Los Alamos
NATIONAL LABORATORY
EST. 1943
Environmental Programs
P.O. Box 1663, MS M991
Los Alamos, New Mexico 87545
(505) 606-2337/FAX (505) 665-1812

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

Date: April 30, 2008
Refer To: EP2008-0116

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

Subject: Submittal of Completion Report for Regional Aquifer Well R-36

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the Completion Report for Regional Aquifer Well R-36. This report is being submitted earlier than the July 11, 2008, Compliance Order on Consent requirement and within 150 days after the proposed well completion date of December 2, 2007.

If you have any questions, please contact Mark Everett at (505) 667-5931 (meverett@lanl.gov) or Mat Johansen at (505) 665-5046 (mjohansen@doeal.gov).

Sincerely,

for Susan G. Stiger, Associate Director
Environmental Programs
Los Alamos National Laboratory

Sincerely,

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

SS/DG/PH/ME:sm

Enclosures: Two hard copies with electronic files- Completion Report for Regional Aquifer Well R-36 (EP2008-0116)

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

Cy: (Letter and CD only)
Laurie King, EPA Region 6, Dallas, TX
Steve Yanicak, NMED-OB, White Rock, NM
Mat Johansen, DOE-LASO, MS A316
Andy Crowder, TPMC
Peggy Reneau, WES-DO, MS M992
EP-LWSP File, MS M992

Cy: (w/o enc.)
Tom Skibitski, NMED-OB, Santa Fe, NM
Melanie Skeet, DOE-LASO (date-stamped copy emailed)
Susan G. Stiger, ADEP, MS J591
Alison M. Dorries, WES-DO, MS M992
Paul R. Huber, EP-LWSP, MS M992
IRM-RMMSO, MS A150

LA-UR-08-2610
April 2008
EP2008-0116

Completion Report for Regional Aquifer Well R-36

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

LA-UR-08-2610
EP2008-0116

Completion Report for Regional Aquifer Well R-36

April 2008

Responsible project leader:

Mark Everett	*[signature]*	Project Leader	Environmental Programs	4-24-08
Printed Name	Signature	Title	Organization	Date

Responsible LANS representative:

Susan G. Stiger	*[signature]*	Associate Director	Environmental Programs	4/28/08
Printed Name	Signature	Title	Organization	Date

Responsible DOE representative:

David R. Gregory	*[signature]*	Project Director	DOE-LASO	4-28-08
Printed Name	Signature	Title	Organization	Date

EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, and aquifer testing of Los Alamos National Laboratory (Laboratory) regional aquifer well R-36, which is located in Sandia Canyon, Los Alamos, New Mexico. This report was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent. This well was installed at the direction of the New Mexico Environment Department (NMED) to construct a single-screen well in the regional aquifer in Sandia Canyon near the eastern Laboratory boundary to monitor groundwater quality and to measure pumping effects from municipal production wells in the vicinity. R-36 also replaces the monitoring function of well screen #3 in the regional aquifer at nearby well R-12 that was plugged and abandoned.

The R-36 borehole was drilled using dual-rotary air-drilling methods. Drilling fluid additives used included potable water and foam. Foam-assisted drilling was used only in the vadose zone; no drilling fluid additives other than small amounts of potable water added to the air were used within the regional aquifer. Additive-free drilling provides minimal impacts to the groundwater and aquifer materials. The borehole was successfully completed to total depth using casing-advance drilling methods.

Well R-36 was completed with a screen near the top of the regional aquifer. The well is intended to act as a Laboratory boundary well to monitor the uppermost part of the regional aquifer within Santa Fe Group sediments above the Miocene basalt. A dedicated submersible pump sampling system was installed in the R-36 well, and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

The total organic carbon measurement at the end of R-36 well development was less than 0.5 ppm; the turbidity measurement was 0.0 nephelometric turbity unit. The hydraulic conductivity values calculated from the aquifer test ranged from 31.5 to 36.0 ft/d, averaging 33.5 ft/d.

The R-36 well was instrumented with a dedicated transducer to monitor hydraulic responses to pumping at production wells and to evaluate hydraulic connectivity between the top of the regional aquifer and the deeper zone that corresponds to the top of the screened intervals in nearby municipal supply wells PM-1 and PM-3. Pumping tests were performed in R-36 after well installation and development. Initial screening sample results indicate chromium concentrations at background levels.

The well was completed in accordance with an NMED-approved well design. The well was thoroughly developed, and all target water-quality parameters were achieved. Hydrogeologic testing indicated that monitoring well R-36 is highly productive and will perform effectively to meet the planned objectives.

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Acronyms and Abbreviations

3-D	three-dimensional
amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
DO	dissolved oxygen
DOE	Department of Energy (U.S.)
EES-6	Environmental and Earth Sciences
ENV-MAQ	Environmental Stewardship–Meterology and Air Quality
EP	Environmental Programs
ft/d	foot per day
gpd	gallon per day
gpm	gallon per minute
ICPOES	inductively coupled (argon) plasma optical emission spectroscopy
ICPMS	inductively coupled (argon) mass spectrometry
ID	identification
I.D.	inside diameter
IDW	investigation-derived waste
IWD	integrated work document
LANL	Los Alamos National Laboratory
µg/L	microgram per liter
µm	micrometer
µS/cm	microsiemen per centimeter
mgC/L	milligram carbon per liter
mV	millivolt
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxygen-reduction potential
PVC	polyvinyl chloride
Qal	Quaternary alluvium
Qbo	Quaternary Otowi Member of the Bandelier Tuff
Qbog	Quaternary Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
RCT	radiation control technician
RPF	Records Processing Facility
SWL	static water level
TA	technical area
Tb 4	Tertiary Cerros del Rio basalt
TD	total depth
TOC	total organic carbon
Tpf	Tertiary Puye formation
Tsfu	Tertiary Santa Fe Group undifferentiated
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development, aquifer testing, and related activities for monitoring well R-36 and was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent (the Consent Order). Well R-36 was drilled and completed from October 2007 to February 2008 at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate Water Stewardship Project.

The R-36 project site is located in Sandia Canyon on the south side of East Jemez Road (the Los Alamos Truck Route) within Technical Area 72 (TA-72) in Los Alamos County, New Mexico (Figure 1.0-1). The purposes of the R-36 monitoring well are to assess whether chromium and other possible contaminants are present in the regional aquifer east of an area of known chromium contamination at well R-28, to monitor water levels within the regional aquifer, and to measure pumping effects from municipal production wells in the vicinity. R-36 also provides groundwater monitoring near the eastern Laboratory boundary, replacing the function of the regional aquifer well screen at R-12 that was plugged and abandoned because of unreliable water-quality data and unrepresentative aquifer conditions in the Miocene basalt.

The primary objective was to drill and install a single-screened regional aquifer monitoring well in the upper portion of the regional aquifer.

The R-36 borehole was successfully drilled to a total depth (TD) of 865 ft below ground surface (bgs). A monitoring well was installed with a screened interval between 766.9 and 789.9 ft bgs. The depth to water after well installation and well development was 749.1 ft bgs. Cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. Postinstallation activities included well development, aquifer testing, surface completion, dedicated sampling system installation, and geodetic surveying. Ongoing activities include waste management and site restoration.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of all activities associated with R-36 project, as well as supporting figures, tables, and appendixes.

2.0 PRELIMINARY ACTIVITIES

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

2.1 Administrative Preparation

The following documents were used to support the implementation of the scope of work for this well: "Drilling Work Plan for Regional Aquifer Well R-36" (LANL 2007, 098122); "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling" (LANL 2007, 100972); "Storm Water Pollution Prevention Plan Addendum" (LANL 2006, 092600); "Waste Characterization Strategy Form (WCSF) for the R-36 Monitoring Well Installation" (LANL 2007, 100969); and "WCSF, Amendment 1, R-36 Monitoring Well Installation" (LANL 2007, 101151).

2.2 Site Preparation

Site preparation was performed between October 11 and 20, 2007, and included clearing and grading a drill pad and access road; excavating and lining a cuttings containment pit; and installing berms, silt fencing, and straw waddles to control stormwater runoff and prevent erosion. The drill pad dimensions are approximately 150 ft × 100 ft and were covered with base course. The access road was 400 ft long and was also covered with base course. A gate was installed to control access to the R-36 drill site. The cuttings pit measured approximately 60-ft × 40-ft × 8-ft average depth. Radiation control technicians (RCTs) from the Laboratory's Radiation Protection Group-1 performed radiological screening of the site and construction equipment as required.

Office and supply trailers, generators, and general field equipment were moved on-site after mobilization of drilling equipment. Potable water was obtained from the East Jemez Road overhead fill stand and a fire hydrant near the Los Alamos County landfill. Safety barriers and signs were installed around the borehole cuttings containment pit and along the perimeter of the work area.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and provides a chronological summary of field activities conducted at monitoring well R-36.

3.1 Drilling Strategy

The drilling strategy for R-36 was developed to drill the borehole to TD without the use of mud-rotary methods. The drilling strategy chosen to complete R-36 also considered the potential for encountering perched groundwater within or beneath the Cerros del Rio basalt. If perched groundwater was encountered at R-36, the goal was to isolate and seal off the perched zone with casing to avoid commingling perched groundwater with the regional aquifer. The selection of drilling equipment and drill-casing sizes was designed to ensure successful completion of the borehole, while retaining the ability to case off perched groundwater, and to reach TD with a sufficiently sized casing to allow for the required minimum annular thickness of the filter pack.

Dual-rotary drilling techniques and a Foremost DR-24HD drill rig were employed to drill the R-36 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, one deck-mounted 900 ft^3/min air compressor, and general drilling equipment. Auxiliary equipment included two Wagner 1150 ft^3/min trailer-mounted air compressors. Three sizes of flush-welded mild carbon-steel casing were used on the R-36 project: 16-in.-inside diameter (I.D.), 12-in.-I.D., and 10-in.-I.D. The dual-rotary method uses air and fluid-assisted air to evacuate cuttings from the borehole. Drilling fluids used in the vadose zone included municipal water and a mixture of municipal water with Baroid AQF-2 foaming agent. The fluids were used to cool the bits and lift cuttings from the borehole. An estimated cumulative total of drilling fluids introduced into the borehole and the total fluids recovered are presented in Table 3.1-1. No additives other than municipal water were used for drilling within the regional aquifer.

3.2 Chronological Drilling Activities

Between October 11 and 13, 2007, drilling equipment and supplies were mobilized to the site. On October 21, 2007, the R-36 borehole was initiated with dual-rotary methods using 16-in. casing and a 15-in. conventional hammer bit. On October 23, 2007, the 16-in. casing was advanced through the alluvium and the Otowi Member of the Bandelier Tuff and landed at 201.5 ft bgs, 6.5 ft into the top of the Cerros del Rio basalt. Drilling continued below the top of the Cerros del Rio basalt using openhole drilling methods with the 15-in. hammer bit.

Seven days of production were lost between October 25, 2007, and October 31, 2007, because of technical and mechanical problems. Mechanical problems were associated with the drill rig's hydraulic systems. After several days of troubleshooting, the rig's main top-head cylinder and primary hydraulic pump were replaced.

Drilling in the Cerros del Rio basalt resumed on November 1, 2007, but severe, adverse geologic conditions impeded progress. After advancing the borehole to 242 ft bgs, the 15-in. hammer bit was removed for examination because of poor penetration rates. Visual inspection revealed that the outer carbide (gauge) buttons were sheared off the bit. On November 2, 2007, a Laboratory downhole video camera was run in the borehole, and highly fractured basalt was observed between 203 and 220 ft bgs and below 238 ft bgs. The drilling contractor had two 15-in. hammer bits on-site (one used and one new). The used 15-in. bit was employed in the upper portion of the borehole to install the 16-in. casing through the alluvium and tuff. The new 15-in. bit was employed for openhole basalt drilling below the 16-in casing and was completely destroyed after approximately 41 ft of drilling. The used bit was reinstalled, and openhole drilling continued from 242 ft bgs. The borehole was advanced only to 260 ft bgs before the bit was again removed for examination because of continued poor penetration rates. Visual inspection revealed that eight carbide buttons were sheared off the outside of the bit, rendering it out of gauge. A new 15-in. bit was express-shipped and delivered on November 5, 2007. The borehole was slowly reamed back to 260 ft bgs with the new bit to ensure the borehole diameter was to gauge.

On November 6 and 7, 2007, the borehole was advanced to 315 ft bgs with no air circulation or returns below 310 ft bgs. Drilling below 310 ft bgs was increasingly difficult, as indicated by the driller's reports of multiple large fractures and basalt rubble falling on top of the tools. The tool string was removed and the Laboratory downhole camera was run in the borehole. Video images showed abundant open fractures in the basalt from 201.5 to 298 ft bgs and a distinct rubble zone from 298 to 304 ft bgs. The borehole had sloughed below 304 ft bgs with coarse rubble. There was no evidence of perched groundwater in the upper portion of the Cerros del Rio basalt, and the decision was made to cement the upper portion of the basalt to stabilize this interval and aid drilling progress.

Two loads of neat (no aggregate) Portland cement were delivered to the site on November 8, 2007. The first delivery of 3 yd^3 filled the bottom of the borehole to 303 ft bgs. The second delivery of 8 yd^3 filled the borehole through the entire basalt interval to 136 ft bgs. The cemented interval was allowed to cure for 24 h and was drilled out on November 9 and 10, 2007. Cement cuttings were contained in a 20-yd^3 rolloff box staged on the drill pad. Cementing the borehole stabilized the formation and drilling operations; progress returned to normal conditions on November 11, 2007, when the borehole was advanced from 315 to 515 ft bgs. Circulation was poor above 345 ft bgs, and a large fracture was encountered between 420 and 425 ft bgs, but geologic conditions below the cement stabilizing plug did not affect progress.

The bottom of the Cerros del Rio basaltic lavas was encountered at 537 ft bgs, and the borehole was advanced to 700 ft bgs before the tools were pulled on November 12, 2007. Injection of AQF-2 drilling foam was stopped at 700 ft bgs. Drilling observations indicated evidence of perched groundwater in a thin interval between 590 and 620 ft bgs. Borehole video logs and geophysical tools (natural gamma ray and induction) were then run in the open borehole using Laboratory equipment on the evening of November 12, 2007, and again on the morning of November 13, 2007. Standing water was measured in the borehole at 571.7 ft bgs after the tools were removed on November 12, 2007, and at 571.9 ft bgs on November 13, 2007. During the logging operations, the bottom of the borehole sloughed to 575 ft bgs.

The sloughing was likely a result of formation instability caused by the saturated, poorly consolidated sediments in the perched groundwater zone.

Three unsuccessful attempts were made to collect a groundwater sample by bailing methods. Returns from the bailer consisted only of wet sand. The abundance of sand in the bottom of the borehole prevented the bailer's check valve from sealing. On November 13, 2007, a 15-in. tricone bit was used to clean out the borehole to 700 ft bgs, and a perched groundwater sample was air-lifted through the tool string. After the borehole was cleaned out to 700 ft bgs, the tools were pulled up to 500 ft bgs to prevent the drill string from becoming stuck in the borehole. On November 14, 2007, the bottom of the borehole was again found to be sloughed-in to 575 ft bgs. Another water sample (collected at 577 ft bgs) was air-lifted through the tool string, and the tools were removed from the borehole. Cleaning the borehole to 700 ft bgs was performed to obtain an extensive geophysical log in the open borehole. After several attempts, this effort was discontinued because the borehole would not stay open below 575 ft bgs, and there was risk of losing the drill string.

After unsuccessful attempts to establish an open borehole to 700 ft bgs, the drive shoe was cut off the 16-in. casing, and sealing off the perched water zone with 12-in. casing started. Sealing off the perched water interval was accomplished with 12-in. casing and two separate bentonite chip seals. The upper seal was installed from 570 to 575 ft bgs, although the amount of bentonite installed (twenty-eight 50-lb bags) indicated that the seal pushed down through the slough and was effectively longer than 5 ft. A 3.5-ft cement plug was installed inside the bottom of the 12-in. casing to prevent bentonite from entering the casing. This technique forces the bentonite into the annular space between the 12-in. casing and the 15-in. borehole. The 12-in. casing string was sealed on November 17, 2007.

On November 18, 2007, the cement plug was drilled out, and the 12-in. casing was advanced with dual-rotary methods and a 10-in. tricone bit. The 12-in. casing was advanced to 705 ft bgs on November 19, 2007. The tools were removed from the borehole, the 12-in. casing was retracted 5 ft, and the lower bentonite seal was installed. The casing was then rotated back down into the lower seal. Drilling was paused for Thanksgiving break between November 20 and November 25, 2007.

After the pause in drilling, no standing water in the borehole was indicated by water-level measurements with an electronic sounder and air circulation returns before drilling resumed, confirming that the perched zone was sealed off. The borehole was then advanced to 707 ft bgs, and the borehole was again checked to ensure that the perched groundwater was sealed off before running the 10-in. casing. Hanging and welding the 10-in.casing string occurred on November 27 and 28, 2007. Water-level measurements indicated there was no water in the bottom of the borehole and that the perched water interval continued to be successfully sealed off.

Drilling resumed on November 29, 2007, with 10-in. casing, a 10-in. tricone bit, and conventional dual-rotary methods with no drilling fluid additives; no drilling additives other than municipal water and air were introduced in the R-36 borehole below 700 ft bgs. The top of the regional aquifer was encountered on November 29, 2007. Water-level measurements on November 30, 2007, and December 1, 2007, recorded the top of water at 748.6 ft bgs and 749.9 ft bgs, respectively. TD was reached at 865 ft bgs on November 30, 2007. One additional water sample was collected through the drilling tools, and the tools were removed from the borehole on December 1, 2007.

The R-36 borehole was originally planned to TD on top of the Miocene-age basalt below the Santa Fe Group sediments. On November 30, 2007, the Laboratory indicated that the borehole would be terminated at 865 ft bgs in the Santa Fe Group. The long-term monitoring objectives for the R-36 well dictated it would be screened in the upper portion of the regional aquifer, which made it unnecessary to drill deeper.

The drive shoe on the 16-in. string of steel casing was cut off and dismembered from the casing to facilitate casing extraction during well construction. The drive shoe is a small piece of steel, but the casing was cut well above the shoe to ensure that the dismembered piece remained aligned with the borehole. The 16-in. drive shoe is located in the borehole at 188.5–201.5 ft bgs (13.0 ft). The drive shoe section was isolated in bentonite during well construction activities. Because of the unconsolidated nature of the Santa Fe Group at this location, the 10-in. and 12-in. casing strings were retracted with the drive shoes still attached, so no casing remains in the borehole from 10-in. and 12-in. casing strings.

The field crew generally worked one 12-h shift per day, 7 d/wk. Field activities were suspended for Thanksgiving (November 20 to November 25, 2007) and at Christmas (December 21, 2007, to January 3, 2008). Operations sustained few weather delays throughout the duration of the project. Numerous technical delays were incurred, mostly because of the fractured nature of the upper portion of the Cerros del Rio basalt. Several mechanical delays stalled progress because the dual-rotary rig experienced hydraulic problems that were difficult and time-consuming to repair.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities at Well R-36. All sampling activities were conducted in accordance with all applicable Laboratory procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-36 borehole at 5-ft intervals from ground surface to the TD of 865 ft bgs. At each interval, approximately 500 mL of bulk cuttings was collected from the discharge hose, sealed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected and placed in chip trays along with unsieved (whole rock) cuttings. The sieved fractions were also collected from ground surface to 865 ft bgs. The RCTs screened all cuttings before they were removed from the site.

Drilling and sample collection methods used at R-36 did not retain a majority of the fine fraction (silt and clay) of the drill cuttings, and much of the fine material throughout the borehole stratigraphy was lost. This effect was particularly evident with increasing depth and in the unconsolidated units below the Cerros del Rio basalt. The foaming agent helped to retain the fines and acquire more representative samples in the intervals where it was used; however, below 700 ft bgs, acquiring samples with representative grain-size distribution became problematic. The volume of compressed air required for nonmud-rotary methods made catching samples difficult because large pits are necessary to contain discharged water. Site geologists manually collected samples with a wire mesh basket directly from the discharge hose, and discharge velocities forced the fine fraction of sample through the basket. Nevertheless, recovery of the coarser fraction of the cuttings samples was excellent in nearly 100% of the borehole. The borehole log for R-36 is presented in Appendix A.

4.2 Water Sampling

Groundwater-screening samples were collected from the drilling discharge hose at 20-ft intervals from the top of regional aquifer to the TD of 865 ft in the R-36 borehole. Typically, upon reaching the bottom of a 20-ft run of casing, the driller would stop water circulation (if injecting water) and circulate air to clean out the borehole. As the discharge cleared, a water sample was collected directly from the discharge hose. Not all depth intervals below the top of the regional groundwater table could be captured at the end of each casing run. Alternatively, some water samples were collected upon start-up of the next casing run after the borehole equilibrated.

Perched groundwater samples were collected by air-lifting a water sample through the drill string. Although many attempts were made to collect samples, only two adequate perched groundwater samples were collected and analyzed.

Regional groundwater samples were also collected at regular durations (one sample per hour) during well development and aquifer testing. The groundwater samples were collected from the discharge port of the submersible development pump and were submitted for analyses.

All groundwater samples were submitted to the Laboratory's Earth and Environmental Sciences 6 groundwater chemistry laboratory for analysis of anions, metals, and (in some cases) total organic carbon (TOC) and tritium. Sampling documentation and containers were provided by the Laboratory and processed through the Laboratory's Sample Management Office. Groundwater analytical results and details of groundwater chemistry at R-36 are presented in Appendix B. Table 4.2-1 presents a summary of all groundwater samples collected during drilling and well development activities.

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-36 is presented below. The Laboratory's geology task leader and site geologists examined cuttings and geophysical logs to determine geologic contacts. Drilling observations, video logging, water-level measurements, and geophysical logs were used to characterize groundwater occurrences encountered at R-36.

5.1 Stratigraphy

The stratigraphy for the R-36 borehole is presented below in order of youngest to oldest geologic units. Lithologic descriptions are based on samples of discharged cuttings. Cuttings and borehole geophysical logs were used to identify geologic contacts. Figure 5.1-1 illustrates the stratigraphy at R-36. A detailed lithologic log is presented in Appendix A.

5.1.1 Quaternary Alluvium, Qal (0–12 ft bgs)

Quaternary alluvium consisting of silty sand with pebbles of volcaniclastic sediments was encountered from 0 to 12 ft bgs. No evidence of alluvial groundwater was observed.

5.1.2 Otowi Member of the Bandelier Tuff, Qbo (12–160 ft bgs)

The Otowi Member of the Bandelier Tuff is present in R-36 from 12 to 160 ft bgs. The Otowi Member is a glassy, lithic-bearing, pumiceous, poorly welded ash-flow tuff. It contains reddish gray to gray, subangular to subrounded, intermediate composition volcanic rocks up to 15 mm in diameter. Vitric pale yellow to white pumice lapilli contain conspicuous phenocrysts of quartz and sanidine.

5.1.3 Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (160–175 ft bgs)

The Guaje Pumice Bed is present from 160 to 175 ft bgs. The pumice bed contains abundant pumice fragments (up to 97%) with subordinate amounts of volcanic lithics, quartz and sanidine phenocrysts, trace mafic minerals, and fine ash.

5.1.4 Upper Puye Formation, Tpf (175–195 ft bgs)

The upper Puye Formation consists of volcaniclastic silty sand and sandy gravel deposits from 175 to 195 ft bgs. Gravels consist of intermediate composition volcanic rock fragments, volcaniclastic sandstones, pumice clasts, and conspicuous felsic and mafic mineral grains. The formation ranges from yellowish gray to light brown. At 193 ft bgs, the upper Puye Formation transitions to brown volcaniclastic sediments with basalt clasts up to 20 mm present. These basalt clasts appear to be derived from the underlying Cerros del Rio basalt.

5.1.5 Cerros del Rio Basalt, Tb 4 (195–537 ft bgs)

Cerros del Rio basalt, from 195 to 537 ft bgs, consists of multiple lava flows of vesicular to massive porphyritic basalt with an aphanitic groundmass. Trace to minor olivine and plagioclase phenocrysts and local clay and clay-filled vesicles are evident. Basalt ranges from dark to medium gray.

5.1.6 Cerros del Rio Maar Deposit (537–545 ft bgs)

A Cerros del Rio maar deposit at 537 to 545 ft bgs consists of abundant (75%) clasts of glassy scoria and clay-coated chips of basalt with a subordinate amount of fine-grained sandstone and siltstone.

5.1.7 Lower Puye Formation, Tpf (545–575 ft bgs)

The lower Puye Formation consists of poorly sorted volcaniclastic sediments with silt, sand, gravels, and cobbles. Gravel and cobbles consist of devitrified intermediate composition lavas, with conspicuous felsic and mafic phenocrysts, siltstones, sandstones, and conglomerates. The formation ranges from very light to medium gray.

5.1.8 Santa Fe Group, Undivided, Tsfu (575–865 ft bgs)

The Miocene Santa Fe Group is present from 575 ft to TD at 865 ft bgs and consists of light tan, fine-grained volcaniclastic and metamorphic to plutonic (e.g., granitic and quartzite source) sediments ranging from silty sands to silty gravels with silt. The gravel and sand component consists primarily of felsic to intermediate composition volcanics, in addition to tuff fragments and basalt, with about 2%–3% Precambrian quartz, quartzite, and granite clasts.

5.2 Groundwater

Regional groundwater was first recognized at R-36 during drilling at approximately 772 ft bgs in the Santa Fe Group on November 29, 2007. Static water levels (SWLs) of 748.6 ft bgs and 749.9 ft bgs were measured on November 30 and December 1, 2007. Groundwater-screening samples (section 4.2) were collected during drilling, well development, and aquifer testing. After well installation and development, the SWL was measured at 749.1 ft bgs. Discussion of groundwater chemistry is presented in Appendix B and aquifer testing data and discussion are detailed in Appendix D.

6.0 BOREHOLE LOGGING

Several video logs and a limited suite of cased-hole geophysical logs were collected during the R-36 drilling project using Laboratory-owned equipment. A summary of video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

Video logs were run in the uncased borehole to check for the presence of perched groundwater in the Cerros del Rio basalt on November 12 and 13, 2007. Perched water was observed in the video logs below the Cerros del Rio basalt. Several other video logs were run in the borehole to verify conditions or investigate problems during drilling and well construction. An additional video log was collected in the completed well for inspection. Selected video logs from the borehole are presented on a digital video disc in Appendix C. Table 6.0-1 details individual video logging runs.

