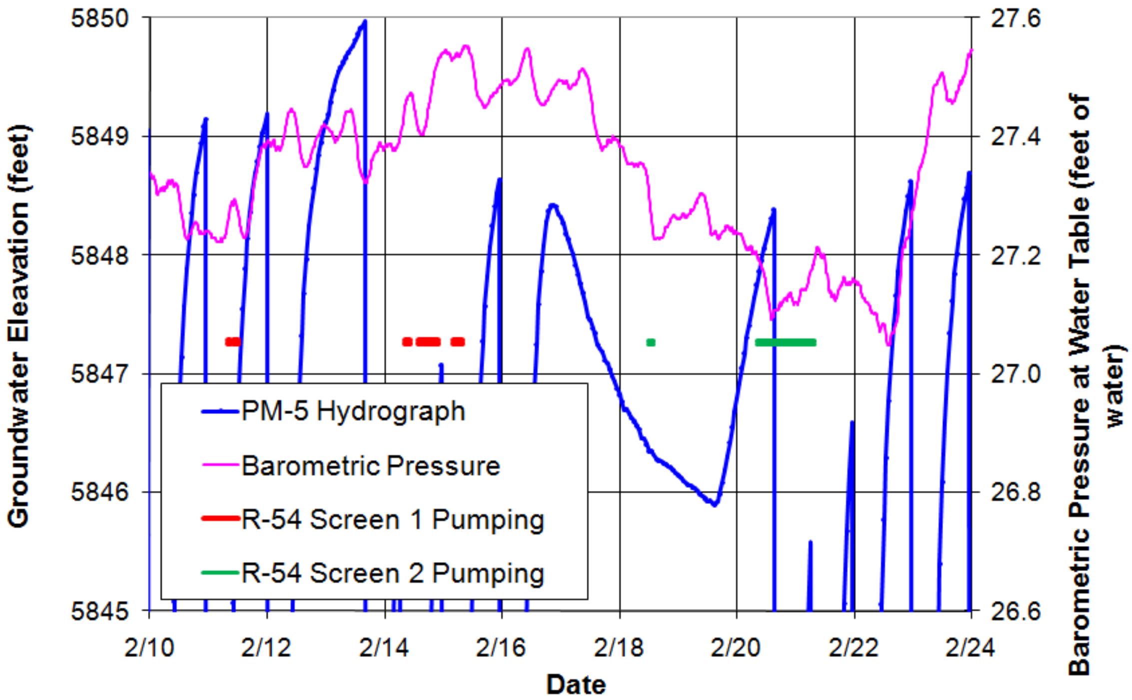

Figure C-9.3-7 Well PM-5 hydrograph

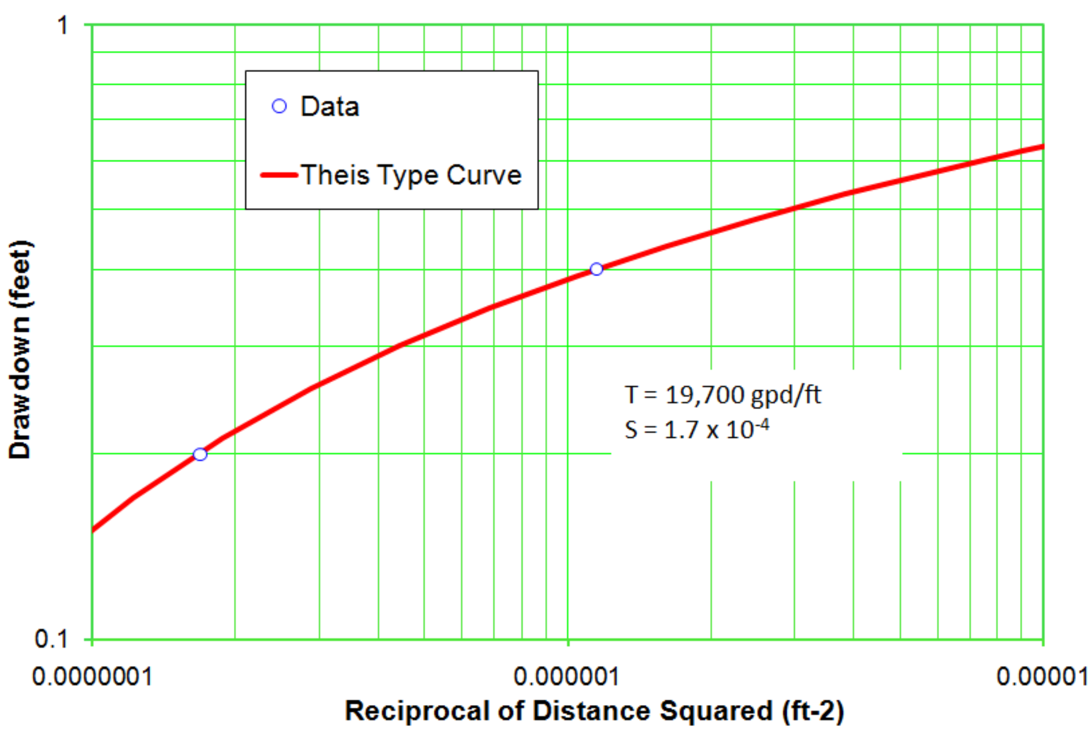

Figure C-9.3-8 Well R-54 screen 2 distance-drawdown

Table C-9.3-1
R-54 Screen 2 Transmissivity Values

Test	Early T (gpd/ft)	Middle T (gpd/ft)	Late T (gpd/ft)
Trial 1 Drawdown	6230	4620	11,500
Trial 1 Recovery	5290	4140	11,400
Trial 2 Drawdown	6500	4340	12,000
Trial 2 Recovery	5780	4370	11,700
Trial 3 Drawdown	7370	3930	11,700
Trial 3 Recovery	6550	4370	10,600
Average	6290	4300	11,500

Table C-9.3-2
Drawdown Response in R-20 and R-40

Screen Zone	Distance from R-54 (ft)	February 17−19 *s* (ft)	February 20−21 *s* (ft)
R-20 Screen 1	932	0.2	0.4
R-20 Screen 2	932	0.9	0.0?*
R-40 Screen 2	2435	0.2	0.2

*See section C-9.3.

Appendix D

Borehole Video Logging (on DVD included with this document)

Appendix E

Geophysical Logging
(on CD included with this document)