6.2 Geophysical Logging

Several natural gamma ray and induction tool logs were run in the R-36 borehole and well using the Laboratory's geophysical equipment. Details of the logging operations are presented in Table 6.0-1. The results of the geophysical logging are presented on plots in Appendix C. Because of the proximity and the similarity in geological conditions encountered at the R-35 well site (installed earlier in 2007), a comprehensive cased-hole geophysical suite was not performed by a geophysical contractor in the R-36 borehole.

7.0 WELL INSTALLATION

R-36 well casing and annular fill were installed between December 4, 2007, and February 12, 2008.

7.1 Well Design

The R-36 well was designed in accordance with the NMED Consent Order. The well design was approved by NMED before installation. The well was designed with a single screened interval to monitor groundwater quality in the upper part of the regional aquifer within productive Santa Fe Group sediments.

7.2 Well Construction

The R-36 monitoring well was constructed of 4.5-in.-I.D./5.0-in.-outside diameter (O.D.) type A304 stainless-steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. External couplings (also type A304 stainless steel fabricated to ASTM A312 standards) were used to connect individual casing and screen sections. The screen sections were nominal 12.3 ft long with 10-ft lengths of 4.375-in.-I.D. rod-based 0.020-in. wire-wrapped well screen. The coupled unions between threaded sections were approximately 0.7 ft long. The casing and screen were factory-cleaned and steam-cleaned on-site before installation. A 2-in.-I.D. steel threaded/coupled tremie pipe was used to deliver all backfill and annular fill materials during well construction.

A nominal 20-ft screened interval was chosen for R-36 with the top of the screen set at 766.9 ft bgs. A 12-ft stainless-steel sump was placed below the well screen. A Semco work-over rig was used for all well construction and development activities except for backfilling the borehole below the well, which was accomplished with the dual-rotary drill rig. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Problems associated with the formation and backfill materials placement were encountered during the initial phase of well construction. During drilling operations it was noted that the Santa Fe Group sediments below the regional water table were soft and unconsolidated. The drilling contractor reported that the drill rig's lower drive had to hold the 10-in. casing above the tools because the casing was falling under its own weight. Typically, the lower drive is relied upon to apply pressure down on the casing during installation.

The bottom of the borehole was backfilled below the proposed well casing depth. Forty feet of 10-in. casing was retracted (two 20-ft sticks) and the borehole was backfilled with 10/20 filter sand to the bottom of the casing after the 40 ft of casing was removed. This method was utilized to minimize formation slough into the borehole below the well; however, substantial sloughing did occur. Backfilling continued until up to the calculated depth of the well. The well components were then threaded together and hung in the borehole.

After the well casing was assembled and lowered into the borehole, the process of installing annular backfill materials was started. This activity had two components: installing materials and retracting the drill casing. While the level of annular fill came up, the drill casing was retracted and removed. As each section of drill casing was cut off the string, it had to be picked up and laid down. During this process, the well casing was hung on a wireline in the borehole. Typically, there are no problems associated with releasing the well casing once the level of backfill material installed is within a few feet of the well sump. However, on December 10, 2007, while installing sand around the bottom of the well sump, the well casing was released from the wireline to remove a section of 10-in. casing, and the top of the well sank to approximately 38 ft bgs. The well was recovered and repositioned with the screen at the target depth on December 11, 2007, and December 12, 2007. A video log was run in the well with the Laboratory downhole camera to assess possible damage to the screen. No visible damage to the screen was observed. An improved system was devised to hold the well securely while extracting the casing. Each piece of casing removed from the borehole was cut at precisely the same height above ground surface, and a landing plate was placed below the well's top coupler. With this method, the well was completely supported when the wireline was released.

Because the borehole was overdrilled, the well was designed and built with a lower bentonite seal below the well screen. Difficulties associated with the placement of the lower seal were encountered on December 18, 2007. The field crew experienced minor difficulties installing backfill materials in the R-36 borehole because of the unconsolidated nature of Santa Fe Group sediments. When installing backfill materials in a cased-hole well construction, it is desirable for the borehole to remain open below the casing as the casing is retracted. The Santa Fe Group was unpredictable; portions of the borehole would remain open while other portions would collapse. While installing the lower seal, bentonite chips were inadvertently installed approximately 4 ft inside the bottom of the 10-in. casing. The field crew was adding bentonite chips very close to the bottom of the casing to prevent the formation from sloughing, but the level of the chips was brought up too high. The result was a bentonite bridge in the annular space at the bottom of the 10-in. casing that presented complications with continuing well construction. Several video logs were run to assess conditions without conclusive results. At this point, work was suspended for Christmas break on December 20, 2007.

Beginning January 3, 2008, several strategies were implemented to clear the bentonite bridge from the bottom of the 10-in. casing. None of the strategies resulted in indisputable success. Eventually, the well was removed from the borehole. The drill casing was cleaned out to 805.1 ft bgs with a 9-in. sand pump (large-diameter cable tool bailer). A video log was run in the drill casing and no bentonite was observed. The bottom of the borehole was also verified to be native sediments. Before reinstalling the well casing, the well design was revised to include a shorter sump and was submitted to NMED for approval. Changing the well design to a shorter sump (nominal 12 ft instead of 22 ft) allowed well construction to proceed without having to clean out the borehole to depth. NMED approved the new well design on January 10, 2008, and the well was reinstalled with a nominal 12-ft sump.

After the problems associated with the initial phases of well construction were resolved, the process proceeded normally. The lower bentonite seal was installed around the well sump from 803.9 to 797.9 ft bgs. The primary filter pack of 10/20 silica sand was placed across the screened interval from 797.9 to 762.3 ft bgs. R-36 is screened from 766.9 to 789.9 ft bgs. During and after installation of the primary filter pack, the work-over rig was used to surge the screened interval with a surge block to promote settling and compacting the filter pack.

The quantities of bentonite and 10/20 filter sand used for the lower seal and filter pack were considerably more than the calculated theoretical volumes. This was attributed to the very soft unconsolidated formation and possible impacts from water sampling during drilling. While air was circulated to retrieve water samples at the end of each casing run, the formation was exposed to enough additional air to erode voids in the borehole, resulting in greater quantities of backfill material needed to fill these voids.

A transition-sand collar of 20/40 silica sand was placed above the primary filter pack from 762.3 to 759.6 ft bgs. After placement of the fine sand collar, a bentonite chip seal was installed from 759.6 to 734.8 ft bgs. The annular space between the top of the upper bentonite chip seal and the bottom of the Cerros del Rio basalt was filled with a high-solids bentonite grout. The interval from the bottom of the Cerros del Rio basalt to the top of the Guaje Pumice Bed was filled with bentonite chips and hydrated with potable water. Above the Guaje Pumice Bed to ground surface, the annular space was filled with cement grout containing 2% bentonite gel. The well was completed as defined in Section IV.A.3.e.iv.g of the Consent Order on February 12, 2008. Figure 7.2-1 depicts depths and volumes used in each interval. Table 7.2-1 details volumes of materials used during well construction.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation, the well was developed and aquifer pumping tests were conducted. A dedicated submersible pump system was installed, and the wellhead and surface pad were constructed. A geodetic survey of the wellhead was performed. Site restoration activities will commence once the final disposition of contained drill cuttings and groundwater is determined in accordance with the NMED-approved waste-decision trees.

8.1 Well Development

Well development was conducted between February 13 and 16, 2008. Initially, the screened interval was bailed and swabbed to remove formation fines in the filter pack. Bailing and swabbing methods were used until returned water was clear, and then a submersible pump was utilized to complete development. The swabbing tool was a 4.25-in.-O.D. 1-in.-thick nylon disc attached to a steel rod. The swabbing tool was lowered by wireline and drawn repeatedly across the screened interval. After bailing and swabbing, a 5-hp, 4-in.-Berkeley submersible pump was lowered into the well for the final stage of well development.

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxygen-reduction potential (ORP), and specific conductance parameters were collected. In addition, water samples for TOC analysis were collected. The required values for TOC and turbidity by the end of well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTUs), respectively. The TOC measurement at the end of R-36 well development was less than 0.5 ppm; the turbidity measurement was 0.0 NTU.

Approximately 40,548 gal. of groundwater was purged at R-36 during development and aquifer pump testing activities. Table 8.1-1 presents the volume of water removed during well development (and aquifer testing) and the corresponding water-quality parameters. Discussion of analytical results is presented in Appendix B.

Two hours of continued pump development was conducted after aquifer testing on February 21, 2008. Additional pumping was conducted to ensure the total purge volume was greater than the introduced volume below within the regional aquifer.

8.1.1 Field Parameters

Results for field parameters consisting of pH, temperature, DO, ORP, specific conductance, and turbidity are provided in Table 8.1-1 and in Appendix B. Field parameters were measured at well R-36 by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This condition probably resulted in a slight variation of field parameters during well development and during the pumping test, most notably, temperature, pH, and DO. Measurements of pH and temperature varied from 8.15 to 9.34 and from 12.10°C to 22.31°C, respectively, at well R-36. Concentrations of DO varied from 7.42 to 10.9 mg/L in the well. Regional aquifer groundwater is relatively oxidizing at well R-36 based on DO and ORP measurements, with ORP varying from 148 to 278 millivolts (mV) (Table 8.1-1). Specific conductance was recorded for a majority of the groundwater samples collected at well R-36, with measurements ranging from 120 to 420 microsiemens per centimeter (µS/cm). Specific conductance ranged from 226 to 230 µS/cm during well purging conducted after the pumping test (Table 8.1-1). Values of turbidity ranged from 0 to 5.0 NTUs for the nonfiltered groundwater samples collected at R-36 (Table 8.1-1).

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-36 between February 17 and 21, 2008. Several short-duration tests with short-duration recovery periods were performed on the first day of testing. A 24-h test followed by a 24-h recovery period completed the testing. A 24-h background data collection period was conducted between the short-duration tests and the 24-h test. The 5-hp Berkeley pump used during development was also used to perform the aquifer testing. The pump was utilized at full capacity. The results of the pump test are presented in Appendix D.

8.3 Dedicated Sampling System Installation

A dedicated 3-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump was installed in R-36 on March 2, 2008. The pump intake was set at 764.5 ft bgs. A transducer access tube was installed to 760.5 ft bgs with a screened interval from 759.9 to 760.4 ft bgs. The transducer tube is 1.0-in.-I.D. flush-threaded schedule 40 polyvinyl chloride (PVC) pipe with a 6-in. long, 0.010-in. screen-slot interval at the bottom of the tube with a threaded bottom cap. A dedicated In-Situ Level Troll 500 transducer was installed in the PVC tube. Postinstallation construction and sampling system component installation details for R-36 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for R-36.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-36 well head. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 10-in.-I.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. Base course was graded around the edges of the pad. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

Geodetic survey data for the stainless-steel well casing top cap, 10-in. protective casing, brass pin, and ground surface at R-36 were collected on March 11, 2008. The survey data are presented in Figure 8.3-1b and Table 8.5-1. Geodetic surveys were conducted using a Trimble 5700 differential global positioning system. The survey data were collected by a licensed surveyor and conform to Laboratory

Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

8.6 Waste Management and Site Restoration

Waste generation and characterization for the R-36 project include a small quantity of contact waste, decontamination fluids, drill cuttings, discharged drilling water, cement slurry, and purged groundwater. Waste characterization samples of drill cuttings, purge water, and cement slurry were collected on February 27 and 29, 2008. A summary of the waste samples collected for the R-36 well is presented in Table 8.6-1.

Fluids, cuttings, cement slurry, and contact waste produced during drilling and development were containerized and sampled in accordance with “WCSF for the R-36 Monitoring Well Installation” (LANL 2007, 100969) and “Amendment 1 of the R-36 Monitoring Well Installation WCSF” (LANL 2007, 101151).

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 (WSCF) and the EP Directorate Standard Operating Procedure (SOP) 010.0, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criteria for land application, the water will be evaluated for treatment and disposal at one of the Laboratory’s six wastewater treatment facilities. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the waste will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA SOP 011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criteria for land application, they will be removed from the pit and disposed of at an authorized facility. The cement slurry waste stream will be managed as industrial nonhazardous waste pending analytical review. Disposal of this concrete slurry will take place at an authorized disposal facility. Characterization of contact waste will be based upon acceptable knowledge, pending the results of the waste samples collected from the drill cuttings, purge water, and cement slurry.

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

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

In general, drilling, sampling, and well construction at R-36 were performed as specified in the “Drilling Work Plan for Regional Aquifer Well R-36” (LANL 2007, 098122).

9.1 NMED-Approved Modifications to the Work Plan

The following changes to the original work plan were implemented after approval by NMED.

- Drilling TD: Drilling at R-36 stopped at 865 ft bgs after a productive interval near the top of the regional aquifer was encountered. The planned TD for the R-36 borehole in the approved work plan (LANL 2007, 098122) was the top of the Miocene basalt, at approximately 980 ft bgs.
- Well Design: The sump length below the screen interval was shortened from nominal 22 ft to 12 ft after difficulties with the formation and annular backfill placement were encountered during well construction.

10.0 ACKNOWLEDGMENTS

D. Schafer of David Schafer and Associates contributed the aquifer testing section of this report (Appendix D).

P. Longmire of Los Alamos National Laboratory contributed the geochemistry section of this report (Appendix B).

Boart Longyear drilled the R-36 borehole and installed the well.

Keers Remediation, Inc., prepared the site for drilling activities.

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

11.0 REFERENCES

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

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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

LANL (Los Alamos National Laboratory), June 2007. "Drilling Work Plan for Regional Aquifer Well R-36," Los Alamos National Laboratory document LA-UR-07-4342, Los Alamos, New Mexico. (LANL 2007, 098122)

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), October 18, 2007. "Waste Characterization Strategy Form for the R-36 Monitoring Well Installation," Los Alamos, New Mexico. (LANL 2007, 100969)

LANL (Los Alamos National Laboratory), December 7, 2007. "Amendment #1 to the Waste Characterization Strategy Form for R-36 Monitoring Well Installation," Los Alamos, New Mexico. (LANL 2007, 101151)

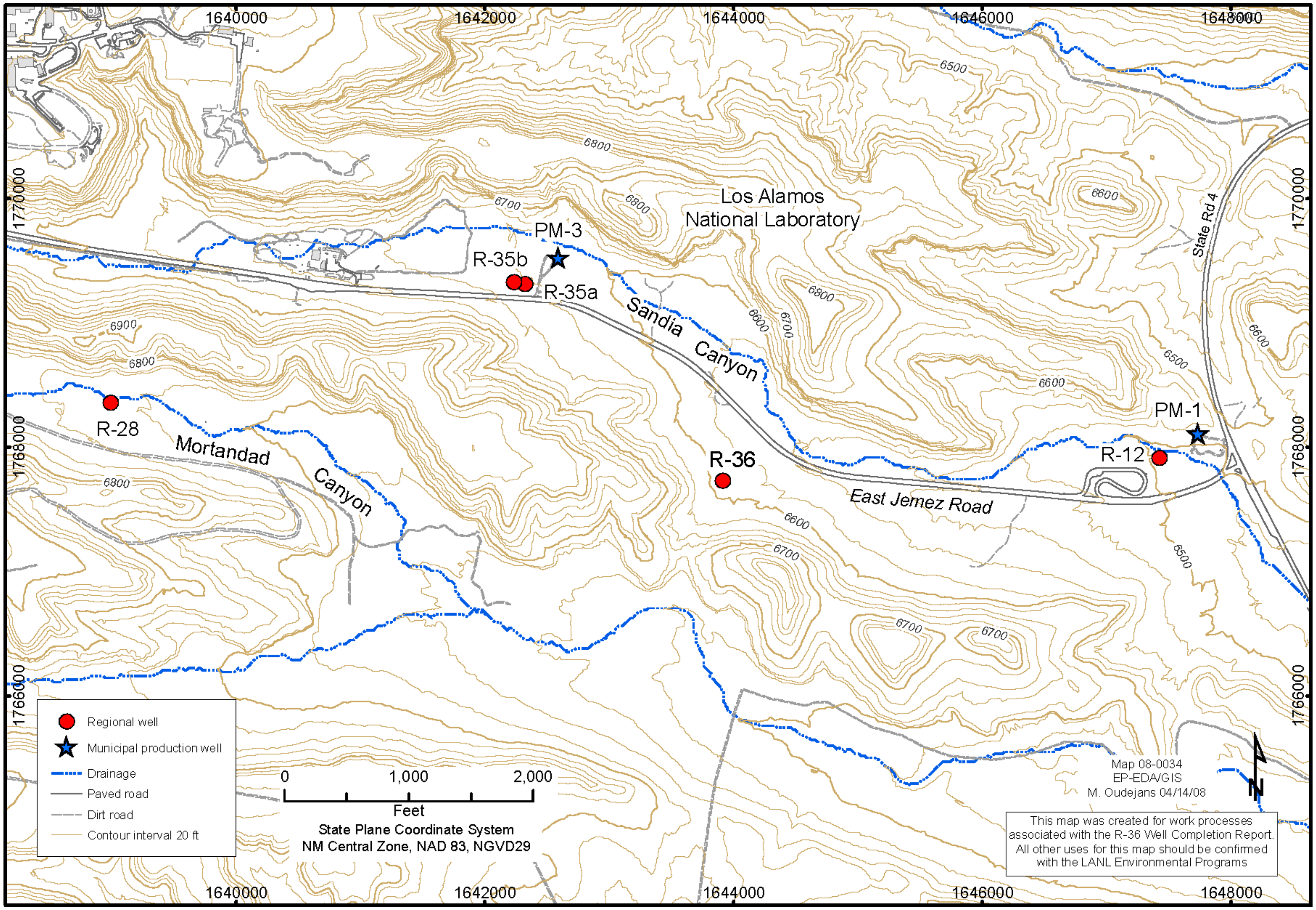


Figure 1.0-1 Location of regional aquifer well R-36 with respect to municipal supply wells PM-1 and PM-3 and additional surrounding regional wells

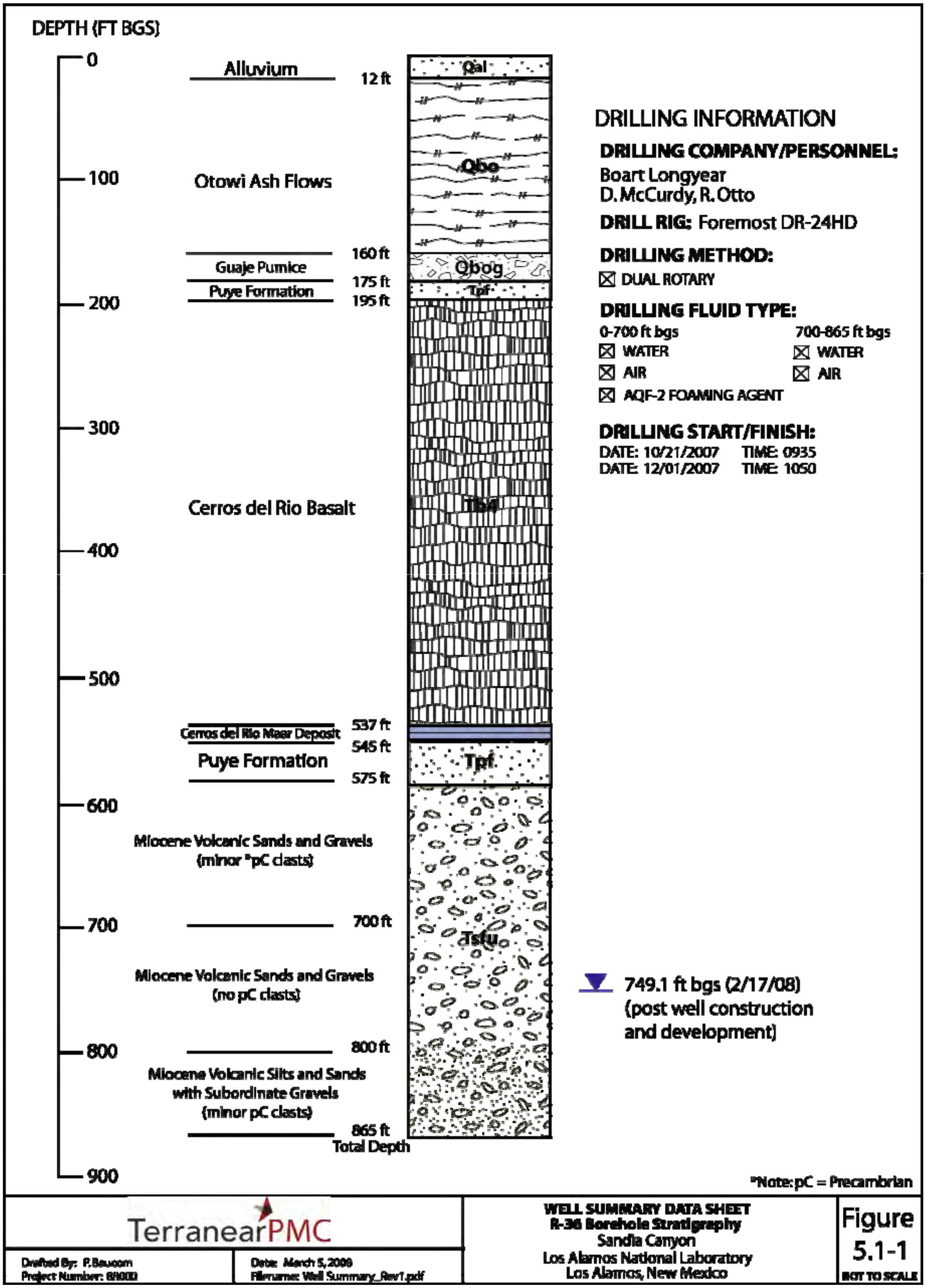


Figure 5.1-1 R-36 borehole stratigraphy

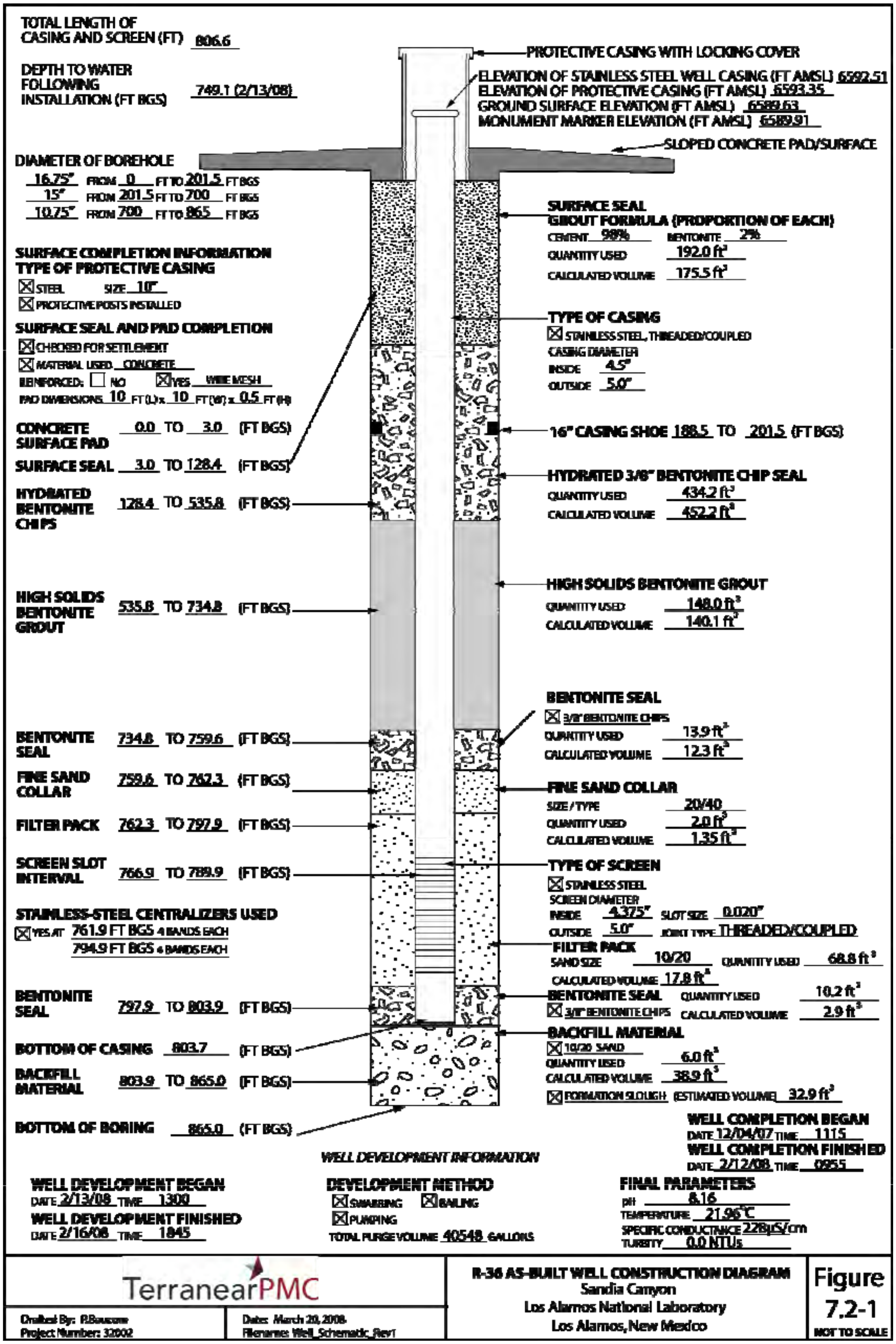


Figure 7.2-1 R-36 as-built well construction diagram

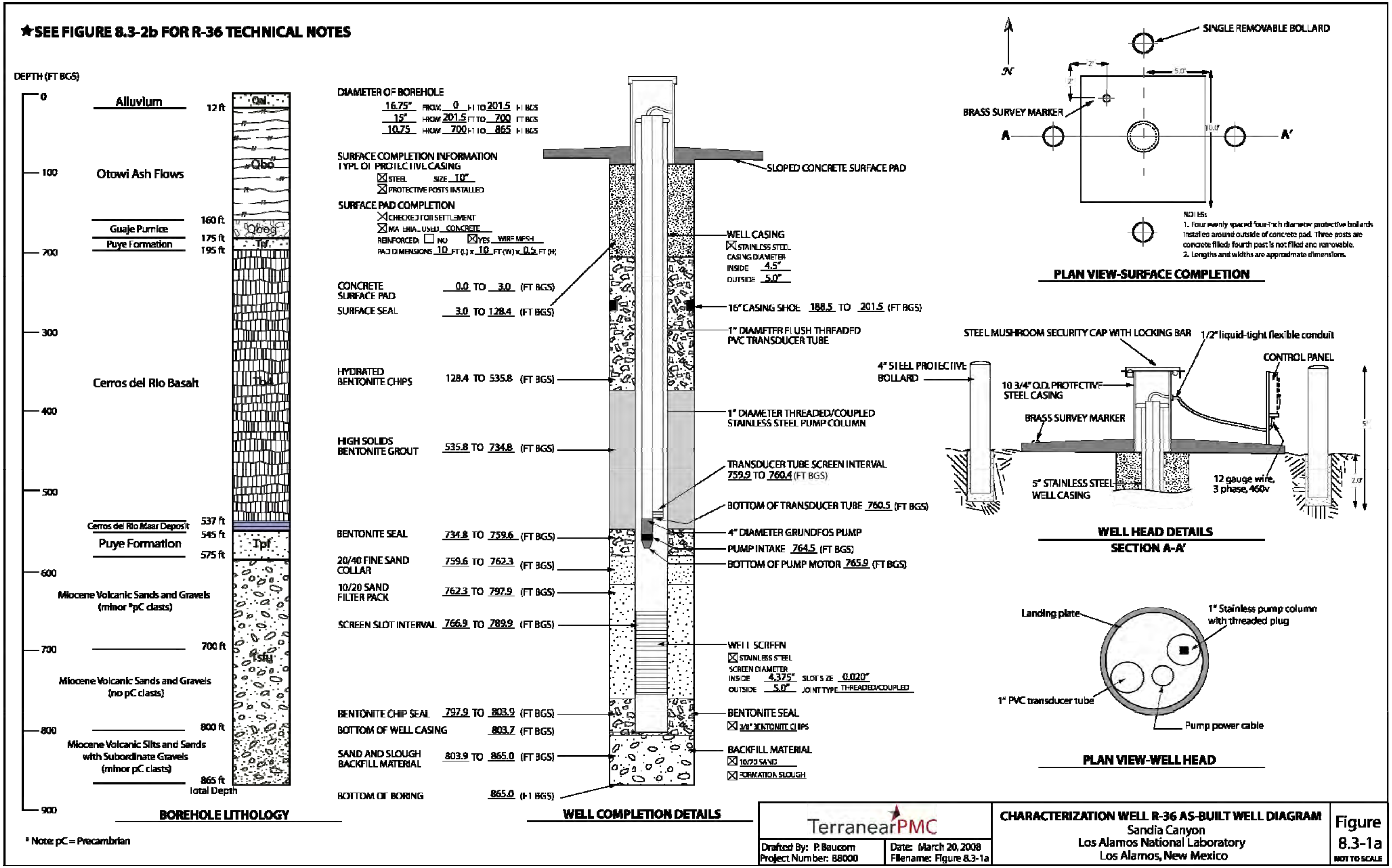


Figure 8.3-1a As-built schematic for regional well R-36

R-36 TECHINCAL NOTES:[1]

SURVEY INFORMATION[2]

Brass Marker
Northing: 1767731.49
Easting: 1643912.08
Elevation: 6589.91

Well Casing (top of stainless steel)
Northing: 1767727.52
Easting: 1643913.44
Elevation: 6592.51

BOREHOLE GEOPHYSICAL LOGS

LANL Natural Gamma Ray, LANL Induction Tool

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam

MILESTONE DATES

Drilling
Start: 10/21/2007
Finished: 12/01/2007

Well Completion
Start: 12/04/2007
Finished: 02/12/2008

Well Development
Start: 02/13/2008
Finished: 02/16/2008

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 10,878 gallons

Parameter Measurments (Final)
pH: 8.16
Temperature: 21.96 C
Specific Conductance: 228 µS/cm
Turbidity: 0.0 NTU

AQUIFER TESTING

Constant Rate Pumping Test
Water Produced: 26,488 gallons
Average Flow Rate: 17.2 gpm
Performed on: 02/17/2008-02/21/2008

DEDICATED SAMPLING SYSTEM

Pump
Grundfos, Type: 5530-820 CBM
Model: 96023161-P10803336
5 U.S. gpm, intake at 764.5 ft bgs
Environmental Retrofit

Motor
Franklin Electric, model: 2343262604, 3HP, 3-phase

Pump Column
1-inch, schedule 40, 304 stainless steel,
threaded/coupled, check valves every 200 ft

Transducer Tube
1-inch, schedule 40 PVC, flush threaded,
0.010-inch screen at 759.9-760.4 ft bgs

Transducer
In-Situ, Level Troll 500, 15 psi vented

NOTES:
1) Additional information available in "Final Completion Report, Characterization Well R-36, Los Alamos National Laboratory, Los Alamos, New Mexico, April 2008.
2) Coordinates based on New Mexico State Plane Grid Coordinates, Central Zone (NAD83); Elevation expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

TerranearPMC		R-36 TECHNICAL NOTES Sandia Canyon Los Alamos National Laboratory Los Alamos, New Mexico	Figure 8.3-1b NOT TO SCALE
Drafted By: P. Baucom Project Number: 00000	Date: March 20, 2008 Filename: Figure 8.3-1b		

Figure 8.3-1b As-built technical notes for R-36

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

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
Drilling					
10/21/07	1200	1200	5	5	100
10/22/07	500	1700	3	8	175
10/23/07	700	2400	2	10	225
10/24/07	0	2400	0	10	225
10/25/07	0	2400	0	10	225
10/26/07	0	2400	0	10	225
10/27/07	0	2400	0	10	225
10/28/07	0	2400	0	10	225
10/29/07	0	2400	0	10	225
10/30/07	0	2400	0	10	225
10/31/07	1200	3600	35	45	350
11/01/07	1550	5150	10	55	450
11/02/07	1850	7000	25	80	600
11/03/07	0	7000	0	80	600
11/04/07	500	7500	15	95	700
11/05/07	0	7500	0	95	700
11/06/07	2400	9900	80	175	1200
11/07/07	1200	11100	45	220	1400
11/08/07	0	11100	0	220	1400
11/09/07	0	11100	0	220	1400
11/10/07	1200	12300	0	220	1800
11/11/07	2400	14700	55	275	2200
11/12/07	1200	15900	0	275	2500
11/13/07	0	15900	0	275	2500
11/14/07	1200	17100	55	330	3000
11/15/07	0	17100	0	330	3000
11/16/07	0	17100	0	330	3000
11/17/07	0	17100	0	330	3000
11/18/07	600	17700	15	345	3200
11/19/07	600	18300	15	360	3300
11/20/07	0	18300	0	360	3300
11/21/07	0	18300	0	360	3300
11/23/07	0	18300	0	360	3300
11/24/07	0	18300	0	360	3300

Table 3.1-1 (Continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
11/25/07	0	18300	0	360	3300
11/26/07	0	18300	0	360	3300
11/27/07	0	18300	0	360	3300
11/28/07	0	18300	0	360	3300
11/29/07	600	18900	0	360	5000
11/30/07	600	19500	0	360	7000
Well Construction					
12/01/07	0	19500	n/a*	n/a	n/a
12/02/07	0	19500	n/a	n/a	n/a
12/03/07	0	19500	n/a	n/a	n/a
12/04/07	0	19500	n/a	n/a	n/a
12/05/07	1200	20700	n/a	n/a	n/a
12/06/07	0	20700	n/a	n/a	n/a
12/07/07	0	20700	n/a	n/a	n/a
12/08/07	0	20700	n/a	n/a	n/a
12/09/07	25	20725	n/a	n/a	n/a
12/10/07	30	20755	n/a	n/a	n/a
12/11/07	0	20755	n/a	n/a	n/a
12/12/07	260	21015	n/a	n/a	n/a
12/13/07	0	21015	n/a	n/a	n/a
12/14/07	400	21415	n/a	n/a	n/a
12/15/07	0	21415	n/a	n/a	n/a
12/16/07	0	21415	n/a	n/a	n/a
12/17/07	2000	23415	n/a	n/a	n/a
12/18/07	4000	27415	n/a	n/a	n/a
12/19/07	2400	29815	n/a	n/a	n/a
12/20/07	1500	31315	n/a	n/a	n/a
Christmas break from 12/21/07 to 1/02/08					
1/03/08	800	32115	n/a	n/a	n/a
1/04/08	0	32115	n/a	n/a	n/a
1/05/08	2800	34915	n/a	n/a	n/a
1/06/08	0	34915	n/a	n/a	n/a
1/07/08	0	34915	n/a	n/a	n/a
1/08/08	0	34915	n/a	n/a	n/a
1/09/08	2400	37315	n/a	n/a	n/a
1/10/08	0	37315	n/a	n/a	n/a

Table 3.1-1 (Continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
1/11/08	0	37315	n/a	n/a	n/a
1/12/08	0	37315	n/a	n/a	n/a
1/13/08	0	37315	n/a	n/a	n/a
1/14/08	0	37315	n/a	n/a	n/a
1/05/08	0	37315	n/a	n/a	n/a
1/16/08	0	37315	n/a	n/a	n/a
1/17/08	0	37315	n/a	n/a	n/a
1/18/08	2100	39415	n/a	n/a	n/a
1/19/08	900	40315	n/a	n/a	n/a
1/20/08	4800	45115	n/a	n/a	n/a
1/21/08	1800	46915	n/a	n/a	n/a
1/22/08	1200	48115	n/a	n/a	n/a
Crew shift break; no site work from 1/23/08 to 1/28/08					
1/29/08	500	48615	n/a	n/a	n/a
1/30/08	1200	49815	n/a	n/a	n/a
1/31/08	1800	51615	n/a	n/a	n/a
2/1/08	0	51615	n/a	n/a	n/a
2/2/08	200	51815	n/a	n/a	n/a
2/03/08	0	51815	n/a	n/a	n/a
2/04/08	1200	53015	n/a	n/a	n/a
2/05/08	0	53015	n/a	n/a	n/a
2/06/08	900	53915	n/a	n/a	n/a
2/07/08	1600	55515	n/a	n/a	n/a
2/08/08	1400	56915	n/a	n/a	n/a
2/09/08	1500	58415	n/a	n/a	n/a
2/10/08	1700	60115	n/a	n/a	n/a
2/11/08	1200	61315	n/a	n/a	n/a
2/12/08	250	61565	n/a	n/a	n/a
Total Volume (gal.)					
R-36	61565				

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

Table 4.2-1
Summary of Groundwater-Screening Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-36

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type
Drilling				
SA-603111	GW36-08-8505[a]	11/13/2007	571–580	Perched Groundwater
SA-603111	GW36-08-8506[a]	11/13/2007	571–580	Perched Groundwater
SA-603111	GW36-08-8509	11/29/2007	772	Groundwater
SA-603111	GW36-08-8510	11/30/2007	792	Groundwater
SA-603111	GW36-08-8511	11/30/2007	812	Groundwater
SA-603111	GW36-08-8512	11/30/2007	850	Groundwater
SA-603111	GW36-08-8514	12/01/2007	865	Groundwater
SA-603111	GW36-08-8546	11/13/2007	na[b]	Municipal Water
SA-603111	GW36-08-8547[a]	11/13/2007	571–580	Perched Groundwater
SA-603111	GW36-08-8548	11/30/2007	812	Groundwater
SA-603111	GW36-08-8549[a]	11/14/2007	571.8–577	Perched Groundwater
SA-603111	GW36-08-8550	11/30/2007	850	Groundwater
SA-603111	GW36-08-8551	12/01/2007	865	Groundwater
SA-603111	GW36-08-8555	11/30/2007	792	Groundwater
SA-603111	GW36-08-8562	11/29/2007	772	Groundwater
Well Development				
SA-603111	GW36-08-10884	2/15/2008	797.06	Groundwater
SA-603111	GW36-08-10885	2/16/2008	790.0	Groundwater
SA-603111	GW36-08-10886	2/16/2008	784.3	Groundwater
SA-603111	GW36-08-10887	2/16/2008	790.0	Groundwater
SA-603111	GW36-08-10888	2/16/2008	788.0	Groundwater
SA-603111	GW36-08-10889	2/16/2008	782.0	Groundwater
SA-603111	GW36-08-10890	2/16/2008	780.0	Groundwater
SA-603111	GW36-08-10891	2/16/2008	777.0	Groundwater
SA-603111	GW36-08-10892	2/16/2008	775.0	Groundwater
SA-603111	GW36-08-10893	2/16/2008	773.0	Groundwater
SA-603111	GW36-08-10894	2/16/2008	771.0	Groundwater
SA-603111	GW36-08-10895	2/16/2008	769.0	Groundwater
SA-603111	GW36-08-10896	2/16/2008	767.0	Groundwater
SA-603111	GW36-08-10897	2/16/2008	766.1	Groundwater
SA-603111	GW36-08-10898	2/16/2008	766.1	Groundwater
SA-603111	GW36-08-10899	2/16/2008	766.1	Groundwater
SA-603111	GW36-08-10900	2/16/2008	766.1	Groundwater

Table 4.2-1 (Continued)

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type
Aquifer Pump Test				
SA-603111	GW36-08-10901	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10902	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10903	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10904	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10905	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10906	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10907	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10908	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10909	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10910	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10911	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10912	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10913	2/19/2008	769.4	Groundwater
SA-603111	GW36-08-10914	2/20/2008	769.4	Groundwater
SA-603111	GW36-08-10915	2/20/2008	769.4	Groundwater
SA-603111	GW36-08-10916	2/20/2008	769.4	Groundwater
SA-603111	GW36-08-10917	2/20/2008	769.4	Groundwater
SA-603111	GW36-08-10918	2/20/2008	769.4	Groundwater
SA-603111	GW36-08-10919	2/20/2008	769.4	Groundwater
SA-603111	GW36-08-10920	2/20/2008	769.4	Groundwater
Postaquifer Pump Test Purging				
SA-603111	GW36-08-10921	2/21/2008	769.4	Groundwater
SA-603111	GW36-08-10922	2/21/2008	769.4	Groundwater
SA-603111	GW36-08-10923	2/21/2008	769.4	Groundwater

[a] Samples collected from air-lifting perched groundwater through tool string from approximately 571 to 580 ft bgs.

[b] na = Not available.

Table 6.0-1
R-36 Video and Geophysical Logging Runs

Date	Depth (ft)	Description
11/02/07	201.5–238	Laboratory video run to view abundantly fractured basalt; 16-in. casing to 201.5 ft
11/07/07	201.5–304	Laboratory video run to view abundant fractured basalt; 16-in. casing to 201.5 ft
11/12 and 11/13/07	0–575	Laboratory video, gamma ray, and induction tools run. 16-in. casing to 201.5 ft. SWL at 571 ft bgs. Openhole suite through Cerros del Rio basalt.
12/1/07	0–865	Laboratory gamma ray run in cased hole to TD. 10-in. casing to 865 ft bgs. SWL at 748.9 ft bgs.
12/12/07	0–803	Laboratory video run to view well screen after well casing dropped.
12/19 and 12/20/08	0–805	Laboratory video run to view bentonite plug in bottom of 10-in. casing.
1/09/08	0–805	Laboratory video run to verify removal of bentonite plug in bottom of 10-in. casing.
2/27/08	0–803.7	As-built. Laboratory video, gamma ray, and induction tools run inside well casing after development and aquifer test. SWL at 749.1 ft bgs. Screen at 766.9 ft to 789.9 ft bgs. Nothing unusual noted.

Table 7.2-1
R-36 Annular Fill Materials

Material	Volume
Surface seal: cement slurry	192.0 ft^3
Bentonite seal: bentonite chips	434.2 ft^3
Bentonite seal: high solids bentonite grout	148.0 ft^3
Upper annular seal: bentonite chips	13.9 ft^3
Fine sand collar: 20/40 silica sand	2.0 ft^3
Primary filter: 10/20 silica sand	68.8 ft^3
Lower annular seal: bentonite chips	10.2 ft^3
Backfill material: 10/20 silica sand	6.0 ft^3
Backfill material: formation slough	32.9 ft^3 (estimated)
Potable water used in the regional aquifer (drilling and well construction)	33,515 gal.

Table 8.1-1
Well Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-36

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
2/13/08	Bailing; parameters not collected						n/a[a]	672
2/14/08	Bailing; parameters not collected						n/a	1150
2/15/08	8.21	17.22	8.66	147.8	n/r[b]	4.9	956	2106
2/16/08	8.16	18.10	8.54	212.6	124	5.0	430	2536
	8.14	12.10	10.90	278.5	n/r	1.7	946	3482
	8.17	17.57	9.18	220.9	n/r	2.0	516	3998
	8.21	19.68	8.59	203.7	122	2.5	516	4514
	8.20	19.58	8.50	194.7	n/r	2.7	516	5030
	8.20	19.21	8.63	216.7	n/r	2.9	516	5546
	8.22	14.55	8.05	214.1	n/r	2.8	602	6148
	8.21	19.43	9.03	206.8	120	3.2	516	6664
	8.20	19.85	9.05	214.0	n/r	3.2	516	7180
	8.22	16.14	8.63	234.9	120	3.2	516	7696
	8.21	17.61	9.06	239.2	n/r	3.4	516	8212
	8.21	18.64	8.87	237.5	121	3.6	516	8728
	8.22	16.39	8.99	243.8	119	2.5	602	9330
	8.21	18.20	9.27	242.5	n/r	3.2	516	9846
	8.20	17.69	9.29	242.2	n/r	3.2	516	10362
	8.23	16.02	8.80	240.1	123	3.4	516	10878
Aquifer Pump Test Volumes								
2/19/08[c]	9.34	17.26	10.66	194.5	n/r	1.3	1978	12856
	8.20	18.75	8.67	211.3	420	3.0	1032	13888
	8.19	19.23	8.74	199.1	n/r	3.2	1032	14920
	8.20	20.44	9.03	195.5	n/r	3.5	1032	15952
	8.19	19.63	9.00	203.9	123	3.6	1032	16984
	8.19	20.05	9.21	201.4	n/r	3.5	1032	18016
	8.19	19.85	8.93	201.4	n/r	3.4	1032	19048
	8.19	19.30	8.83	208.4	n/r	3.7	1032	20080
	8.20	19.77	9.20	209.3	n/r	3.8	1032	21112
	8.21	19.09	8.52	228.2	224	0.9	1032	22144
	8.22	17.32	8.50	222.1	228	2.9	1032	23176
Postpump Test Purging								
2/21/08	8.31	20.03	7.42	198.7	239	0.0	14792	37968
	8.18	21.57	7.56	185.7	229	0.0	172	38140
	8.18	21.72	8.37	169.7	230	0.5	172	38312

Table 8.1-1 (Continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Postpump Test Purging (continued)								
2/21/08	8.17	21.88	7.89	180.1	228	0.7	172	38484
	8.17	22.03	7.65	175.8	229	0.1	172	38656
	8.17	21.97	8.16	172.8	230	0.0	172	38828
	8.17	21.85	8.18	166.8	230	0.0	172	39000
	8.16	22.31	7.46	167.1	228	0.0	172	39172
	8.16	21.94	7.94	166.4	229	0.2	172	39344
	8.16	22.16	8.17	173.1	229	0.0	172	39516
	8.16	22.26	8.45	168.7	229	0.0	172	39688
	8.16	22.23	7.84	171.8	230	0.0	172	39860
	8.15	22.24	7.79	172.3	228	0.0	172	40032
	8.16	22.26	8.18	171.5	226	0.0	172	40204
	8.16	22.06	8.54	171.9	229	0.0	172	40376
	8.16	21.96	8.28	168.3	228	0.0	172	40548

Note: Cumulative purge volumes calculated using average pump discharge rate of 17.2 gallons per minute.

[a] na = Not available.

[b] n/r = Not recorded.

[c] Field parameters not collected overnight during 24-h pump test.

Table 8.5-1
R-36 Survey Coordinates

North	East	Elevation	Identification
1767731.49	1643912.08	6589.91	R-36 brass pin embedded in pad
1767731.50	1643908.80	6589.63	R-36 ground surface near pad
1767727.83	1643913.67	6593.35	R-36 top of 10-in. protective casing
1767727.52	1643913.44	6592.51	R-36 top of stainless-steel well casing

Notes: All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83). Elevation is expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-36

Location ID	Sample ID	Date Collected	Description	Sample Type
WST-600902	GW36-08-11132	2/27/08	Frac Tank	Purge Water
WST-600902	GW36-08-11133	2/27/08	Frac Tank	Purge Water
WST-600902	GW36-08-9715	2/29/08	Drum and Rolloff Container	Cement Slurry
WST-600902	GW36-08-11135	2/29/08	Cuttings Pit Solids	Drill Cuttings
WST-600902	GW36-08-11140	2/29/08	Cuttings Pit Fluids	Drilling Water
WST-600902	GW36-08-11141	2/29/08	Cuttings Pit Fluids	Drilling Water

Appendix A

Well R-36 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

Borehole Identification (ID): R-36	**Technical Area (TA):** 72	**Page:** 1 of 7
Drilling Company: Boart Longyear	**Start Date/Time:** 10/21/07: 0935	**End Date/Time:** 12/01/07:1050
Drilling Method: Dual Rotary	**Machine**: Foremost DR-24 HD	**Sampling Method:** Grab
Ground Elevation: 6589.63 ft above mean sea level (amsl)		**Total Depth:** 865 ft below ground surface (bgs)
Drillers: D. McCurdy/R. Otto	**Site Geologist:** C. Pigman/J.R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
0–12	**Alluvium:** Volcaniclastic Sediments/Tuff—silty sand, grayish orange pink (5YR 7/2) G/S/F = 2–5/65–78/20–30, pebbles 3–20 mm of pumice and dacite in v fine to coarse sand of quartz, dacite, and sanidine in silt matrix, clasts angular to subangular	Qal	Alluvium 0–12 ft bgs, 12 ft thick Qal/Qbo contact at 12 ft bgs
12–20	**Otowi Member of the Bandelier Tuff:** Tuff—grayish orange pink (5YR 7/2), pumice-rich, poorly welded, pumice 35%, lithics 25% (mostly dacite), phenocrysts 15% (quartz and sanidine), glass matrix 25%	Qbo	Otowi Member Bandelier Tuff (12–160 ft bgs), 148 ft thick
20–50	Tuff—v pale orange (10YR 8/2), pumice-rich, poorly to slightly welded, pumice 60%–99% (glassy to devitrified, rounded), lithics 20%–50% (mostly dacite), phenocrysts 2%–3% (quartz), glass matrix 7%–33%		
50–135	Tuff—pinkish gray (5YR 8/1), mostly pumice-rich, poorly welded, pumice 15%–75% (mostly glassy, some devitrification, up to 15 mm), lithics 8%–30% (mostly pink dacite, up to 15 mm), phenocrysts 1%-12% (mostly quartz, some sanidine), glassy matrix 14%–71%		
135–160	Pumice Bed—pinkish gray (5YR 8/1), pumice 50%-85% (mostly glassy, up to 15 mm), lithics 15%-50% (mostly dacite, up to 25 mm), phenocrysts 1%–2% (mostly quartz, some sanidine), ash matrix 2%–23%		
160–175	**Guaje Pumice Bed:** Pumice Bed—lt pinkish gray (5YR 8/1) to white (N9), pumice fragments 90%–97% (white, vitric, fibrous, up to 10 mm), lithics 2%–10% (dacites, partly oxidized, up to 13 mm), free quartz and sanidine crystals 1%-3%, fine ash 1%–2%	Qbog	Guaje Pumice (160–175 ft bgs), 15 ft thick

Borehole Lithologic Log (continued)

Borehole ID: R-36	**TA:** 72		**Page:** 2 of 7
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
175–180	**Puye Formation:** Pumiceous Volcaniclastic Sediments—yellowish gray (5Y 8/1), pumice fragments 30%–35% (white, vitric, with rare hornblende/amphibole/biotite phenocrysts, up to 15 mm), lithics 45%–50% (med to lt gray dacite and/or sediment clasts), volcaniclastic sandstone fragments 10%–15% (orange-brown, pumice/dacite/tr obsidian granules), free quartz and sanidine crystals 1%, clay fines 2%–3%	Tpf	Base of Guaje Pumice Bed and top of Puye Formation at 175 ft
180–190	Pumiceous Volcaniclastic Sediments—yellowish gray (5Y 8/1) to lt olive-brown (5Y 6/1), pumice fragments 30%–55% (white, glassy to earthy, with amphibole and biotite phenocrysts, up to 15 mm), lithics/clasts (pinkish to med gray dacite, up to 15 mm), volcaniclastic sandstone 10%–20% with dacite pebbles/granules (lt brown), free quartz and sanidine crystals 1%–3%, clay fines 1%–2%	Tpf	Puye Formation, upper part above Cerros del Rio basalt (175–195 ft bgs), 20 ft thick slight color change Some pumice fragments contain amphibole and biotite as phenocrysts.
190–195	Volcaniclastic Sediments/Basaltic Sediments—lt brown (5YR 5/6), distinct color change, entire sample consists of volcaniclastic detritus, pumice fragments 20%–25% (earthy, up to 3 mm), volcanic clasts 30%-35% (med to dk gray, dacite and olivine basalt, up to 20 mm), volcaniclastic sandstone fragments 30%–35% (lt brown), free quartz and sanidine crystals 1%–2% (some biotite)		distinct color/textual change
195–200	**Cerros Del Rio Basalt:** Basalt/Caliche(?)—varicolored grayish black (N2) to yellowish gray (5Y 8/1), basalt chips 70%–75% (vesicular, porphyritic with aphanitic groundmass, vesicles commonly filled with clay on weathered surfaces), phenocrysts 10%–15% (plagioclase commonly in glomerophyric clusters with green olivine and brown pyroxene, subhedral to euhedral, up to 4 mm; many chips appear weathered or with lt brown cooling surfaces), volcaniclastic sandstone or possible caliche 25%–30% (pale tan, with enclosed basalt grains/granules)	Tb 4	Cerros del Rio Basalt (est. 190-545 ft bgs), 355 ft thick
200–240	Basalt—med gray (N4), basalt 100% (vesicular to locally scoriaceous, porphyritic with aphanitic groundmass, occasionally glomerophyric, occasional vesicles filled with brown clay, minor lt tan clay on fractured/weathered surfaces), phenocrysts 10%-15% (plagioclase, olivine, and pyroxene)		monolithologic sample

Borehole Lithologic Log (continued)

Borehole ID: R-36	**TA** 72		**Page:** 3 of 7
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
240–255	Basalt—med dk gray (N5), basalt 100% (massive to weakly vesicular, porphyritic with aphanitic groundmass, glomerophyric, local white clay and $CaCO_3$? on fractures), phenocrysts 3%–7% (plagioclase, brown pyroxene, and green olivine with some iddingsite)	Tb 4	Cerros del Rio Basalt cont. olivine more abundant
255–305	Basalt—med dk gray (N4) to med gray (N5), basalt 100% (massive, porphyritic with aphanitic groundmass), phenocrysts 2%–7% (black opaque pyroxene and plagioclase)		decrease phenocryst appearance (260 ft)
305–320	No returns		
320–330	Basalt and Clay—med gray (N5) to lt gray (N7) basalt (vesicular, porphyritic with aphanitic groundmass), phenocrysts (olivine and plagioclase), few pebbles of quartz and sandstone (30% of +10 fractions), silty clay (v pale orange [10YR 8/2])		
330–350	Basalt—lt gray (N7) to med gray (N6) basalt (vesicular, porphyritic with aphanitic groundmass), phenocrysts 2%–10% (plagioclase and olivine), quartz grains (1%–2% in +35 fractions), clay (2%–4% in +35 fractions)		
350–380	Basalt/Clayey-Silty Basalt—med dk gray (N4) basalt (vesicular with vesicles commonly <2 mm, porphyritic with aphanitic groundmass), phenocrysts 8%–13% (olivine and plagioclase), silt/clay (<1%–3% of whole rock sample, slightly competent, dry, also coats basalt chips)		
380–435	Basalt—dk gray (N3) to med dk gray (N5) basalt (largely massive, weakly vesicular, minor scoria, porphyritic with aphanitic groundmass), phenocrysts 7%–17% (olivine, plagioclase, pyroxene), commonly clayey, clay coats some vesicular chips.		
435–445	Basalt—brownish gray (5YR 4/1), basalt (vesicular to scoriaceous, porphyritic with aphanitic groundmass), phenocrysts ~3%–4% (olivine and plagioclase, some olivine altered to iddingsite), clayey silt (2% of whole rock sample, coats some chips)		
445–525	Basalt—med dk gray (N4) to med lt gray (N6), basalt (vesicular to massive, porphyritic with aphanitic groundmass), phenocrysts 5%–15% (olivine, plagioclase pyroxene), clay (trace to 4% of whole rock sample, infills vesicles, and coats chip edges)		

Borehole Lithologic Log (continued)

Borehole ID: R-36	**TA:** 72		**Page:** 4 of 7
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
525–535	Basalt and Sandstone—basalt, med dk gray (N4), (massive, vesicular to scoriaceous, porphyritic with aphanitic groundmass), phenocrysts 16% (3:4:1 euhedral olivine, subhedral plagioclase, euhedral pyroxene), clay (infills a few chips), v fine-grained sandstone (olive gray [5Y 4/1], 3% of whole rock sample, olivine and basalt grains)	Tb 4	Cerros del Rio Basalt cont.
535–537	Basalt and Volcaniclastic Sandstone/Sandy Siltstone—basalt, dk gray ([N3] largely massive, porphyritic with aphanitic groundmass), phenocrysts 13% (olivine, plagioclase, pyroxene), v fine-grained sandstone, olive gray (5Y 4/1, olivine, basalt, plagioclase, rhyolite/glass grains), sandy siltstone, (v pale orange [10YR 8/2], coarse grains of rhyolite)		
537–545	**Cerros Del Rio Basalt Maar Deposit:** Maar Deposits and Volcaniclastic Sediments—basalt and basaltic vitrophyre, med gray (N5), 75% (abundant glassy scoria and clay, chips frequently coated with white clay), vesicular sideromelane glass, fine-grained sandstone and siltstone 25%, subangular pebbles of porphyritic dacite, also v fine-grained basaltic sediments?		Maar deposits at base of Cerros del Rio are believed to end at 545-ft depth.
545–550	**Puye Formation:** Volcaniclastic Sediments and Maar Deposits—volcaniclastics (80% pebble to cobbly gravel with coarse sand, subrounded porphyritic dacite clasts, and fine-grained sandstone chips, 20% basaltic scoria, porphyritic, glassy with green olivine, abundant lt tan clay, local basaltic sandstone), maar deposits (+35 fraction, abundant vitric basalt scoria and clay),	Tpf	Puye Formation Puye Formation lower part (545–575 ft bgs), 30 ft thick Overall Puye Formation encompassing Cerros del Rio (175–575 ft bgs), 400 ft thick Note: Compositional change to dominantly dacite and pumice, minor basalt
550–575	Volcaniclastic Sediments—v light gray (N8) to med gray (N5), pebble to cobble gravel, sandstone and occasional siltstone (mainly coarsely porphyritic hornblende-, pyroxene-dacites, some altered pumice, subangular to subrounded clasts, up to 22 mm, +35 fraction, vitric basaltic scoria, quartz crystals, trace black vitrophyre, siltstone, and clay)		
575–590	**Santa Fe Group:** Volcaniclastic Sediments—pebble gravel, v fine-grained sandstone, and siltstone, pebbles 10%–50% (lt gray [N7]), mainly porphyritic dacite, to 20 mm, subangular to subrounded, 2% pale orange (10YR 8/2) microcline, siltstone 10%–15%, +35 fraction (abundant siltstone fragments, 3%–5% Precambrian clasts, pink-orange feldspars, 1%–2% quartz crystals)	Tsfu	Santa Fe Group

Borehole Lithologic Log (continued)

Borehole ID: R-36	**TA:** 72		**Page:** 5 of 7
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
590–610	Granitic and Volcaniclastic Sediments—siltstone, silty sandstone and pebble gravel; sandstones 25%–40% (fine- to med-grained sandstone and siltstone), clasts 40%–60% (20% lt gray [N7] dacite, subrounded, up to 5 mm; 25%–40% Precambrian feldspar and granite pebbles, up to 8 mm, commonly rounded), +35 fraction (30%–50% Precambrian quartz, feldspar, and granite grains)	Tsfu	Santa Fe Group cont.
610–625	Granitic and Volcaniclastic Sediments—clay, siltstone, sandstone, and granule/pebble conglomerate; sandstone/siltstones 25%–50% (claystone, siltstone, v fine- to coarse-grained sandstone, pale tan [10YR 7/4]), clasts 40%–70% (25%–40% lt gray [N7] dacite, subrounded, up to 20 mm, and other intermediate volcanic rocks, 15%–30% Precambrian quartz and feldspar, subrounded)		decrease in Precambrian clast abundance
625–635	Volcaniclastic and Granitic Sediments—siltstone, sandstone, and pebble conglomerate; sandstone/siltstones 10%–20% (claystone, siltstone, and med-grained sandstone, pale tan [10YR 7/4]), clasts 75%–95% (60%–80% lt gray [N7] to med gray [N4] porphyritic dacite and minor dk gray [N3] vitrophyre, broken and subrounded, up to 20 mm, 15%–20% Precambrian quartz and feldspar)		
635–650	Volcaniclastic Sediments—pebble conglomerate and sandstone; sandstones 2%–15% (fine- to med-grained sandstone and siltstone, lt tan [10YR 7/4]), clasts 75%–95% (lt gray porphyritic dacite, broken and subangular, up to 18 mm, 3%–10% Precambrian quartz and feldspar)		
650–665	Granitic and Volcaniclastic Sediments—pebble gravel, sandstone, and siltstone; sandstones 10%–40% (pinkish [5YR 8/4] siltstone/claystone, med-grained sandstone chips), clasts 45%–85% (30%–70% lt gray [N7] dacite and occasionally other intermediate/felsic and volcanic rocks, subangular to subrounded, up to 8 mm, 15%–40% Precambrian quartz, feldspar, and granite, subrounded to rounded, up to 5 mm)		increase in Precambrian clast abundance
665–690	Volcaniclastic Sediments—pebble gravel, sandstone, and siltstone; sandstones 20% (fine- to med-grained sandstone), clasts 80%–100% (70%–90% lt gray dacite, subrounded to subangular, up to 13 mm, 3%-15% Precambrian quartz, feldspar, and granite, subangular to subrounded)		decrease in Precambrian clast abundance

Borehole Lithologic Log (continued)

Borehole ID: R-36	**TA** 72		**Page:** 6 of 7
Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
690–705	No returns		lost circulation zone
705–710	Volcaniclastic Sediments—siltstone and pebble gravel; fines 40%–60% (30%–40% yellowish tan [10YR 7/4] siltstone chips/clots, 10%–20% white [N9] clayey/waxy sediment containing ferromagnesian crystals and small quartz and feldspars; likely altered ash or pumice), clasts 40%–50% (lt gray [N7] porphyritic dacite, subrounded, up to 10 mm)	Tsfu	Santa Fe Group cont. Note: Altered volcanic ash deposits Note: Absence of Precambrian clasts from 700 to 800 ft
710–735	Volcaniclastic Sediments—coarse conglomerate, sandstone and siltstone; fines 1%–10% (clays and fine-grained sandstone), clasts 90%–99% (lt to med gray [N7-N5] porphyritic dacite and pale altered dacite, subrounded to subangular and broken, to 10 mm), +35 fraction (1% free detrital quartz crystals)		
735–755	Volcaniclastic Sediments—coarse conglomerate and sandstone in a clayey matrix; clasts >=99% (almost exclusively lt gray [N7] to v pale porphyritic biotite dacite, broken, subangular to subrounded, up to 18 mm), +35 fraction (<1% free quartz crystals)		monolithologic sample
755–770	Volcaniclastic Sediments—coarse gravel/conglomerate, sandstone, and siltstone; fines 3%–7% (lt tan [5YR 8/1] siltstone chips, 1% free quartz and feldspar crystals), clasts 93%–98% (lt gray [N7] biotite dacite and white [N9] hornblende-biotite dacite, partial weathering of some clasts, broken, subrounded to subangular, up to 15 mm)		
770–790	Volcaniclastic Sediments—coarse conglomerate and sandstone; clasts >99% (lt gray porphyritic dacite with some vitric to earthy pumice fragments, broken, subrounded to subangular, up to 20 mm)		
790–800	Volcaniclastic Sediments—coarse conglomerate and sandstone; clasts >99% (lt gray [N7] porphyritic dacite, subrounded, whole rock sample has 40-mm clast of ferruginous biotite dacite), rare Precambrian quartz and quartzite		minimal returns, 790–800 ft bgs
800–840	Volcaniclastic and Granitic Sediments—whole rock sample; fines 90% (silt and v fine- to coarse-grained sandstone), clasts 1%–15% (compositionally diverse, 90% mixed volcanics (dacite, andesite, rhyodacite) subrounded to rounded, up to 4 mm, 10% Precambrian quartzite, quartz, and granite clasts; chert present at 800–810 ft bgs)		Santa Fe Group cont. Note: Precambrian clasts reappear at 800 ft and below. Below 810 ft sediment size is notably finer. Calcite-cemented sands appear and become common below 815 ft.

Borehole Lithologic Log (continued)

Borehole ID: R-36	**TA** 72		**Page:** 7 of 7
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
840–850	Volcaniclastic Sediments—whole rock sample; fines 70% (60%-65% fine-grained sand, 5%–10% silt), clasts 30% (gravel), +10 fraction (65%–75% lt tan [5YR 8/1] fragments of cemented fine-grained sandstone, 25%–30% mixed intermediate volcanic granules, subrounded, 1%–3% Precambrian quartzite and quartz granules)	Tsfu	Santa Fe Group cont.
850–865	Volcaniclastic Sediments—whole rock sample; (silt, v fine-grained sandy silt, and minor gravel), +10 fraction (70%–95% mixed intermediate to felsic volcanic granules, subrounded, up to 15 mm, 10%–25% fragments of lt tan [5YR 8/1] fine-grained cemented sandstone, 2%–3% Precambrian microcline and quartzite granules)		
865	Total Depth		

Abbreviations

5YR 8/1 = Munsell soil color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g., 1) are expressed. Hue indicates soil color's relation to red, yellow, green, blue, and purple. Value indicates soil color's lightness. Chroma indicates soil color's strength.

dk = Dark.

est = Estimated.

F = Fines.

Fm = Formation.

G = Gravel.

lt = Light.

med = Medium.

N = Neutrals.

Qal = Quaternary Alluvium.

Qbo = Otowi Member of Bandelier Tuff.

Qbog = Guaje Pumice Bed.

S = Sand.

Tb4 = Cerros del Rio Basalt.

Tpf = Puye Formation.

Tsfu = Santa Fe Group.

tr = Trace.

v = Very.

YR = Yellow red.

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-36

A total of 14 groundwater-screening samples were collected from borehole R-36 during drilling from November 13 to December 3, 2007. These groundwater-screening samples were filtered through 0.45-micrometer (μm) membranes before preservation, if required, before chemical analyses. A total of 40 groundwater-screening samples were collected at well R-36 during well development and during and after the pumping tests conducted from February 15 to February 21, 2008. The samples were collected from the screen interval of 766.9 to 789.9 ft below ground surface (bgs) within the regional aquifer. The nonfiltered samples were analyzed for total organic carbon (TOC), cations, anions, perchlorate, and metals. A total of 40,548 gal. of groundwater was pumped from well R-36 during sample collection.

B-1.1 Field Preparation and Analytical Techniques

Chemical analyses of groundwater-screening samples were performed at Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 6 (EES-6). Groundwater samples collected from well R-36 were not filtered before chemical analyses. Samples were acidified at the EES-6 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified in the U.S. Environmental Protection Agency SW-846 Manual. Ion chromatography was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, chlorate, perchlorate, phosphate, and sulfate. The instrument detection limit for perchlorate was 0.001 ppm. Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was used for analyses of calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS). The precision limits (analytical error) for major ions and trace elements were generally less than ±10% by using ICPOES and ICPMS. Total carbonate alkalinity was measured using standard titration techniques. Total dissolved sulfide was not measured at well R-36. Charge balance errors for total cations and anions were generally less than ±9% for complete analyses of the above inorganic chemicals. The negative cation-anion charge balance values indicate slight excess of major anions (chloride, sulfate, and total carbonate alkalinity) for the nonfiltered samples.

B-1.2 Analytical Results for Borehole Screening Samples

Four groundwater-screening samples (GW36-08-8505, GW36-08-8506, GW36-08-8647, and GW36-08-8649) were collected from a perched intermediate zone during drilling of borehole R-36. The groundwater samples collected from R-36 are presented in Table 4.2-1 in the main text of this document. Analytical results for screening groundwater samples collected at borehole R-36 are provided in Table B.1-1. Sample GW36-08-8546 consisted of municipal water collected from the water truck's tank on November 13, 2007. Groundwater samples (GW36-08-8505, GW36-08-8506, GW36-08-8547, and GW86-08-8549) were collected within a perched intermediate-depth zone from 571 to 580 ft bgs on November 13 and 14, 2007. Samples GW36-08-8505 and GW36-08-8506 were collected only for TOC analyses but were not analyzed. Sample GW36-08-8549 was analyzed only for tritium. Sample GW36-08-8547 was analyzed for cations, anions, perchlorate, and metals. Borehole water samples were not analyzed for TOC because of inappropriate plastic containers.

Dissolved concentrations in the perched groundwater sample (GW36-08-8547) were bromide 0.59 ppm, chloride 9.15 ppm, total chromium 0.003 ppm, fluoride 1.16 ppm, molybdenum 0.640 ppm, nitrate(N) 0.028 ppm, sodium 88.5 ppm, sulfate 28.8 ppm, and uranium 0.0061 ppm (Table B.1-1). During well development, detectable concentrations of molybdenum were 0.002 ppm (see Table B.1-1). It is possible that elevated concentrations of molybdenum were derived from lubricants used during drilling and/or degradation of the drill tooling because concentrations of molybdenum significantly decreased during well development and aquifer performance testing. Perchlorate is less than the detection limits (0.001, 0.002, and 0.005 ppm) in the borehole screening sample collected from the perched intermediate-depth zone (Table B.1-1). The activity of tritium in the perched intermediate zone (sample GW36 08 8549) encountered at borehole R-36 was 2.8 $\pm$ 2.0 tritium units (TU) (9.0 $\pm$ 6.4 pCi/kg H_2O). Direct counting was performed at the University of Miami for the measurement.

Five groundwater-screening samples were collected from the regional aquifer during drilling of borehole R-36. Samples GW36-08-8548, GW36-08-8550, GW36-08-8551, GW36-08-8555, and GW36-08-8562 were collected at 812, 850, 865, 792, and 772 ft bgs, respectively, from November 30 to December 3, 2007. Dissolved concentrations of bromide ranged from 0.04 to 0.06 ppm in the groundwater-screening samples collected from the regional aquifer at borehole R-36 (Table B.1-1). Dissolved concentrations of chloride and total chromium ranged from 6.74 to 7.97 ppm and from 0.007 to 0.008 ppm, respectively (Table B.1-1). Dissolved concentrations of fluoride and molybdenum ranged from 0.46 to 0.61 ppm and from 0.027 to 0.140 ppm, respectively (Table B.1-1). Dissolved concentrations of nitrate (N) and sulfate ranged from 0.823 to 1.838 ppm and from 5.96 to 9.36 ppm, respectively (Table B.1-1). Dissolved concentrations of uranium were less than 0.001 ppm (Table B.1-1) in the borehole water screening samples at R-36. Perchlorate was less than analytical detection (0.001 and 0.005 ppm) in the borehole screening samples collected from the regional aquifer (Table B.1-1).

B-1.2 Field Parameters

Table 8.1 in the main text provides results of field parameters consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity. Field parameters were measured at well R-36 by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This condition probably resulted in slight variation of field parameters, most notably temperature, pH, and DO, during well development and during the pumping test. Measurements of pH and temperature varied from 8.15 to 9.34 and from 12.10°C to 22.31°C, respectively, at well R-36. Concentrations of DO varied from 7.42 to 10.9 mg/L at the well. Regional aquifer groundwater is relatively oxidizing at well R-36, based on DO and ORP measurements, with ORP varying from 148 to 278 millivolts (mV). Specific conductance was recorded for a majority of the groundwater samples collected at well R-36, with measurements ranging from 120 to 420 microsiemens per centimeter (μS/cm). Specific conductance ranged from 226 to 230 μS/cm during well purging conducted after the pumping test. Values of turbidity ranged from 0 to 5.0 nephelometric turbidity units (NTUs) for the nonfiltered groundwater samples collected at R-36. All but one of the turbidity values was less than 5 NTUs.

B-1.3 Analytical Results for Groundwater-Screening Samples

Analytical results for groundwater-screening samples (GW36-08-10884 through GW36-08-10923) collected at well R-36 are provided in Table B.1-2. Calcium and sodium are the dominant cations in groundwater pumped from well R-36. Total concentrations of calcium and sodium in nonfiltered samples ranged from 16.0 to 18.4 ppm and from 13.5 to 15.2 ppm, respectively. Concentrations of chloride and fluoride in nonfiltered samples ranged from 8.14 to 8.94 ppm and from 0.60 to 0.92 ppm, respectively, at well R-36. Concentrations of nitrate (N) and sulfate in nonfiltered samples ranged from 2.23 to 2.81 ppm and from 8.29 to 9.61 ppm, respectively, at the well. Total concentrations of chloride, fluoride, nitrate(N), and sulfate at well R-36 exceed Laboratory background within the regional aquifer (LANL 2007, 095817). Maximum background concentrations in the regional aquifer for relevant dissolved species of total anions are chloride 7.56 mg/L, fluoride 0.63 mg/L, nitrate plus nitrite(N) 0.79 mg/L, and sulfate 7.03 mg/L (LANL 2007, 095817). Concentrations of TOC ranged from 0.25 to 0.44 milligram carbon per liter (mgC/L; also ppm) at well R-36 (Table B.1-2), suggesting that residual organic drilling fluid used within the vadose zone is not present in the regional aquifer at R-36. Concentrations of perchlorate were less than analytical detection (<0.001 ppm) at well R-36.

Total concentrations of iron and manganese ranged from 0.22 to 1.22 ppm and from 0.005 to 0.025 ppm, respectively, in groundwater-screening samples collected at R-36 (Table B.1-2). Total concentrations of iron and manganese are less than the maximum background values in nonfiltered sampled for these two trace metals within the regional aquifer (iron 1270 microgram per liter [μg/L]; manganese 220 μg/L) (LANL 2007, 095817). Detectable concentrations of molybdenum in nonfiltered samples were 0.002 ppm (Table B.1-2). Total concentrations of zinc ranged from 0.002 to 0.083 ppm (2 to 83 μg/L) in groundwater-screening samples collected at R-36, with four samples exceeding the maximum background concentration of this trace metal in nonfiltered samples (Table B.1-2). Background mean, median, and maximum concentrations of zinc in nonfiltered samples are 5.30 μg/L, 2.50 μg/L, and 51 μg/L, respectively, for the regional aquifer (LANL 2007, 095817). Concentrations of total boron ranging from 0.024 to 0.044 ppm (24 to 44 μg/L) at well R-36 are less than the Laboratory maximum background value of 52 μg/L for the regional aquifer (LANL 2007, 095817). Total concentrations of chromium in nonfiltered samples ranged from 0.003 to 0.007 ppm (3 to 7 μg/L) at well R-36, with most values equal to 0.004 ppm (4 μg/L) (Table B.1-2). Background mean, median, and maximum concentrations of total chromium in nonfiltered samples are 3.85 μg/L, 3.90 μg/L, and 9.80 μg/L, respectively, for the regional aquifer (LANL 2007, 095817).

B-2.0 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 number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), 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.1-1
Analytical Results for Perched Groundwater and Borehole Groundwater-Screening Samples Collected from R-36

Sample ID	Date Received	ER/RRES-WQH[a]	Deep (ft)	Ag Result (ppm)	stdev (Ag)	Al Result (ppm)	stdev (Al)	As Result (ppm)	stdev (As)	B Result (ppm)	stdev (B)	Ba Result (ppm)	stdev (Ba)	Be Result (ppm)	stdev (Be)	Br(-) ppm	Br(-) (U)	TOC Result (mgC/L, ppm)	TOC (U)
GW36-08-8546	11/13/2007	Not provided	n/a[b]	0.001	U[c]	0.001	0.000	0.0014	0.0000	0.033	0.000	0.031	0.000	0.001	U	0.01	U	Not analyzed	—
GW36-08-8547	11/13/2007	Not provided	n/a	0.001	U	0.030	0.000	0.0014	0.0000	0.011	0.001	0.021	0.001	0.001	U	0.59	—[d]	Not analyzed	—
GW36-08-8548	11/30/2007	08-295	812	0.001	U	0.005	0.000	0.0006	0.0000	0.034	0.000	0.028	0.000	0.001	U	0.05	—	Not analyzed	—
GW36-08-8550	12/3/2007	08-302	850	0.001	U	0.010	0.001	0.0010	0.0001	0.035	0.001	0.030	0.003	0.001	U	0.04	—	Not analyzed	—
GW36-08-8551	12/3/2007	08-302	865	0.001	U	0.005	0.000	0.0003	0.0000	0.029	0.000	0.026	0.001	0.001	U	0.05	—	Not analyzed	—
GW36-08-8555	11/30/2007	08-295	792	0.001	U	0.018	0.001	0.0002	0.0000	0.055	0.001	0.020	0.001	0.001	U	0.06	—	Not analyzed	—
GW36-08-8562	11/30/2007	08-295	772	0.001	U	0.018	0.002	0.0003	0.0001	0.029	0.000	0.022	0.002	0.001	U	0.04	—	Not analyzed	—

Table B.1-1
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Deep (ft)	Ca Result (ppm)	stdev (Ca)	Cd Result (ppm)	stdev (Cd)	Cl(-) ppm	Cl(-) (U)	ClO_4(-) ppm	ClO_4(-) (U)	Co Result (ppm)	stdev (Co)	Alk-CO_3 Result (ppm)	ALK-CO_3 (U)	Cr Result (ppm)	stdev (Cr)	Cs Result (ppm)	stdev (Cs)	Cu Result (ppm)
GW36-08-8546	11/13/2007	Not provided	n/a	18.0	0.0	0.001	U	9.20	—	0.002	U	0.001	U	0.8	U	0.005	0.000	0.001	U	0.002
GW36-08-8547	11/13/2007	Not provided	n/a	18.2	0.0	0.001	U	9.15	—	0.005	U	0.001	U	11.8	U	0.003	0.000	0.001	U	0.004
GW36-08-8548	11/30/2007	08-295	812	20.8	0.0	0.001	U	7.91	—	0.005	U	0.001	U	0.8	U	0.007	0.000	0.001	U	0.002
GW36-08-8550	12/3/2007	08-302	850	21.0	0.0	0.001	U	6.74	—	0.005	U	0.001	U	0.8	U	0.008	0.001	0.001	U	0.002
GW36-08-8551	12/3/2007	08-302	865	19.0	0.1	0.001	U	6.77	—	0.001	U	0.001	U	0.8	U	0.007	0.000	0.001	U	0.001
GW36-08-8555	11/30/2007	08-295	792	18.7	0.1	0.001	U	7.97	—	0.001	U	0.001	U	0.8	U	0.007	0.001	0.001	U	0.003
GW36-08-8562	11/30/2007	08-295	772	17.9	0.1	0.001	U	6.78	—	0.001	U	0.001	U	0.8	U	0.007	0.001	0.001	U	0.003

Table B.1-1
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Deep (ft)	stdev (Cu)	F(-) ppm	F(-) (U)	Fe Result (ppm)	stdev (Fe)	Alk-CO_3+HCO_3 Result (ppm)	ALK-CO_3+HCO_3 (U)	Hg Result (ppm)	stdev (Hg)	K Result (ppm)	stdev (K)	Li Result (ppm)	stdev (Li)	Mg Result (ppm)	stdev (Mg)	Mn Result (ppm)	stdev (Mn)
GW36-08-8546	11/13/2007	Not provided	n/a	0.000	0.41	—	0.28	0.00	116	—	0.00005	U	2.69	0.01	0.028	0.000	5.61	0.02	0.035	0.001
GW36-08-8547	11/13/2007	Not provided	n/a	0.000	1.16	—	0.04	0.00	172	—	0.00028	0.00001	6.26	0.05	0.043	0.001	3.40	0.02	0.005	0.000
GW36-08-8548	11/30/2007	08-295	812	0.000	0.55	—	0.01	U	99.1	—	0.00005	0.00001	2.81	0.01	0.024	0.000	4.53	0.03	0.031	0.000
GW36-08-8550	12/3/2007	08-302	850	0.000	0.55	—	0.04	0.00	107	—	0.00005	U	2.59	0.01	0.031	0.003	4.32	0.02	0.034	0.003
GW36-08-8551	12/3/2007	08-302	865	0.000	0.61	—	0.03	0.00	95.5	—	0.00005	U	2.67	0.04	0.028	0.001	3.34	0.04	0.089	0.004
GW36-08-8555	11/30/2007	08-295	792	0.000	0.51	—	0.03	0.00	96.7	—	0.00005	U	2.99	0.08	0.033	0.002	4.13	0.07	0.128	0.005
GW36-08-8562	11/30/2007	08-295	772	0.000	0.46	—	0.07	0.00	97.4	—	0.00005	U	2.30	0.02	0.034	0.005	3.90	0.02	0.018	0.002

Table B.1-1
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Deep (ft)	Mo Result (ppm)	stdev (Mo)	Na Result (ppm)	stdev (Na)	Ni Result (ppm)	stdev (Ni)	NO_2 (ppm)	NO_2-N Result	NO_2-N (U)	NO_3 ppm	NO_3-N Result	NO_3-N (U)	C_2O_4 Result (ppm)	C_2O_4 (U)	Pb Result (ppm)	stdev (Pb)	pH	$PO_4^{(-3)}$ Result (ppm)	$PO_4^{(-3)}$ (U)	Rb Result (ppm)
GW36-08-8546	11/13/2007	Not provided	n/a	0.001	0.000	16.9	0.1	0.001	U	0.01	0.003	U	2.15	0.486	—	0.01	U	0.0002	U	7.98	0.05	—	0.004
GW36-08-8547	11/13/2007	Not provided	n/a	0.640	0.004	88.5	0.8	0.001	U	0.01	0.003	U	0.13	0.028	—	1.80	—	0.0002	U	8.67	0.01	U	0.009
GW36-08-8548	11/30/2007	08-295	812	0.140	0.001	12.2	0.1	0.001	—	0.01	0.003	U	5.60	1.265	—	0.05	—	0.0002	U	7.90	0.01	U	0.003
GW36-08-8550	12/3/2007	08-302	850	0.026	0.000	12.5	0.0	0.002	U	0.01	0.003	U	3.69	0.833	—	0	U	0.0006	0.0000	7.96	0.01	U	0.002
GW36-08-8551	12/3/2007	08-302	865	0.079	0.000	11.9	0.2	0.001	U	0.01	0.003	U	3.64	0.823	—	0.04	—	0.0002	U	7.76	0.01	U	0.003
GW36-08-8555	11/30/2007	08-295	792	0.064	0.001	19.9	0.4	0.004	U	0.06	0.018	—	8.14	1.838	—	0.15	—	0.0002	U	7.56	0.01	U	0.004
GW36-08-8562	11/30/2007	08-295	772	0.027	0.000	14.4	0.1	0.001	U	0.01	0.003	U	5.81	1.313	—	0.13	—	0.0004	0.0000	7.89	0.01	U	0.004

Table B.1-1
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Deep (ft)	stdev (Rb)	S_2 Result (ppm)	S_2 (U)	Sb Result (ppm)	stdev (Sb)	Se Result (ppm)	stdev (Se)	Si Result (ppm)	stdev (Si)	SiO_2 Result (ppm)	stdev (SiO_2)	Sn Result (ppm)	stdev (Sn)	$SO_4^{(-2)}$ Result (ppm)	$SO_4^{(-2)}$ (U)	Sr Result (ppm)	stdev (Sr)	Th Result (ppm)	stdev (Th)
GW36-08-8546	11/13/2007	Not provided	n/a	0.000	n/a	—	0.001	U	0.001	U	42.2	0.2	90.3	0.4	0.001	U	4.96	—	0.080	0.001	0.001	U
GW36-08-8547	11/13/2007	Not provided	n/a	0.000	n/a	—	0.001	U	0.001	U	14.8	0.1	31.8	0.2	0.001	U	28.8	—	0.107	0.000	0.001	U
GW36-08-8548	11/30/2007	08-295	812	0.000	n/a	—	0.001	U	0.001	U	14.7	0.1	31.4	0.1	0.001	U	9.36	—	0.106	0.001	0.001	U
GW36-08-8550	12/3/2007	08-302	850	0.000	n/a	—	0.001	U	0.001	U	23.2	0.1	49.7	0.2	0.001	U	7.19	—	0.156	0.001	0.001	U
GW36-08-8551	12/3/2007	08-302	865	0.000	n/a	—	0.001	U	0.001	U	13.1	0.1	28.1	0.3	0.001	U	7.42	—	0.134	0.002	0.001	U
GW36-08-8555	11/30/2007	08-295	792	0.000	n/a	—	0.001	U	0.001	U	18.3	0.4	39.2	0.8	0.001	U	7.55	—	0.078	0.004	0.001	U
GW36-08-8562	11/30/2007	08-295	772	0.000	n/a	—	0.001	U	0.001	U	18.5	0.2	39.6	0.4	0.001	U	5.96	—	0.077	0.007	0.001	U

Table B.1-1
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Deep (ft)	stdev (Th)	Ti Result (ppm)	stdev (Ti)	Tl Result (ppm)	stdev (Tl)	U Result (ppm)	stdev (U)	V Result (ppm)	stdev (V)	Zn Result (ppm)	stdev (Zn)	TDS[e] (ppm)	Cations	Anions	Balance	Status	Cations
GW36-08-8546	11/13/2007	Not provided	n/a	U	0.002	U	0.001	U	0.0009	0.0000	0.011	0.000	0.002	0.000	267	2.17	2.35	-0.04	No request number	2.17
GW36-08-8547	11/13/2007	Not provided	n/a	U	0.003	0.000	0.001	U	0.0061	0.0001	0.007	0.000	0.016	0.001	372	5.21	4.13	0.11	No request number	5.21
GW36-08-8548	11/30/2007	08-295	812	U	0.002	U	0.001	U	0.0007	0.0000	0.006	0.000	0.002	0.000	196	2.02	2.19	-0.04	Completed	2.02
GW36-08-8550	12/3/2007	08-302	850	U	0.007	0.000	0.001	U	0.0007	0.0001	0.009	0.001	0.005	0.000	217	2.03	2.21	-0.04	Completed	2.03
GW36-08-8551	12/3/2007	08-302	865	U	0.002	U	0.001	U	0.0002	U	0.002	0.000	0.003	0.000	180	1.82	2.03	-0.05	Completed	1.82
GW36-08-8555	11/30/2007	08-295	792	U	0.002	U	0.001	U	0.0002	U	0.002	0.000	0.006	0.000	207	2.22	2.16	0.01	Completed	2.22
GW36-08-8562	11/30/2007	08-295	772	U	0.002	U	0.001	U	0.0008	0.0001	0.003	0.000	0.006	0.001	196	1.91	2.06	-0.04	Completed	1.91

[a] ER/RRES-WGH = Environmental Restoration/Risk Reduction and Environmental Stewardship-Water Quality and Hydrology.

[b] n/a = Not applicable.

[c] U = Undetected.

[d] — = No qualifier.

[e] TDS = Total dissolved solids.

Table B.1-2
Analytical Results for Groundwater-Screening Samples Collected from Well R-36

Sample ID	Date Received	ER/RRES-WQH[a]	Ag Result (ppm)	stdev (Ag)	Al Result (ppm)	stdev (Ag)	Al Result (ppm)	stdev (Al)	As Result (ppm)	stdev (As)	B Result (ppm)	stdev (B)	Ba Result (ppm)	stdev (Ba)	Be Result (ppm)	stdev (Be)	Br(-) ppm
GW36-08-10884	2/19/2008	08-744	0.001	U[b]	0.472	U	0.472	0.010	0.0018	0.0000	0.028	0.001	0.029	0.000	0.001	U	0.03
GW36-08-10885	2/19/2008	08-744	0.001	U	0.308	U	0.308	0.004	0.0017	0.0000	0.027	0.000	0.026	0.000	0.001	U	0.03
GW36-08-10886	2/19/2008	08-744	0.001	U	0.198	U	0.198	0.003	0.0018	0.0000	0.027	0.000	0.028	0.000	0.001	U	0.03
GW36-08-10887	2/19/2008	08-744	0.001	U	0.184	U	0.184	0.001	0.0018	0.0000	0.028	0.000	0.029	0.000	0.001	U	0.03
GW36-08-10888	2/19/2008	08-744	0.001	U	0.151	U	0.151	0.001	0.0018	0.0001	0.029	0.001	0.030	0.000	0.001	U	0.03
GW36-08-10889	2/19/2008	08-744	0.001	U	0.133	U	0.133	0.001	0.0017	0.0001	0.030	0.000	0.031	0.001	0.001	U	0.04
GW36-08-10890	2/19/2008	08-744	0.001	U	0.125	U	0.125	0.001	0.0018	0.0000	0.041	0.000	0.031	0.000	0.001	U	0.04
GW36-08-10891	2/19/2008	08-744	0.001	U	0.128	U	0.128	0.000	0.0019	0.0000	0.037	0.002	0.030	0.000	0.001	U	0.04
GW36-08-10892	2/19/2008	08-744	0.001	U	0.115	U	0.115	0.001	0.0018	0.0001	0.025	0.000	0.031	0.000	0.001	U	0.04
GW36-08-10893	2/19/2008	08-744	0.001	U	0.107	U	0.107	0.002	0.0019	0.0000	0.026	0.000	0.032	0.000	0.001	U	0.04
GW36-08-10894	2/19/2008	08-744	0.001	U	0.108	U	0.108	0.001	0.0018	0.0001	0.026	0.000	0.030	0.001	0.001	U	0.04
GW36-08-10895	2/19/2008	08-744	0.001	U	0.106	U	0.106	0.000	0.0019	0.0000	0.026	0.000	0.031	0.001	0.001	U	0.04
GW36-08-10896	2/19/2008	08-744	0.001	U	0.101	U	0.101	0.000	0.0018	0.0000	0.026	0.000	0.032	0.000	0.001	U	0.04
GW36-08-10897	2/19/2008	08-744	0.001	U	0.099	U	0.099	0.000	0.0017	0.0000	0.027	0.000	0.030	0.001	0.001	U	0.04
GW36-08-10898	2/19/2008	08-744	0.001	U	0.095	U	0.095	0.001	0.0019	0.0000	0.028	0.000	0.031	0.000	0.001	U	0.04
GW36-08-10899	2/19/2008	08-744	0.001	U	0.087	U	0.087	0.001	0.0018	0.0000	0.035	0.000	0.033	0.000	0.001	U	0.04
GW36-08-10900	2/19/2008	08-744	0.001	U	0.088	U	0.088	0.000	0.0019	0.0000	0.044	0.001	0.032	0.000	0.001	U	0.06
GW36-08-10901	2/21/2008	08-744	0.001	U	0.020	U	0.020	0.000	0.0017	0.0000	0.044	0.000	0.027	0.000	0.001	U	0.04
GW36-08-10902	2/21/2008	08-744	0.001	U	0.013	U	0.013	0.000	0.0017	0.0001	0.034	0.000	0.025	0.001	0.001	U	0.04
GW36-08-10903	2/21/2008	08-744	0.001	U	0.022	U	0.022	0.002	0.0016	0.0001	0.029	0.000	0.024	0.000	0.001	U	0.04
GW36-08-10904	2/21/2008	08-744	0.001	U	0.028	U	0.028	0.001	0.0016	0.0000	0.028	0.000	0.025	0.001	0.001	U	0.04
GW36-08-10905	2/21/2008	08-744	0.001	U	0.033	U	0.033	0.000	0.0018	0.0000	0.026	0.000	0.027	0.000	0.001	U	0.04
GW36-08-10906	2/21/2008	08-744	0.001	U	0.031	U	0.031	0.003	0.0018	0.0000	0.026	0.000	0.027	0.000	0.001	U	0.04
GW36-08-10907	2/21/2008	08-744	0.001	U	0.036	U	0.036	0.002	0.0017	0.0001	0.025	0.001	0.027	0.001	0.001	U	0.04
GW36-08-10908	2/21/2008	08-744	0.001	U	0.031	U	0.031	0.000	0.0017	0.0001	0.026	0.000	0.028	0.000	0.001	U	0.04
GW36-08-10909	2/21/2008	08-744	0.001	U	0.022	U	0.022	0.001	0.0017	0.0000	0.025	0.000	0.028	0.000	0.001	U	0.04
GW36-08-10910	2/21/2008	08-744	0.001	U	0.030	U	0.030	0.001	0.0017	0.0000	0.037	0.002	0.028	0.001	0.001	U	0.04
GW36-08-10911	2/21/2008	08-744	0.001	U	0.029	U	0.029	0.000	0.0017	0.0000	0.038	0.000	0.029	0.001	0.001	U	0.04
GW36-08-10912	2/21/2008	08-744	0.001	U	0.027	U	0.027	0.001	0.0017	0.0001	0.031	0.001	0.029	0.001	0.001	U	0.04
GW36-08-10913	2/21/2008	08-744	0.001	U	0.024	U	0.024	0.002	0.0016	0.0000	0.028	0.000	0.028	0.000	0.001	U	0.04
GW36-08-10914	2/21/2008	08-744	0.001	U	0.027	U	0.027	0.001	0.0017	0.0001	0.026	0.001	0.029	0.001	0.001	U	0.05
GW36-08-10915	2/21/2008	08-744	0.001	U	0.023	U	0.023	0.000	0.0017	0.0000	0.027	0.000	0.028	0.000	0.001	U	0.04
GW36-08-10916	2/21/2008	08-744	0.001	U	0.023	U	0.023	0.000	0.0017	0.0001	0.026	0.001	0.027	0.001	0.001	U	0.04
GW36-08-10917	2/21/2008	08-744	0.001	U	0.014	U	0.014	0.002	0.0017	0.0000	0.025	0.000	0.029	0.001	0.001	U	0.04
GW36-08-10918	2/21/2008	08-744	0.001	U	0.018	U	0.018	0.001	0.0017	0.0000	0.024	0.000	0.029	0.000	0.001	U	0.04
GW36-08-10919	2/21/2008	08-744	0.001	U	0.017	U	0.017	0.000	0.0017	0.0001	0.024	0.000	0.028	0.000	0.001	U	0.04
GW36-08-10920	2/21/2008	08-744	0.001	U	0.015	U	0.015	0.001	0.0017	0.0000	0.037	0.001	0.029	0.000	0.001	U	0.04
GW36-08-10921	2/21/2008	08-744	0.001	U	0.013	U	0.013	0.001	0.0016	0.0000	0.039	0.001	0.026	0.001	0.001	U	0.04
GW36-08-10922	2/21/2008	08-744	0.001	U	0.018	U	0.018	0.000	0.0017	0.0000	0.046	0.000	0.026	0.001	0.001	U	0.04
GW36-08-10923	2/21/2008	08-744	0.001	U	0.017	U	0.017	0.000	0.0016	0.0000	0.036	0.001	0.027	0.000	0.001	U	0.04

Table B.1-2
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Br(-) (U)	TOC Result (mgC/L, ppm)	TOC (U)	Ca Result (ppm)	stdev (Ca)	Cd Result (ppm)	stdev (Cd)	Cl(-) ppm	Cl(-) (U)	ClO_4(-) ppm	ClO_4(-) (U)	Co Result (ppm)	stdev (Co)	Alk-CO_3 Result (ppm)	ALK-CO_3 (U)
GW36-08-10884	2/19/2008	08-744	—[c]	0.44	—	18.4	0.0	0.001	U	8.85	—	0.001	U	0.001	U	0.8	U
GW36-08-10885	2/19/2008	08-744	—	0.39	—	17.9	0.0	0.001	U	8.51	—	0.001	U	0.001	U	0.8	U
GW36-08-10886	2/19/2008	08-744	—	0.33	—	17.9	0.0	0.001	U	8.46	—	0.001	U	0.001	U	0.8	U
GW36-08-10887	2/19/2008	08-744	—	0.35	—	18.0	0.0	0.001	U	8.45	—	0.001	U	0.001	U	0.8	U
GW36-08-10888	2/19/2008	08-744	—	0.35	—	18.1	0.1	0.001	U	8.17	—	0.001	U	0.001	U	0.8	U
GW36-08-10889	2/19/2008	08-744	—	0.33	—	17.9	0.1	0.001	U	8.26	—	0.001	U	0.001	U	0.8	U
GW36-08-10890	2/19/2008	08-744	—	0.44	—	17.8	0.1	0.001	U	8.28	—	0.001	U	0.001	U	0.8	U
GW36-08-10891	2/19/2008	08-744	—	0.43	—	18.0	0.2	0.001	U	8.40	—	0.001	U	0.001	U	0.8	U
GW36-08-10892	2/19/2008	08-744	—	0.32	—	17.7	0.1	0.001	U	8.37	—	0.001	U	0.001	U	0.8	U
GW36-08-10893	2/19/2008	08-744	—	0.37	—	17.7	0.0	0.001	U	8.14	—	0.001	U	0.001	U	0.8	U
GW36-08-10894	2/19/2008	08-744	—	0.42	—	17.7	0.0	0.001	U	8.40	—	0.001	U	0.001	U	0.8	U
GW36-08-10895	2/19/2008	08-744	—	0.43	—	17.7	0.1	0.001	U	8.27	—	0.001	U	0.001	U	0.8	U
GW36-08-10896	2/19/2008	08-744	—	0.37	—	17.8	0.1	0.001	U	8.28	—	0.001	U	0.001	U	0.8	U
GW36-08-10897	2/19/2008	08-744	—	0.39	—	17.9	0.1	0.001	U	8.10	—	0.001	U	0.001	U	0.8	U
GW36-08-10898	2/19/2008	08-744	—	0.33	—	18.0	0.1	0.001	U	8.63	—	0.001	U	0.001	U	0.8	U
GW36-08-10899	2/19/2008	08-744	—	0.37	—	17.8	0.0	0.001	U	8.14	—	0.001	U	0.001	U	0.8	U
GW36-08-10900	2/19/2008	08-744	—	0.39	—	17.6	0.1	0.001	U	8.89	—	0.001	U	0.001	U	0.8	U
GW36-08-10901	2/21/2008	08-744	—	0.33	—	17.6	0.0	0.001	U	8.71	—	0.001	U	0.001	U	0.8	U
GW36-08-10902	2/21/2008	08-744	—	0.32	—	17.2	0.1	0.001	U	8.60	—	0.001	U	0.001	U	0.8	U
GW36-08-10903	2/21/2008	08-744	—	0.28	—	17.2	0.0	0.001	U	8.62	—	0.001	U	0.001	U	0.8	U
GW36-08-10904	2/21/2008	08-744	—	0.25	—	17.2	0.1	0.001	U	8.52	—	0.001	U	0.001	U	0.8	U
GW36-08-10905	2/21/2008	08-744	—	0.30	—	17.1	0.1	0.001	U	8.64	—	0.001	U	0.001	U	0.8	U
GW36-08-10906	2/21/2008	08-744	—	0.29	—	17.0	0.1	0.001	U	8.53	—	0.001	U	0.001	U	0.8	U
GW36-08-10907	2/21/2008	08-744	—	0.26	—	17.1	0.1	0.001	U	8.51	—	0.001	U	0.001	U	0.8	U
GW36-08-10908	2/21/2008	08-744	—	0.23	—	17.0	0.0	0.001	U	8.45	—	0.001	U	0.001	U	0.8	U
GW36-08-10909	2/21/2008	08-744	—	0.25	—	16.9	0.1	0.001	U	8.58	—	0.001	U	0.001	U	0.8	U
GW36-08-10910	2/21/2008	08-744	—	0.29	—	16.9	0.0	0.001	U	8.51	—	0.001	U	0.001	U	0.8	U
GW36-08-10911	2/21/2008	08-744	—	0.28	—	16.7	0.1	0.001	U	8.55	—	0.001	U	0.001	U	0.8	U
GW36-08-10912	2/21/2008	08-744	—	0.24	—	16.8	0.1	0.001	U	8.51	—	0.001	U	0.001	U	0.8	U
GW36-08-10913	2/21/2008	08-744	—	0.29	—	16.8	0.2	0.001	U	8.58	—	0.001	U	0.001	U	0.8	U
GW36-08-10914	2/21/2008	08-744	—	0.32	—	16.6	0.1	0.001	U	8.94	—	0.001	U	0.001	U	0.8	U
GW36-08-10915	2/21/2008	08-744	—	0.31	—	16.4	0.0	0.001	U	8.46	—	0.001	U	0.001	U	0.8	U
GW36-08-10916	2/21/2008	08-744	—	0.25	—	16.3	0.0	0.001	U	8.58	—	0.001	U	0.001	U	0.8	U
GW36-08-10917	2/21/2008	08-744	—	0.34	—	16.6	0.2	0.001	U	8.71	—	0.001	U	0.001	U	0.8	U
GW36-08-10918	2/21/2008	08-744	—	0.31	—	16.5	0.1	0.001	U	8.51	—	0.001	U	0.001	U	0.8	U
GW36-08-10919	2/21/2008	08-744	—	0.43	—	16.1	0.0	0.001	U	8.37	—	0.001	U	0.001	U	0.8	U
GW36-08-10920	2/21/2008	08-744	—	0.35	—	16.1	0.0	0.001	U	8.36	—	0.001	U	0.001	U	0.8	U
GW36-08-10921	2/21/2008	08-744	—	0.31	—	16.0	0.1	0.001	U	8.45	—	0.001	U	0.001	U	0.8	U
GW36-08-10922	2/21/2008	08-744	—	0.37	—	17.1	0.2	0.001	U	8.36	—	0.001	U	0.001	U	0.8	U
GW36-08-10923	2/21/2008	08-744	—	0.27	—	17.3	0.1	0.001	U	8.71	—	0.001	U	0.001	U	0.8	U

Table B.1-2
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	Cr Result (ppm)	stdev (Cr)	Cs Result (ppm)	stdev (Cs)	Cu Result (ppm)	stdev (Cu)	F(-) ppm	F(-) (U)	Fe Result (ppm)	stdev (Fe)	Alk-CO_3+HCO_3 Result (ppm)	ALK-CO_3+HCO_3 (U)	Hg Result (ppm)
GW36-08-10884	2/19/2008	08-744	0.005	0.000	0.001	U	0.001	0.000	0.60	—	0.76	0.00	98.4	—	0.00005
GW36-08-10885	2/19/2008	08-744	0.004	0.000	0.001	U	0.002	0.000	0.60	—	1.22	0.00	95.7	—	0.00005
GW36-08-10886	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.64	—	0.66	0.00	93.1	—	0.00005
GW36-08-10887	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.65	—	0.47	0.00	92.7	—	0.00005
GW36-08-10888	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.67	—	0.46	0.00	91.8	—	0.00005
GW36-08-10889	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.64	—	0.41	0.00	91.9	—	0.00005
GW36-08-10890	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.64	—	0.42	0.00	91.3	—	0.00005
GW36-08-10891	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.65	—	0.42	0.00	91.4	—	0.00005
GW36-08-10892	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.65	—	0.36	0.00	91.2	—	0.00005
GW36-08-10893	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.64	—	0.36	0.00	90.7	—	0.00005
GW36-08-10894	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.62	—	0.37	0.01	90.7	—	0.00005
GW36-08-10895	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.65	—	0.40	0.00	90.8	—	0.00005
GW36-08-10896	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.65	—	0.36	0.00	90.7	—	0.00005
GW36-08-10897	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.63	—	0.86	0.00	90.7	—	0.00005
GW36-08-10898	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.61	—	0.42	0.00	90.3	—	0.00005
GW36-08-10899	2/19/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.63	—	0.35	0.00	90.8	—	0.00005
GW36-08-10900	2/19/2008	08-744	0.006	0.001	0.001	U	0.001	U	0.62	—	0.38	0.00	93.5	—	0.00005
GW36-08-10901	2/21/2008	08-744	0.003	0.000	0.001	U	0.001	0.000	0.78	—	0.23	0.00	95.2	—	0.00005
GW36-08-10902	2/21/2008	08-744	0.007	0.000	0.001	U	0.001	U	0.76	—	0.29	0.00	90.2	—	0.00005
GW36-08-10903	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.83	—	0.31	0.00	89.8	—	0.00005
GW36-08-10904	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.76	—	0.33	0.00	89.7	—	0.00005
GW36-08-10905	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	0.000	0.82	—	0.33	0.00	89.5	—	0.00005
GW36-08-10906	2/21/2008	08-744	0.005	0.000	0.001	U	0.002	0.000	0.82	—	0.33	0.00	89.4	—	0.00005
GW36-08-10907	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.78	—	0.32	0.00	89.4	—	0.00005
GW36-08-10908	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.78	—	0.33	0.00	89.4	—	0.00005
GW36-08-10909	2/21/2008	08-744	0.005	0.000	0.001	U	0.001	U	0.84	—	0.32	0.00	88.9	—	0.00005
GW36-08-10910	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.79	—	0.30	0.00	89.4	—	0.00005
GW36-08-10911	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.84	—	0.29	0.00	89.1	—	0.00005
GW36-08-10912	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.82	—	0.37	0.00	89.3	—	0.00005
GW36-08-10913	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.83	—	0.27	0.00	89.2	—	0.00005
GW36-08-10914	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.91	—	0.25	0.00	89.1	—	0.00005
GW36-08-10915	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.80	—	0.25	0.00	89.1	—	0.00005
GW36-08-10916	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.88	—	0.24	0.00	89.1	—	0.00005
GW36-08-10917	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.88	—	0.23	0.00	89.2	—	0.00005
GW36-08-10918	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.83	—	0.22	0.00	89.2	—	0.00005
GW36-08-10919	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.79	—	0.22	0.00	88.9	—	0.00005
GW36-08-10920	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.83	—	0.23	0.00	88.7	—	0.00005
GW36-08-10921	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.85	—	0.40	0.00	88.4	—	0.00005
GW36-08-10922	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.82	—	0.32	0.00	88.6	—	0.00005
GW36-08-10923	2/21/2008	08-744	0.004	0.000	0.001	U	0.001	U	0.92	—	0.27	0.00	88.5	—	0.00005

Table B.1-2
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	stdev (Hg)	K Result (ppm)	stdev (K)	Li Result (ppm)	stdev (Li)	Mg Result (ppm)	stdev (Mg)	Mn Result (ppm)	stdev (Mn)	Mo Result (ppm)	stdev (Mo)	Na Result (ppm)	stdev (Na)	Ni Result (ppm)	stdev (Ni)
GW36-08-10884	2/19/2008	08-744	U	2.33	0.00	0.031	0.000	4.25	0.02	0.024	0.000	0.001	0.000	15.2	0.1	0.002	0.000
GW36-08-10885	2/19/2008	08-744	U	2.20	0.01	0.030	0.000	4.15	0.04	0.025	0.000	0.002	0.000	15.1	0.1	0.002	0.000
GW36-08-10886	2/19/2008	08-744	U	2.13	0.03	0.029	0.000	4.10	0.02	0.014	0.000	0.002	0.000	14.5	0.1	0.001	0.000
GW36-08-10887	2/19/2008	08-744	U	2.10	0.01	0.029	0.000	4.14	0.02	0.013	0.000	0.002	0.000	14.6	0.1	0.001	0.000
GW36-08-10888	2/19/2008	08-744	U	2.10	0.01	0.029	0.001	4.16	0.03	0.011	0.000	0.002	0.000	14.6	0.1	0.001	0.000
GW36-08-10889	2/19/2008	08-744	U	2.10	0.01	0.029	0.000	4.15	0.04	0.011	0.000	0.002	0.000	14.5	0.1	0.001	0.000
GW36-08-10890	2/19/2008	08-744	U	2.08	0.01	0.029	0.000	4.06	0.00	0.010	0.000	0.002	0.000	14.2	0.1	0.001	0.000
GW36-08-10891	2/19/2008	08-744	U	2.19	0.02	0.028	0.000	4.13	0.03	0.011	0.000	0.002	0.000	14.7	0.1	0.001	0.000
GW36-08-10892	2/19/2008	08-744	U	1.92	0.01	0.028	0.000	4.11	0.03	0.009	0.000	0.002	0.000	14.3	0.1	0.001	0.000
GW36-08-10893	2/19/2008	08-744	U	1.91	0.03	0.028	0.001	4.10	0.03	0.009	0.000	0.002	0.000	14.2	0.1	0.001	0.000
GW36-08-10894	2/19/2008	08-744	U	1.89	0.02	0.029	0.001	4.10	0.05	0.010	0.000	0.002	0.000	14.1	0.1	0.002	0.000
GW36-08-10895	2/19/2008	08-744	U	1.90	0.01	0.027	0.001	4.10	0.03	0.010	0.000	0.002	0.000	14.2	0.1	0.001	0.000
GW36-08-10896	2/19/2008	08-744	U	1.89	0.01	0.027	0.000	4.07	0.02	0.009	0.000	0.002	0.000	14.1	0.0	0.001	0.000
GW36-08-10897	2/19/2008	08-744	U	1.93	0.01	0.026	0.001	4.14	0.02	0.012	0.000	0.002	0.000	14.3	0.2	0.001	0.000
GW36-08-10898	2/19/2008	08-744	U	1.89	0.01	0.025	0.000	4.07	0.03	0.009	0.000	0.002	0.000	14.2	0.0	0.001	0.000
GW36-08-10899	2/19/2008	08-744	U	1.94	0.01	0.023	0.000	4.10	0.03	0.008	0.000	0.002	0.000	14.3	0.1	0.001	0.000
GW36-08-10900	2/19/2008	08-744	U	1.93	0.01	0.022	0.000	4.03	0.00	0.008	0.000	0.002	0.000	14.1	0.1	0.001	0.000
GW36-08-10901	2/21/2008	08-744	U	2.07	0.02	0.026	0.000	4.23	0.01	0.014	0.001	0.001	U	14.6	0.0	0.002	0.000
GW36-08-10902	2/21/2008	08-744	U	2.02	0.00	0.026	0.000	4.14	0.00	0.010	0.000	0.001	U	14.7	0.0	0.001	0.000
GW36-08-10903	2/21/2008	08-744	U	1.91	0.01	0.024	0.000	3.96	0.02	0.008	0.000	0.001	U	13.9	0.1	0.001	0.000
GW36-08-10904	2/21/2008	08-744	U	1.97	0.01	0.026	0.000	4.12	0.02	0.009	0.000	0.001	U	14.4	0.0	0.001	0.000
GW36-08-10905	2/21/2008	08-744	U	1.95	0.01	0.025	0.000	4.09	0.02	0.007	0.000	0.001	U	14.2	0.0	0.001	0.000
GW36-08-10906	2/21/2008	08-744	U	1.92	0.01	0.025	0.000	4.05	0.05	0.008	0.000	0.001	U	14.0	0.1	0.001	0.000
GW36-08-10907	2/21/2008	08-744	U	1.92	0.02	0.025	0.000	4.02	0.04	0.007	0.000	0.001	U	13.9	0.1	0.001	0.000
GW36-08-10908	2/21/2008	08-744	U	2.73	0.01	0.025	0.000	4.14	0.04	0.006	0.000	0.001	U	15.2	0.0	0.001	0.000
GW36-08-10909	2/21/2008	08-744	U	2.01	0.01	0.025	0.000	4.12	0.02	0.006	0.000	0.001	U	14.2	0.1	0.001	0.000
GW36-08-10910	2/21/2008	08-744	U	2.11	0.02	0.026	0.000	4.10	0.04	0.007	0.000	0.001	U	14.3	0.1	0.001	0.000
GW36-08-10911	2/21/2008	08-744	U	2.01	0.01	0.025	0.000	4.07	0.01	0.006	0.000	0.001	U	13.9	0.1	0.001	0.000
GW36-08-10912	2/21/2008	08-744	U	2.00	0.01	0.025	0.000	4.08	0.02	0.006	0.000	0.001	U	14.0	0.0	0.001	0.000
GW36-08-10913	2/21/2008	08-744	U	2.00	0.01	0.025	0.000	4.07	0.00	0.006	0.000	0.001	U	13.9	0.1	0.001	0.000
GW36-08-10914	2/21/2008	08-744	U	1.97	0.01	0.025	0.000	4.07	0.02	0.006	0.000	0.001	U	13.8	0.1	0.001	0.000
GW36-08-10915	2/21/2008	08-744	U	1.97	0.02	0.025	0.000	4.02	0.05	0.006	0.000	0.001	U	13.7	0.1	0.001	0.000
GW36-08-10916	2/21/2008	08-744	U	1.93	0.01	0.025	0.000	4.02	0.01	0.005	0.000	0.001	U	13.6	0.0	0.001	0.000
GW36-08-10917	2/21/2008	08-744	U	2.02	0.01	0.026	0.000	4.19	0.03	0.005	0.000	0.001	U	14.2	0.1	0.001	0.000
GW36-08-10918	2/21/2008	08-744	U	1.91	0.02	0.024	0.000	3.98	0.04	0.006	0.000	0.001	U	13.5	0.1	0.001	0.000
GW36-08-10919	2/21/2008	08-744	U	1.99	0.02	0.026	0.000	4.13	0.03	0.005	0.000	0.001	U	14.0	0.1	0.001	0.000
GW36-08-10920	2/21/2008	08-744	U	2.11	0.01	0.026	0.000	4.15	0.02	0.005	0.000	0.001	U	14.2	0.1	0.001	0.000
GW36-08-10921	2/21/2008	08-744	U	2.06	0.01	0.026	0.000	4.08	0.01	0.010	0.000	0.001	U	13.9	0.0	0.001	0.000
GW36-08-10922	2/21/2008	08-744	U	2.061	0.009	0.026	0.000	4.03	0.02	0.008	0.000	0.001	U	13.9	0.1	0.001	0.000
GW36-08-10923	2/21/2008	08-744	U	2.017	0.005	0.025	0.000	4.04	0.01	0.008	0.000	0.001	U	13.8	0.1	0.001	0.000

Table B.1-2
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	NO_2 (ppm)	NO_2-N Result	NO_2-N (U)	NO_3 ppm	NO_3-N Result	NO_3-N (U)	C_2O_4 Result (ppm)	C_2O_4 (U)	Pb Result (ppm)	stdev (Pb)	pH	$PO_4^{(-3)}$ Result (ppm)	$PO_4^{(-3)}$ (U)	Rb Result (ppm)	stdev (Rb)
GW36-08-10884	2/19/2008	08-744	0.01	0.003	U	10.6	2.40	—	0.01	U	0.0005	0.0000	8.20	0.01	U	0.004	0.000
GW36-08-10885	2/19/2008	08-744	0.01	0.003	U	11.1	2.51	—	0.01	U	0.0018	0.0001	8.19	0.01	U	0.004	0.000
GW36-08-10886	2/19/2008	08-744	0.01	0.003	U	11.8	2.66	—	0.01	U	0.0015	0.0000	8.11	0.01	U	0.004	0.000
GW36-08-10887	2/19/2008	08-744	0.01	0.003	U	11.9	2.68	—	0.01	U	0.0004	0.0000	8.12	0.01	U	0.004	0.000
GW36-08-10888	2/19/2008	08-744	0.01	0.003	U	11.7	2.64	—	0.01	U	0.0002	U	8.12	0.01	U	0.004	0.000
GW36-08-10889	2/19/2008	08-744	0.01	0.003	U	11.8	2.67	—	0.01	U	0.0002	U	8.11	0.01	U	0.004	0.000
GW36-08-10890	2/19/2008	08-744	0.01	0.003	U	12.1	2.73	—	0.01	U	0.0003	0.0000	8.09	0.01	U	0.004	0.000
GW36-08-10891	2/19/2008	08-744	0.01	0.003	U	12.1	2.74	—	0.01	U	0.0003	0.0000	8.10	0.01	U	0.004	0.000
GW36-08-10892	2/19/2008	08-744	0.01	0.003	U	12.2	2.75	—	0.01	U	0.0002	U	8.08	0.01	U	0.004	0.000
GW36-08-10893	2/19/2008	08-744	0.01	0.003	U	12.1	2.73	—	0.01	U	0.0002	U	8.05	0.01	U	0.004	0.000
GW36-08-10894	2/19/2008	08-744	0.01	0.003	U	12.4	2.81	—	0.01	U	0.0002	U	8.08	0.01	U	0.003	0.000
GW36-08-10895	2/19/2008	08-744	0.01	0.003	U	12.2	2.76	—	0.01	U	0.0009	0.0000	8.07	0.01	U	0.004	0.000
GW36-08-10896	2/19/2008	08-744	0.01	0.003	U	12.3	2.77	—	0.01	U	0.0003	0.0000	8.06	0.01	U	0.004	0.000
GW36-08-10897	2/19/2008	08-744	0.01	0.003	U	12.1	2.73	—	0.01	U	0.0017	0.0000	8.06	0.02	—	0.004	0.000
GW36-08-10898	2/19/2008	08-744	0.01	0.003	U	12.1	2.74	—	0.01	U	0.0003	0.0000	7.98	0.01	U	0.004	0.000
GW36-08-10899	2/19/2008	08-744	0.01	0.003	U	12.2	2.75	—	0.01	U	0.0002	U	7.99	0.01	U	0.004	0.000
GW36-08-10900	2/19/2008	08-744	0.01	0.003	U	12.1	2.74	—	0.01	U	0.0005	0.0000	8.05	0.01	U	0.004	0.000
GW36-08-10901	2/21/2008	08-744	0.01	0.003	U	9.95	2.25	—	0.01	U	0.0002	U	8.21	0.01	U	0.003	0.000
GW36-08-10902	2/21/2008	08-744	0.01	0.003	U	9.95	2.25	—	0.01	U	0.0002	U	7.97	0.01	U	0.003	0.000
GW36-08-10903	2/21/2008	08-744	0.01	0.003	U	9.99	2.26	—	0.01	U	0.0002	U	8.02	0.01	U	0.003	0.000
GW36-08-10904	2/21/2008	08-744	0.01	0.003	U	9.89	2.23	—	0.01	U	0.0002	U	8.04	0.01	U	0.003	0.000
GW36-08-10905	2/21/2008	08-744	0.01	0.003	U	10.0	2.27	—	0.01	U	0.0002	U	8.05	0.01	U	0.003	0.000
GW36-08-10906	2/21/2008	08-744	0.01	0.003	U	9.98	2.25	—	0.01	U	0.0002	U	8.07	0.01	U	0.003	0.000
GW36-08-10907	2/21/2008	08-744	0.01	0.003	U	9.93	2.24	—	0.01	U	0.0002	U	8.07	0.01	U	0.003	0.000
GW36-08-10908	2/21/2008	08-744	0.01	0.003	U	9.88	2.23	—	0.01	U	0.0003	0.0000	8.08	0.01	U	0.003	0.000
GW36-08-10909	2/21/2008	08-744	0.01	0.003	U	9.99	2.26	—	0.01	U	0.0002	U	8.08	0.01	U	0.003	0.000
GW36-08-10910	2/21/2008	08-744	0.01	0.003	U	9.92	2.24	—	0.01	U	0.0002	U	8.11	0.01	U	0.003	0.000
GW36-08-10911	2/21/2008	08-744	0.01	0.003	U	10.0	2.26	—	0.01	U	0.0002	U	8.09	0.01	U	0.003	0.000
GW36-08-10912	2/21/2008	08-744	0.01	0.003	U	9.99	2.26	—	0.01	U	0.0002	U	8.08	0.01	U	0.003	0.000
GW36-08-10913	2/21/2008	08-744	0.01	0.003	U	10.0	2.27	—	0.01	U	0.0002	U	8.08	0.01	U	0.003	0.000
GW36-08-10914	2/21/2008	08-744	0.01	0.003	U	10.1	2.28	—	0.01	U	0.0002	U	8.09	0.01	U	0.003	0.000
GW36-08-10915	2/21/2008	08-744	0.01	0.003	U	9.92	2.24	—	0.01	U	0.0002	U	8.10	0.01	U	0.003	0.000
GW36-08-10916	2/21/2008	08-744	0.01	0.003	U	9.99	2.26	—	0.01	U	0.0002	U	8.11	0.01	U	0.003	0.000
GW36-08-10917	2/21/2008	08-744	0.01	0.003	U	10.0	2.27	—	0.01	U	0.0002	U	8.13	0.01	U	0.003	0.000
GW36-08-10918	2/21/2008	08-744	0.01	0.003	U	9.97	2.25	—	0.01	U	0.0002	U	8.12	0.01	U	0.003	0.000
GW36-08-10919	2/21/2008	08-744	0.01	0.003	U	9.89	2.23	—	0.01	U	0.0002	U	8.10	0.01	U	0.003	0.000
GW36-08-10920	2/21/2008	08-744	0.01	0.003	U	9.84	2.22	—	0.01	U	0.0002	U	8.10	0.01	U	0.003	0.000
GW36-08-10921	2/21/2008	08-744	0.01	0.003	U	10.0	2.27	—	0.01	U	0.0002	U	8.11	0.01	U	0.003	0.000
GW36-08-10922	2/21/2008	08-744	0.01	0.003	U	9.94	2.24	—	0.01	U	0.0002	U	8.13	0.01	U	0.003	0.000
GW36-08-10923	2/21/2008	08-744	0.01	0.003	U	10.1	2.29	—	0.01	U	0.0002	U	8.11	0.01	U	0.003	0.000

Table B.1-2
(continued)

Sample ID	Date Received	ER/RRES-WQH[a]	S_2 Result (ppm)	S_2 (U)	Sb Result (ppm)	stdev (Sb)	Se Result (ppm)	stdev (Se)	Si Result (ppm)	stdev (Si)	SiO_2 Result (ppm)	stdev (SiO_2)	Sn Result (ppm)	stdev (Sn)	$SO_4^{(-2)}$ rslt (ppm)	$SO_4^{(-2)}$ (U)
GW36-08-10884	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	35.1	0.2	75.1	0.4	0.001	U	8.55	—
GW36-08-10885	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.3	73.2	0.7	0.001	U	8.29	—
GW36-08-10886	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.9	0.4	72.5	0.8	0.001	U	8.57	—
GW36-08-10887	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.5	0.2	73.8	0.5	0.001	U	8.59	—
GW36-08-10888	2/19/2008	08-744	not provided	not provided	0.001	U	0.002	0.000	34.6	0.2	74.0	0.3	0.001	U	8.42	—
GW36-08-10889	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.5	0.0	73.9	0.1	0.001	U	8.54	—
GW36-08-10890	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.0	0.0	72.8	0.1	0.001	U	8.60	—
GW36-08-10891	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.4	73.2	0.8	0.001	U	8.59	—
GW36-08-10892	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.2	73.2	0.5	0.001	U	8.67	—
GW36-08-10893	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.3	0.4	73.4	0.8	0.001	U	8.47	—
GW36-08-10894	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.2	73.2	0.4	0.001	U	8.72	—
GW36-08-10895	2/19/2008	08-744	not provided	not provided	0.001	U	0.002	0.000	34.3	0.5	73.4	1.0	0.001	U	8.60	—
GW36-08-10896	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.2	73.2	0.4	0.001	U	8.59	—
GW36-08-10897	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.3	0.3	73.3	0.6	0.001	U	8.46	—
GW36-08-10898	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.0	0.2	72.8	0.4	0.001	U	8.60	—
GW36-08-10899	2/19/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.4	0.1	73.7	0.1	0.001	U	8.57	—
GW36-08-10900	2/19/2008	08-744	not provided	not provided	0.001	U	0.002	0.000	33.8	0.1	72.3	0.2	0.001	U	9.00	—
GW36-08-10901	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.3	0.2	73.4	0.5	0.001	U	9.19	—
GW36-08-10902	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.4	0.1	73.6	0.2	0.001	U	9.24	—
GW36-08-10903	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.0	0.1	70.6	0.2	0.001	U	9.33	—
GW36-08-10904	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.4	0.1	73.6	0.3	0.001	U	9.26	—
GW36-08-10905	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.0	0.2	72.8	0.4	0.001	U	9.37	—
GW36-08-10906	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.0	0.2	72.8	0.5	0.001	U	9.28	—
GW36-08-10907	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.6	0.3	71.8	0.7	0.001	U	9.24	—
GW36-08-10908	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.3	0.1	73.5	0.1	0.001	U	9.21	—
GW36-08-10909	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.3	0.2	73.3	0.3	0.001	U	9.29	—
GW36-08-10910	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.8	0.1	72.4	0.3	0.001	U	9.25	—
GW36-08-10911	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.4	0.4	71.4	0.9	0.001	U	9.28	—
GW36-08-10912	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.9	0.2	72.5	0.3	0.001	U	9.25	—
GW36-08-10913	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.7	0.3	72.0	0.6	0.001	U	9.27	—
GW36-08-10914	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.6	0.1	71.9	0.2	0.001	U	9.61	—
GW36-08-10915	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.2	0.5	71.0	1.1	0.001	U	9.22	—
GW36-08-10916	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.0	0.2	70.7	0.4	0.001	U	9.30	—
GW36-08-10917	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.6	0.3	74.0	0.6	0.001	U	9.44	—
GW36-08-10918	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	32.5	0.1	69.5	0.2	0.001	U	9.23	—
GW36-08-10919	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.0	0.3	72.8	0.7	0.001	U	9.15	—
GW36-08-10920	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.3	0.1	73.5	0.3	0.001	U	9.11	—
GW36-08-10921	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	33.4	0.3	71.5	0.7	0.001	U	9.21	—
GW36-08-10922	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.3	73.2	0.6	0.001	U	9.17	—
GW36-08-10923	2/21/2008	08-744	not provided	not provided	0.001	U	0.001	0.000	34.2	0.1	73.1	0.2	0.001	U	9.44	—

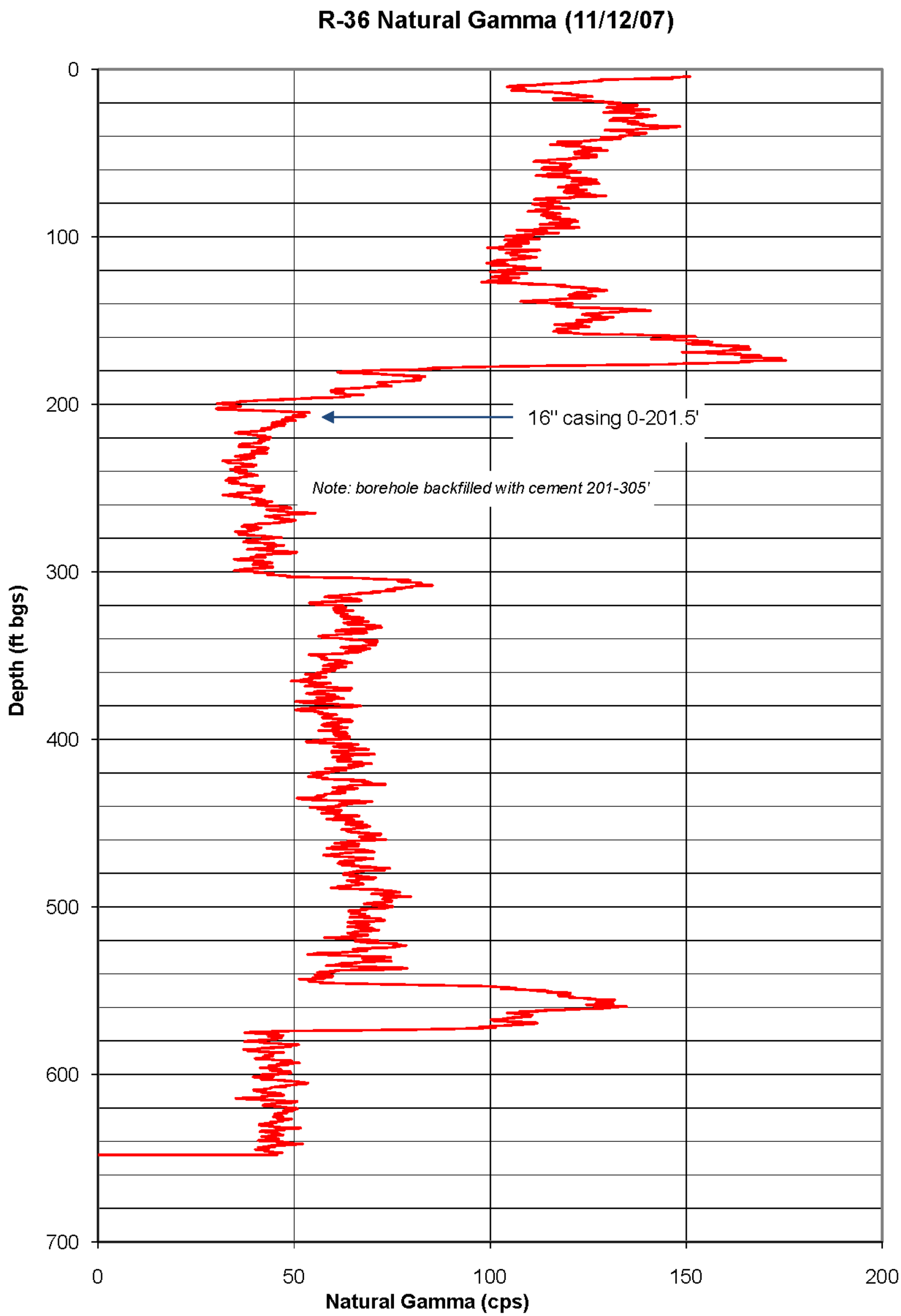
Table B.1-2
(continued)

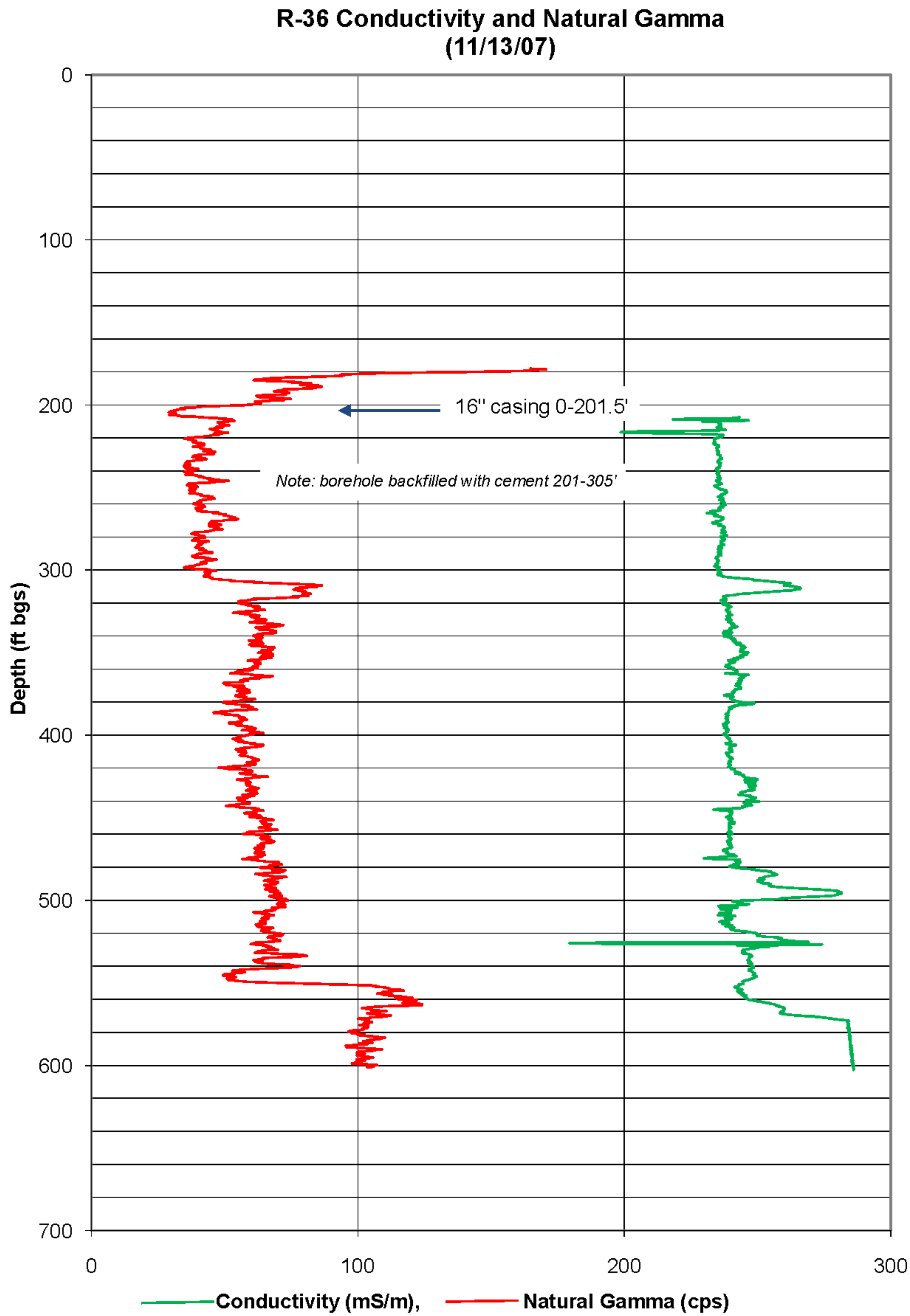
Sample ID	Date Received	ER/RRES-WQH[a]	Sr Result (ppm)	stdev (Sr)	Th Result (ppm)	stdev (Th)	Ti Result (ppm)	stdev (Ti)	Tl Result(ppm)	stdev (Tl)	U Result (ppm)	stdev (U)	V Result (ppm)	stdev (V)	Zn Result (ppm)	stdev (Zn)	TDS[d] (ppm)	Cations	Anions	Balance
GW36-08-10884	2/19/2008	08-744	0.098	0.001	0.001	U	0.006	0.000	0.001	U	0.0007	0.0000	0.011	0.000	0.041	0.000	235	2.00	2.28	-0.07
GW36-08-10885	2/19/2008	08-744	0.093	0.001	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.010	0.000	0.083	0.001	235	1.96	2.23	-0.06
GW36-08-10886	2/19/2008	08-744	0.086	0.004	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.012	0.000	0.085	0.000	234	1.93	2.20	-0.07
GW36-08-10887	2/19/2008	08-744	0.088	0.002	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.012	0.000	0.010	0.000	235	1.93	2.19	-0.06
GW36-08-10888	2/19/2008	08-744	0.089	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.008	0.000	234	1.94	2.17	-0.05
GW36-08-10889	2/19/2008	08-744	0.088	0.002	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.012	0.000	0.008	0.000	233	1.93	2.17	-0.06
GW36-08-10890	2/19/2008	08-744	0.088	0.002	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.011	0.001	233	1.90	2.17	-0.07
GW36-08-10891	2/19/2008	08-744	0.087	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.012	0.000	0.008	0.000	233	1.94	2.18	-0.06
GW36-08-10892	2/19/2008	08-744	0.087	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.008	0.000	233	1.90	2.17	-0.07
GW36-08-10893	2/19/2008	08-744	0.090	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.008	0.000	234	1.90	2.15	-0.06
GW36-08-10894	2/19/2008	08-744	0.087	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.009	0.000	233	1.89	2.17	-0.07
GW36-08-10895	2/19/2008	08-744	0.088	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.035	0.001	234	1.89	2.16	-0.07
GW36-08-10896	2/19/2008	08-744	0.087	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.011	0.000	236	1.89	2.16	-0.07
GW36-08-10897	2/19/2008	08-744	0.085	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.012	0.000	0.078	0.001	237	1.91	2.15	-0.06
GW36-08-10898	2/19/2008	08-744	0.089	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.010	0.000	232	1.90	2.16	-0.06
GW36-08-10899	2/19/2008	08-744	0.087	0.001	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.013	0.000	0.011	0.000	228	1.90	2.16	-0.06
GW36-08-10900	2/19/2008	08-744	0.086	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.014	0.000	0.064	0.001	231	1.88	2.23	-0.08
GW36-08-10901	2/21/2008	08-744	0.073	0.001	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.011	0.000	0.007	0.000	230	1.92	2.23	-0.07
GW36-08-10902	2/21/2008	08-744	0.071	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.003	0.000	229	1.89	2.14	-0.06
GW36-08-10903	2/21/2008	08-744	0.068	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.012	0.000	0.006	0.000	228	1.84	2.14	-0.08
GW36-08-10904	2/21/2008	08-744	0.070	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.012	0.000	0.003	0.000	232	1.88	2.13	-0.06
GW36-08-10905	2/21/2008	08-744	0.068	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.012	0.000	0.003	0.000	230	1.86	2.14	-0.07
GW36-08-10906	2/21/2008	08-744	0.068	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.008	0.000	229	1.84	2.13	-0.07
GW36-08-10907	2/21/2008	08-744	0.068	0.001	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.012	0.000	0.003	0.000	227	1.84	2.13	-0.07
GW36-08-10908	2/21/2008	08-744	0.069	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.012	0.000	0.003	0.000	229	1.93	2.12	-0.05
GW36-08-10909	2/21/2008	08-744	0.067	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.003	0.000	228	1.86	2.13	-0.07
GW36-08-10910	2/21/2008	08-744	0.068	0.001	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.003	0.000	228	1.86	2.13	-0.07
GW36-08-10911	2/21/2008	08-744	0.066	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.002	0.000	226	1.83	2.13	-0.08
GW36-08-10912	2/21/2008	08-744	0.067	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.002	0.000	226	1.84	2.13	-0.07
GW36-08-10913	2/21/2008	08-744	0.067	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.012	0.000	0.002	0.000	231	1.83	2.13	-0.08
GW36-08-10914	2/21/2008	08-744	0.066	0.001	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.002	0.000	224	1.82	2.15	-0.08
GW36-08-10915	2/21/2008	08-744	0.065	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.003	0.000	227	1.80	2.12	-0.08
GW36-08-10916	2/21/2008	08-744	0.063	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.003	0.000	228	1.79	2.13	-0.09
GW36-08-10917	2/21/2008	08-744	0.067	0.001	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.002	0.000	226	1.85	2.14	-0.07
GW36-08-10918	2/21/2008	08-744	0.064	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.001	0.002	0.000	229	1.79	2.13	-0.09
GW36-08-10919	2/21/2008	08-744	0.066	0.001	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.002	0.000	229	1.81	2.11	-0.08
GW36-08-10920	2/21/2008	08-744	0.066	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.004	0.000	235	1.82	2.11	-0.07
GW36-08-10921	2/21/2008	08-744	0.065	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.003	0.000	235	1.80	2.12	-0.08
GW36-08-10922	2/21/2008	08-744	0.064	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.005	0.000	234	1.85	2.11	-0.07
GW36-08-10923	2/21/2008	08-744	0.064	0.000	0.001	U	0.002	U	0.001	U	0.0004	0.0000	0.013	0.000	0.002	0.000	235	1.85	2.13	-0.07

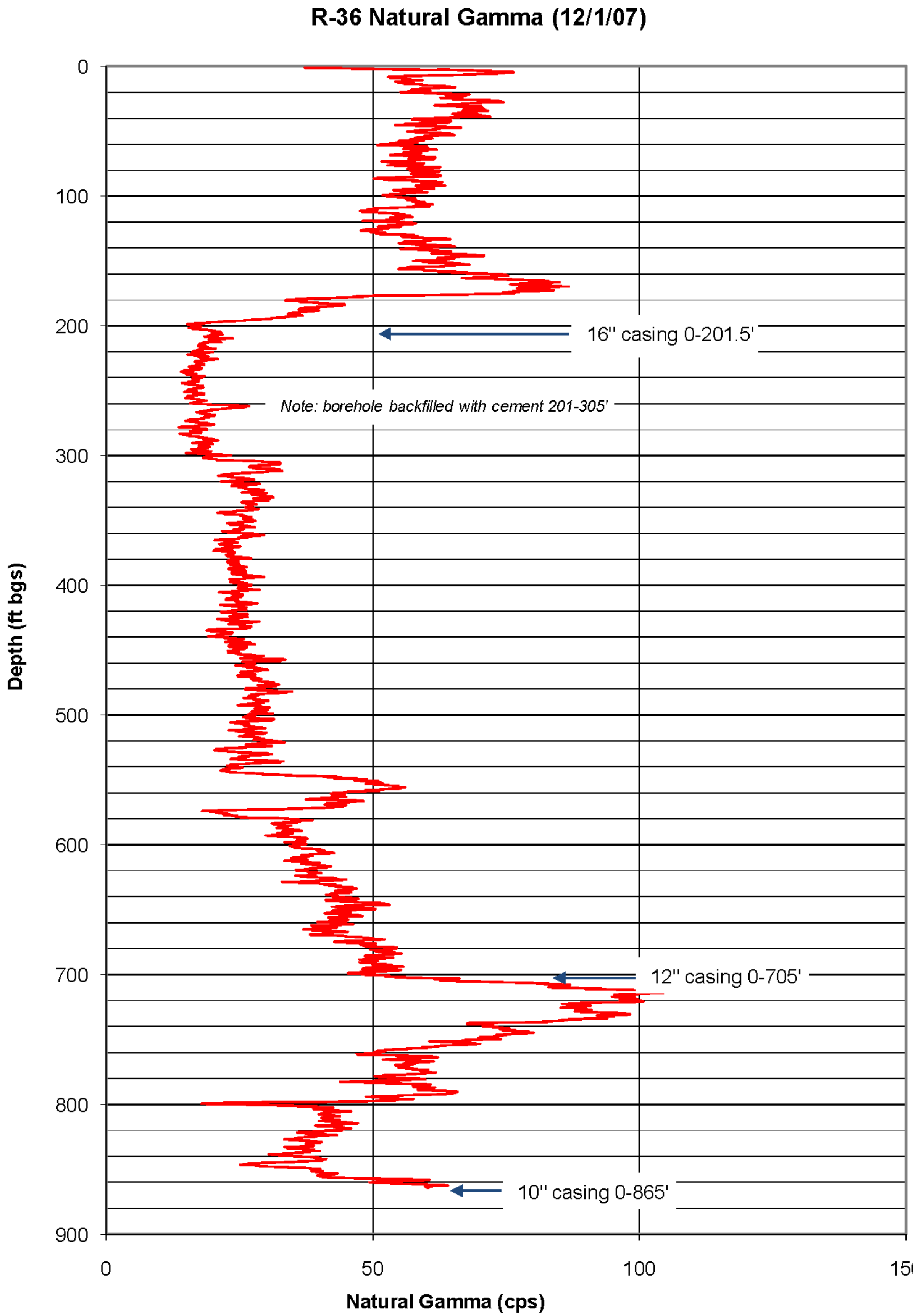
[a] ER/RRES-WGH = Environmental Restoration/Risk Reduction and Environmental Stewardship-Water Quality and Hydrology.
[b] U = Not detected.
[c] — = No qualifier.
[d] TDS = Total dissolved solids.

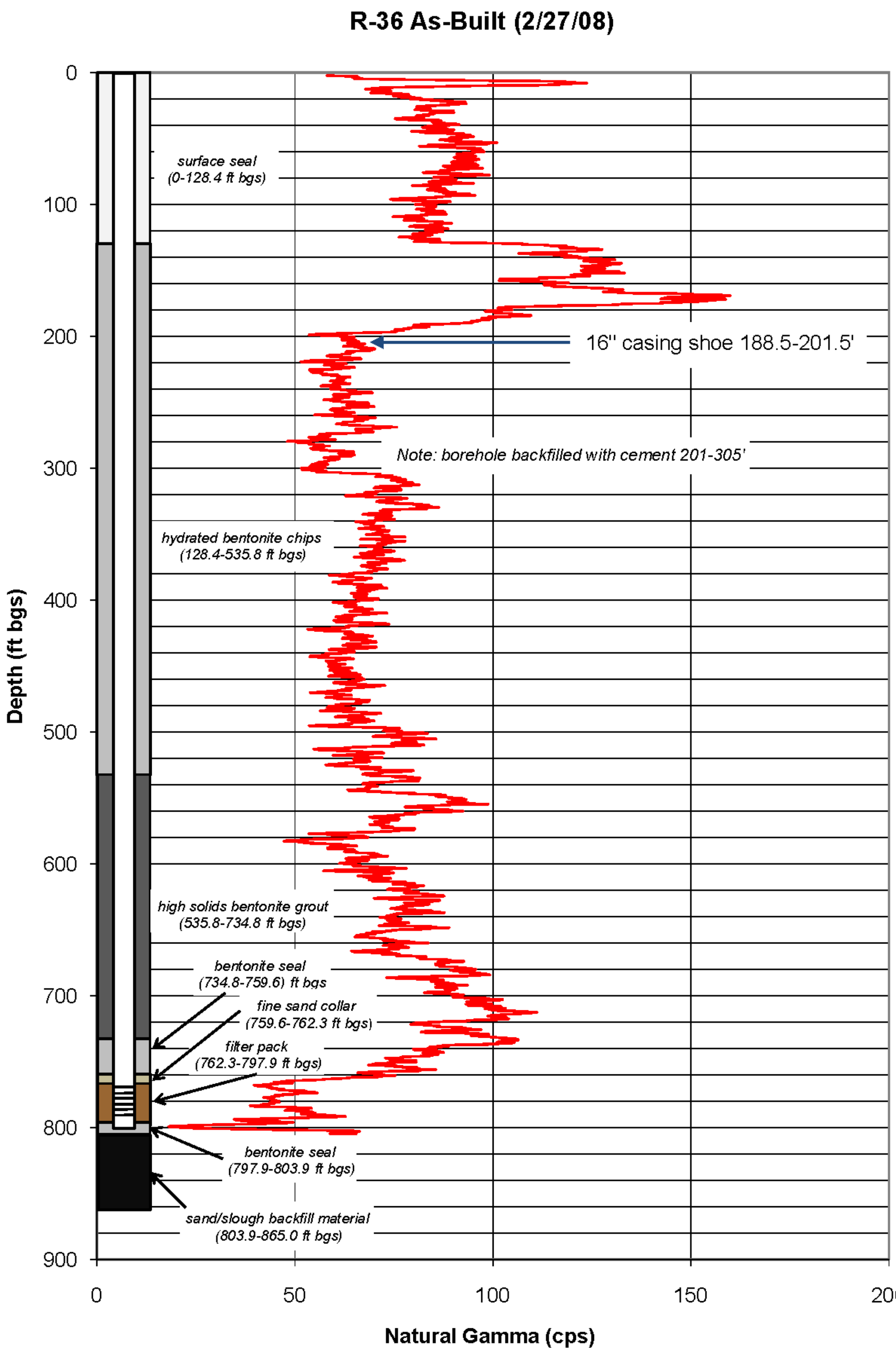
Appendix C

Video Logging (on DVD included with this document)
and Geophysical Logging Results


R-36 Natural Gamma (11/12/07)
Depth (ft bgs)
0
100
200
300
400
500
600
700
0
50
100
150
200
Natural Gamma (cps)
16" casing 0-201.5'
Note: borehole backfilled with cement 201-305'


R-36 Conductivity and Natural Gamma
(11/13/07)
Depth (ft bgs)
0
100
200
300
400
500
600
700
0
100
200
300
16" casing 0-201.5'
Note: borehole backfilled with cement 201-305'
Conductivity (mS/m),
Natural Gamma (cps)


R-36 Natural Gamma (12/1/07)
Depth (ft bgs)
0
100
200
300
400
500
600
700
800
900
Natural Gamma (cps)
0
50
100
150
16" casing 0-201.5'
Note: borehole backfilled with cement 201-305'
12" casing 0-705'
10" casing 0-865'


R-36 As-Built (2/27/08)
Depth (ft bgs)
0
100
200
300
400
500
600
700
800
900
surface seal
(0-128.4 ft bgs)
16" casing shoe 188.5-201.5'
Note: borehole backfilled with cement 201-305'
hydrated bentonite chips
(128.4-535.8 ft bgs)
high solids bentonite grout
(535.8-734.8 ft bgs)
bentonite seal
(734.8-759.6) ft bgs
fine sand collar
(759.6-762.3 ft bgs)
filter pack
(762.3-797.9 ft bgs)
bentonite seal
(797.9-803.9 ft bgs)
sand/slough backfill material
(803.9-865.0 ft bgs)
0
50
100
150
200
Natural Gamma (cps)

Appendix D

Aquifer Testing Report

D-1.0 INTRODUCTION

This appendix describes the analysis of constant-rate pumping tests conducted in February 2008 at R-36, located in Sandia Canyon, roughly between and south of Los Alamos County supply wells PM-1 and PM-3 (Figure 1.0-1). The primary objective of the analysis was to determine the hydraulic properties of the sediments screened in R-36. Consistent with the protocol used in most of the R-well pumping tests, the R-36 testing incorporated an inflatable packer above the pump to eliminate the effects of casing storage on the measured data.

R-36 is completed with a single screen, 23 ft long and between 767 and 790 ft deep. The screen is within saturated Miocene Santa Fe Group sands and gravels with abundant volcanic detritus and few to no Precambrian plutonic and metamorphic clasts that extend from 575 ft above the static water level (SWL) of 749.1–800 ft. The sediments below 800 ft, to a total depth (TD) at 865 ft, comprise finer-grained sands and silts with some gravel; this deeper section below the well screen has abundant clasts of both volcanic and Precambrian lithologies. The permeability of the lower silty zone was not known; thus, two conceptual models of the aquifer materials were considered initially: (1) a vast, unknown thickness of permeable sediments and (2) a 50.9-ft-thick aquifer (749.1–800 ft) underlain by an aquitard (silty material) and deeper aquifer materials. Subsequent hydraulic analysis suggested a third conceptual model—that of a fully penetrating aquifer with strong leakage contribution from highly transmissive overlying and/or underlying materials. In all interpretations, the aquifer was assumed to be unconfined because the observed water table intersected the sand and gravel sediments.

Hydraulic testing consisted of brief trial pumping on February 17, 2008, followed by a 24-h constant-rate pumping test that began on February 19, 2008. Additional well purging was performed for a couple of hours on the morning of February 21, 2008.

Two trial tests were conducted on February 17, 2008. Trial 1 was conducted at a discharge rate of 17.0 gallons per minute (gpm) for 40 min from 3:20 p.m. to 4:00 p.m. and was followed by 60 min of recovery until 5:00 p.m. Trial 2 was conducted at a rate of 17.3 gpm for 60 min from 5:00 p.m. to 6:00 p.m. After shutdown, recovery was monitored for 38.5 h until 8:30 a.m. on February 19, 2008. The extended recovery period was also expected to provide background water-level data.

The constant-rate pumping test was started at 8:30 p.m. on February 19, 2008, at a discharge rate of 17.4 gpm. Pumping continued for 24 h until 8:30 p.m. on February 20, after which the pump was shut down and recovery measurements were recorded for 1483 min until 9:13 a.m. on February 21, 2008. At that time, the pump was restarted and final purging of the well was performed for 126 min until 11:19 a.m.

D-2.0 BACKGROUND DATA

The background water-level data collected by running the pumping tests allow the analyst to see what water-level fluctuations occur naturally in the aquifer and also help the analyst distinguish between water-level changes caused by conducting the pumping test and changes caused by interacting with other factors.

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 hydrograph from the R-36 testing was compared with barometric pressure data from the area to determine if a correlation existed.

Previous pumping tests have demonstrated a barometric efficiency for most wells on the Pajarito Plateau 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 as part of the R-well drilling project, downhole pressure was monitored using *vented* transducers. This equipment measures the *difference* between the total pressure applied to the transducer and the barometric pressure, this difference being the true height of water above the transducer.

Subsequent pumping tests, including R-36, have utilized *nonvented* transducers. These devices record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated "apparent" hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an *increase* in barometric pressure of 1 unit causes a *decrease* in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, 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 Environmental Stewardship–Meteorology and Air Quality Division (ENV-MAQ). The TA-54 measurement location is at an elevation of 6548 ft above mean sea level (amsl) whereas the wellhead elevation was estimated at the time of this analysis to be 6590 ft amsl (subsequently surveyed elevation of the brass marker at R-36 is 6589.9 ft). The SWL in R-36 was about 749 ft below land surface, making the water-table elevation approximately 5841 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-36.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R36} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R36}}{T_{WELL}}\right)\right] \qquad \textbf{Equation 1}$$

Where P_{WT} = barometric pressure at the water table inside R-36,

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

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

R = gas constant, in J/Kg/degree Kelvin (287.04 J/Kg/^{o}K),

E_{R36} = land surface elevation at R-36, in feet (estimated at 6590 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-36, in feet (estimated at 5841 ft),

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 35.4^{o}F, or 275.1^{o}K), and

T_{WELL} = air temperature inside R-36, in degrees Kelvin (assigned a value of 61.5 ^{o}F, or 289.5 ^{o}K).

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

The corrected barometric pressure data reflecting pressure conditions at the water table were compared with the water-level hydrograph to test the correlation between the two.

D-3.0 THICK AQUIFER RESPONSE

A complicating aspect of the R-well pumping tests is that the wells are severely partially penetrating. The typical well design incorporates relatively short well screens (a few feet to tens of feet in length) installed within a massively thick aquifer (possibly hundreds of feet or more).

As a result, during pumping, the cone of depression expands not only horizontally but also expands vertically throughout the test. As the cone intercepts a greater and greater aquifer thickness, the data plot reflects a steadily flattening slope, corresponding to the continuously increasing vertical height of the zone of investigation. As a result, later data tend to produce a greater calculated transmissivity than do early data. This complicates the analysis because for any given slope (or transmissivity value), it is not possible to know what the corresponding aquifer thickness is (vertical extent of the cone of depression).

If an aquitard is encountered at depth, which limits the vertical growth of the cone of depression, the data curve may reach a steady slope, reflecting the transmissivity of the sediments above the aquitard. In that case, a definitive transmissivity can be determined and the hydraulic conductivity can be calculated by dividing the transmissivity by the saturated thickness above the aquitard (if that dimension is known). If no aquitard is encountered, the drawdown curve gets steadily flatter, reflecting a continuum of transmissivities corresponding to the effective depth of the cone of depression at any given time.

D-3.1 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 R-well pumping tests, the early pumping period is the only time that the effective height of the cone of depression is known with certainty. Thus, the early data potentially offer the best opportunity to obtain hydraulic conductivity information because conductivity would equal the earliest time transmissivity is divided by the well screen length.

Unfortunately, in the R-wells, casing storage effects dominate the early-time data, 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 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 gpm, and

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

In some instances, it may be possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. Therefore, this option has been implemented for the R-well testing program, including the R-36 pumping test. Using the packer was successful in eliminating casing storage effects in the R-36 pumping test.

D-4.0 TIME-DRAWDOWN METHODS

The majority of analytical methods used for interpreting pumping test data is based on the assumption of confined aquifer conditions. The R-36 aquifer may be unconfined at the water table, potentially violating this assumption, depending on sediment makeup, layering, and hydraulic conductivity distribution. When unconfined conditions exist, early and late data analyses using conventional methods are generally still valid. There can be, however, a transitional period at intermediate time where the drawdown data curve flattens temporarily because of the effects of delayed yield (physical movement of the phreatic surface). When this occurs, strict application of confined methods is not directly applicable to the data. In the R-wells on the Pajarito Plateau, the data curve flattening caused by delayed yield generally is obscured by flattening caused by vertical expansion of the cone of depression, which continues long after drainage is completed. Confined aquifer methods were used for analyzing the R-36 pumping test data. This was not a serious limitation because the key aquifer parameters were obtained from early data and other observations and conclusions were based on late data. The presence, or lack thereof, of a transitional drainage phase did not alter the conclusions drawn from the test.

Time-drawdown data can be analyzed using a variety of methods. Among them is the Cooper-Jacob method (1946, 098236), a simplification of the Theis equation (1934–1935, 098241) that is mathematically equivalent to the Theis equation for 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 3

Where *s* = drawdown, in feet,

Q = discharge rate, in gpm,

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

t = pumping time, in days,

r = distance from center of pumpage, in feet, and

S = storage coefficient (dimensionless).

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, where *u* is defined as follows:

$$u = \frac{1.87 r^2 S}{Tt}$$

Equation 4

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 all measured drawdown values. Thus, for the pumped well, the Cooper-Jacob equation 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 5**

Where *T* = transmissivity, in gpd/ft,

Q = discharge rate, in gpm, and

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

Because the R-wells are severely partially penetrating, an alternate solution considered for determining aquifer parameters is the Hantush equation (1961, 098237) for partially penetrating wells. The Hantush equation is as follows:

Equation 6

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

where, in consistent units, *s*, *Q*, *T*, *t*, *r*, *S*, and *u* are as previously defined, except that they are expressed in consistent units, 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*,*β*) is the Hantush well function for leaky aquifers.

Another analytical procedure used in the analysis was the Hantush-Jacob leaky method (Hantush and Jacob 1955, 070091), later modified by Hantush. In this method, recharge to the pumped aquifer is assumed to be provided via vertical leakage across underlying and/or overlying aquitards from an infinitely permeable adjacent aquifer. According to this method (Duffield 2002, 100997)

Equation 7

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

In this equation, *B* is the leakage factor, defined as

$$B = \sqrt{\frac{T}{l}}$$ **Equation 8**

Also, *l* is the aquitard leakance, defined as

$$l = \frac{K'}{b'}$$ **Equation 9**

Where *K'* = vertical hydraulic conductivity of the aquitard, and

b' = thickness of the aquitard.

All other parameters are as defined in Equation 6. Note that for single-well tests, *d* = *d'* and *l* = *l'*.

D-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 10**

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

D-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 11**

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 12**

To apply this formula, a storage coefficient value must be assigned. Storage coefficient values for unconfined conditions, as suspected in R-36, can be expected to range from about 0.01 to 0.25. Typically, a value of about 0.1 may be assigned for calculation purposes. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate of the storage coefficient is adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, *b*, which is often not known. In R-36, there was no way to know the extent of permeable sediments beneath the well. Fortunately, it is only necessary to estimate a value for aquifer thickness. As long as a value substantially greater than the screen length is used, the calculations will be approximately correct because the yield contribution of sediments far above or below the well screen can be considered negligible. In the R-36 calculations, an arbitrary aquifer thickness of 200 ft was assigned.

Computing the lower-bound estimate of hydraulic conductivity can provide a useful frame of reference for evaluating the other pumping test calculations.

D-7.0 R-36 DATA ANALYSIS

This section presents the data obtained from the R-36 test pumping and the results of the analytical interpretations. Analyses were applied to recovery data from trial 1, pumping and recovery data from trial 2, and from the 24-h constant-rate test. Background data recorded before and after the constant-rate pumping test are also discussed. Finally, during the background and test periods, data were recorded in nearby wells R-35a and R-35b. These data were examined to discern whether a response occurred.

D-7.1 Background Data

Figure D-7.1-1 shows the apparent water-level hydrograph for R-36 and the barometric pressure data recorded before and after the constant-rate pumping test. It is clear that the total measured pressure in R-36 changed little in response to changes in barometric pressure, although a possible subtle response may have been masked by the apparent “noise” in the water-pressure data. To reduce the noise in the data plot, a rolling average water-pressure graph was prepared as shown in Figure D-7.1-2.

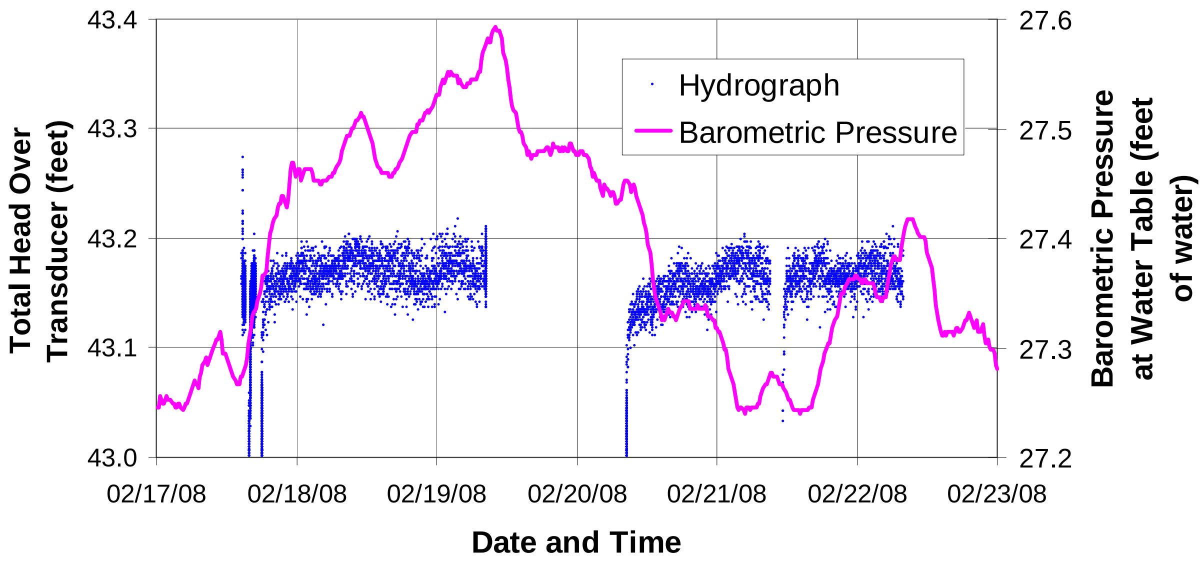


Figure D-7.1-1 Comparison of R-36 apparent hydrograph and adjusted TA-54 barometric pressure

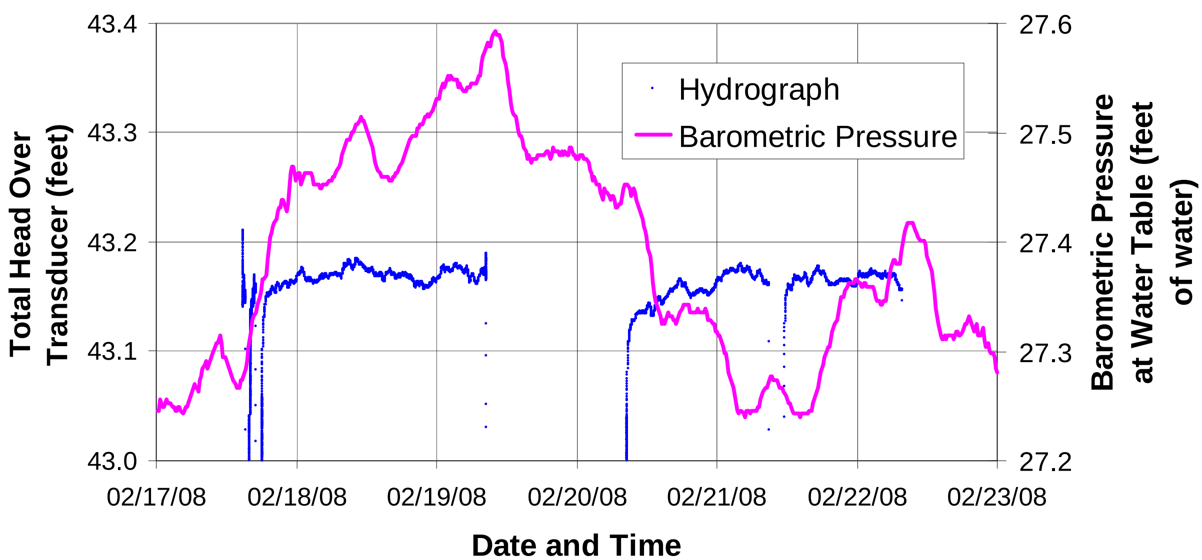


Figure D-7.1-2 Rolling average of R-36 apparent hydrograph and adjusted TA-54 barometric pressure

Examination of the rolling average graph showed no correlation between barometric pressure and water pressure. The slight perturbations in the hydrograph were likely caused by municipal pumping in the area.

The observation of essentially constant pressure in the well indicated that barometric pressure changes did not readily reach the saturated sediments in R-36. This suggested a fairly high barometric efficiency, consistent with what has been observed in most wells on the Pajarito Plateau.

Background and test data plots were prepared for the nearby R-35 well pair. Wells R-35a and R-35b are located northwest of R-36 at distances of 2239 ft and 2314 ft, respectively.

Figure D-7.1-3 shows the background and pumping data observed in R-35a. The episodes of pumping at R-36 are indicated on the plot, including the two trial tests, the 24-h constant-rate test, and the final well purging. There were numerous prominent peaks and valleys on the hydrograph spanning a range of about 7 ft, showing the response in R-35a to operation of close-by Los Alamos County water-supply well PM-3, and to a lesser extent, to distant well O-4.

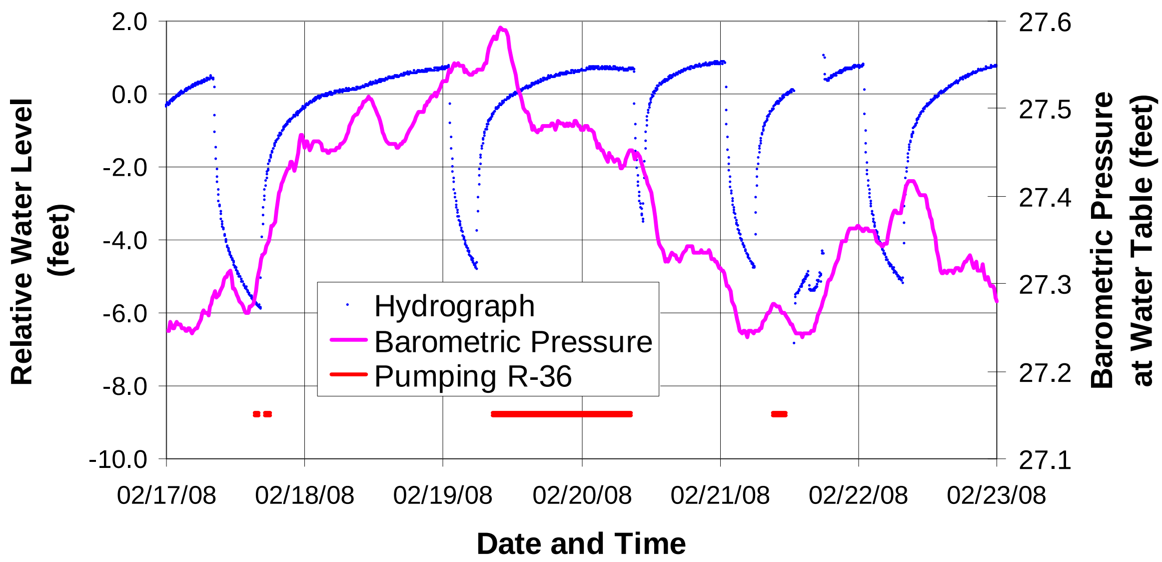


Figure D-7.1-3 Comparison of R-35a apparent hydrograph and adjusted TA-54 barometric pressure

Response to the R-36 pumping test was not readily discernible from Figure D-7.1-3 because of the magnitude of the scale on the graph. A closer examination of the response was made using the expanded-scale graph of the data shown in Figure D-7.1-4. This plot shows three of the PM-3 related recovery peaks.

Also included in the plot in Figure D-7.1-4 are the times of operation of PM-3 and O-4 obtained from Los Alamos County Utilities. There are two discrepancies to point out in the graph. First, there was a 1-h-offset in the times reported for R-35a compared with PM-3; the R-35a time was 1 h greater than that of PM-3. This offset was determined by comparing the start and stop times for PM-3 with the corresponding response times in R-35a. Second, the County's records did not reflect the brief pumping of PM-3 during late morning on February 20, even though the R-35a water-level data clearly showed that such pumping occurred.

In examining Figure D-7.1-4, it is apparent that the water-level peak recorded while pumping R-36 was blunted in comparison to the other peaks. In fact, the water-level recovery trend actually reversed direction, with water levels declining toward the end of the R-36 pumping test and then rising slightly again following shutdown of the R-36 test.

At first glance, this effect might appear to be related to pumping R-36. However, it is more likely to have been caused by operation of O-4. Note that O-4 was operated throughout the early morning of February 20, 2008, and shut down before the end of the R-36 pumping test. The distortion in the shape of the water-level recovery peak in Figure D-7.1-4 coincided with the O-4 operating period, except for the 1-h offset. Note that a similar ripple in the R-35a hydrograph occurred on February 18 during a time when O-4 was running.

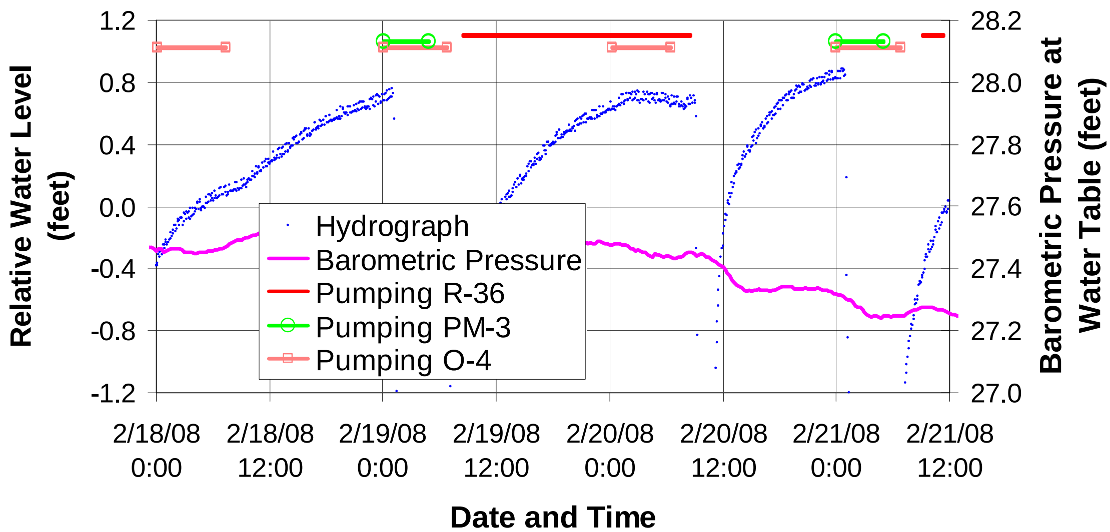


Figure D-7.1-4 Expanded view of R-35a apparent hydrograph and adjusted TA-54 barometric pressure

Although there apparently was drawdown in R-35a caused by pumping O-4, it was not possible to determine its magnitude. This is because it was not possible to know the height that the affected peaks would have reached if pumping in O-4 had not occurred. Nevertheless, a visual examination of the curves suggested a water-level change caused by O-4 on the order of tenths of a foot. This is similar to the magnitude of the R-35a water-level changes caused by O-4 during 2007 testing and monitoring of R-35a. It is unlikely that operating R-36 at just over 17 gpm could have caused water-level changes of this magnitude. In addition, any minor water-level effects from pumping R-36, if present, would have been obscured by the operation of O-4.

Background data from R-35b were plotted along with barometric pressure as shown in Figure D-7.1-5. Unlike the background data from R-36, which showed a flat line response, the R-35b data matched the barometric pressure curve almost perfectly. This was because the R-35b data were recorded using a vented transducer, which measures the height of water over the transducer. As shown in the graph, a given increase or decrease in barometric pressure caused an equal drop or rise in water level in the well. (Note that the water-level data were plotted on a reverse scale to accentuate the similarity of the two curves.) The data in Figure D-7.1-5 indicated a barometric efficiency for R-35a near 100%. This was consistent with conclusions drawn from data recorded during constant-rate testing of R-35b in 2007.

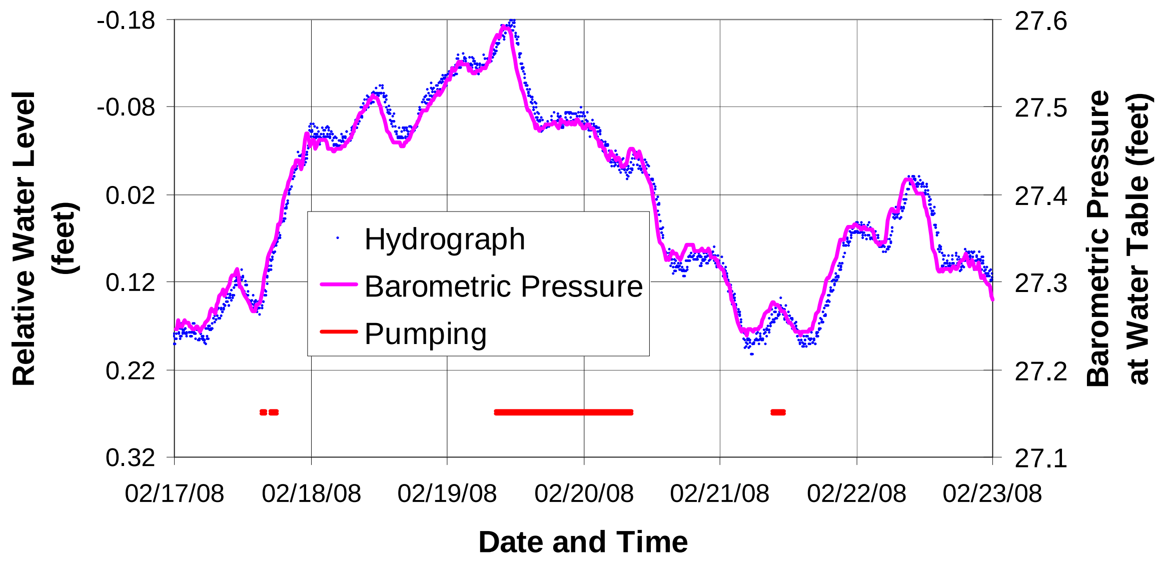


Figure D-7.1-5 Comparison of R-35b apparent hydrograph and adjusted TA-54 barometric pressure

Figure D-7.1-6 shows an expanded-scale plot of a portion of the R-35b data that illustrates that the water-level changes in the well lagged behind the barometric pressure changes. The lag time determined from several peaks and valleys in Figure D-7.1-6 suggested a value having a magnitude of about 1 h. If this apparent lag is real and not an artifact of the clock time set in the transducer, it is possibly related to sluggish air movement through narrow openings in the well monument cover and well head assembly in response to barometric pressure fluctuations and to the time required to adjust the pressure of the 800-ft air column in the well. It also could be related to a sluggish water-level response caused by casing storage effects or perhaps by a combination of both slow air movement and casing storage.

One perplexing aspect of the observed time lag was that the magnitude of the water-level fluctuations was not attenuated compared with the barometric pressure amplitude. Theoretically, there should be some reduction in the amplitude of the water-level peaks in a cyclical signal when time lag occurs. It is possible that the attenuation was too small to be detected within the noise (data scatter/accuracy) of the measured values.

A second perplexing item was that the apparent lag of about 1 h observed in the R-35b data was the same as the 1-h lag observed in the R-35a data compared with PM-3 pumping records. Thus, both the R-35a and R-35b data sets appeared to be not sychronized with other measurements. However, the clock times in the R-35 pressure transducers were checked and verified to be correct.

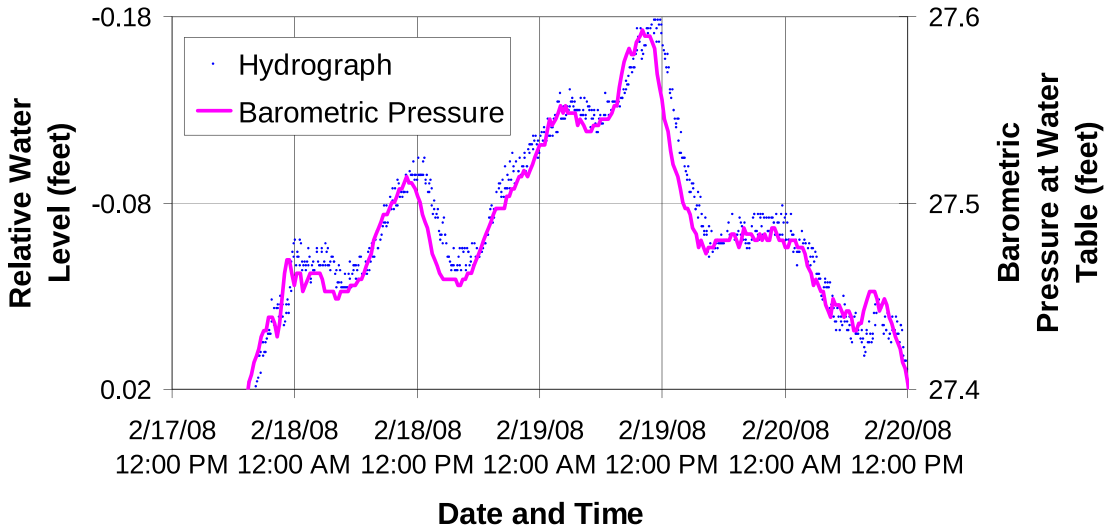


Figure D-7.1-6 Expanded view of R-35b apparent hydrograph and adjusted TA-54 barometric pressure

D-7.2 Trial Testing

After pump installation, R-36 was pumped briefly (trial testing) to evaluate well capacity, fill the drop pipe in preparation for the long-term test, and generate some useful data. Trial pumping began at 3:20 p.m. on February 17, 2008. Trial 1 lasted 40 min until 4:00 p.m., followed by 60 min of recovery until 5:00 p.m. The pumping rate during trial 1 was 17.0 gpm.

Trial 2 began at 5:00 p.m. and lasted 60 min until 6:00 p.m., after which recovery was monitored for 38.5 h until the start of the constant-rate test at 8:30 a.m. on February 19, 2008. The discharge rate during trial 2 was 17.3 gpm.

Figure D-7.2-1 shows data from the trial 1 pumping event. There was exaggerated drawdown for several minutes because the pump initially produced a greater discharge rate against reduced head while the drop pipe filled. As the pipe filled, the pumping head increased, and the pumping rate decreased accordingly, allowing water levels to recover.

The late data showed steady flattening, consistent with partial penetration effects and vertical expansion of the cone of depression over time. Alternate explanations for the curve flattening include (1) delayed drainage of the potentially unconfined aquifer and (2) lateral boundary conditions in which the cone of depression expands laterally into sediments having greater transmissivity than the aquifer near the pumped well. It is possible that faulting in the area has juxtaposed aquifers with differing transmissivity or that the hydraulic conductivity varies greatly laterally within the same aquifer. All of these effects have the appearance of recharge and are indistinguishable from one another. In R-36, it is likely that one or more of these effects are present. The combination of variable pumping rate and flattening of the drawdown curve made it impossible to quantify aquifer properties from the data in Figure D-7.2-1

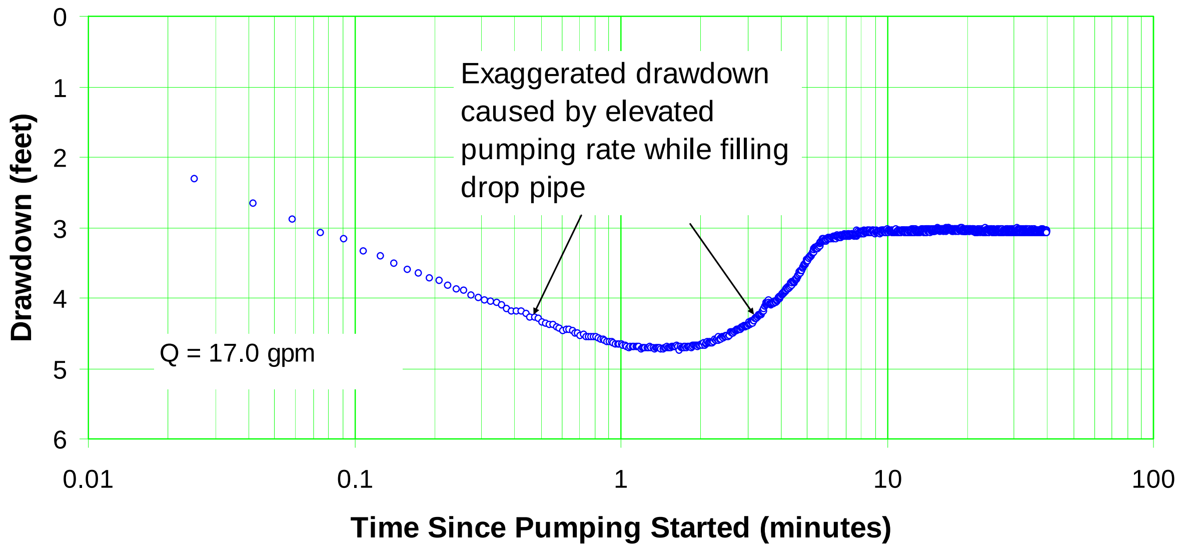


Figure D-7.2-1 Well R-36 trial 1 drawdown

Figure D-7.2-2 shows the trial 1 recovery data. Analysis of the data suggested a transmissivity of the 23-t screened interval of 5840 gpd/ft and a hydraulic conductivity of 254 gpd/ft^2, or 33.9 feet per day (ft/d).

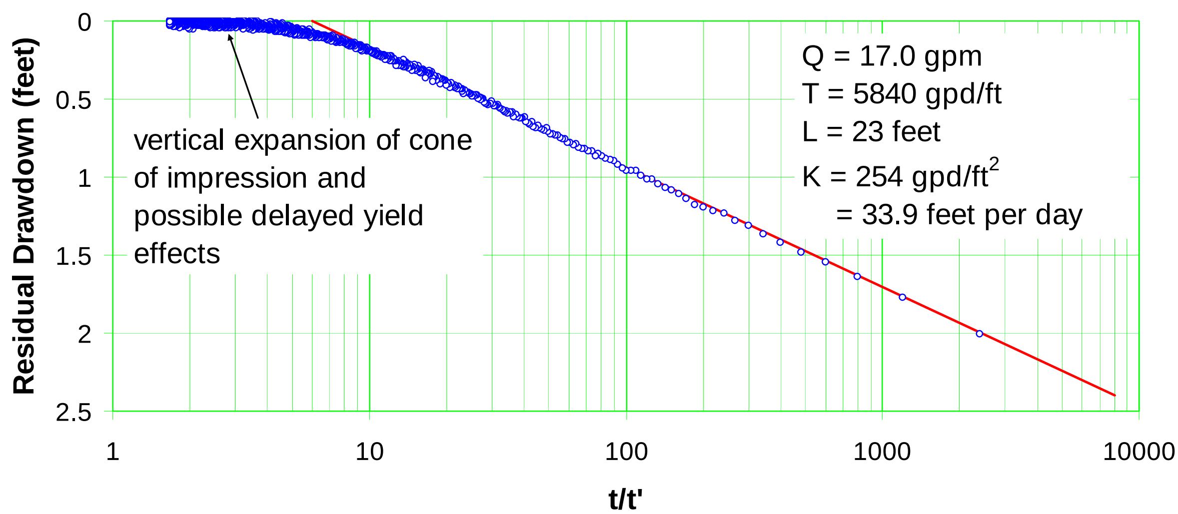


Figure D-7.2-2 Well R-36 trial 1 recovery

After a few minutes of recovery, the slope of the plot flattened steadily as the cone of impression expanded vertically through a progressively more transmissive body of sediments and/or into a lateral zone of higher transmissivity. In addition to partial penetration effects, it is possible that delayed drainage of the presumed unconfined aquifer contributed somewhat to the slope change.

Figure D-7.2-3 shows time-drawdown data from the 60-min duration trial 2 test conducted at a pumping rate of 17.3 gpm. Analysis of the data suggested a transmissivity of 5670 gpd/ft and a hydraulic conductivity of 247 gpd/ft^2, or 33.0 ft/d, consistent with the results of trial 1. As before, data after just a few minutes showed flattening of the drawdown curve in response to vertical growth of the cone of depression with time, lateral changes in transmissivity, and possible delayed drainage effects.

The early data in Figure D-7.2-3 showed slightly exaggerated drawdown for the first half second or so of pumping. This effect could have been caused by either inertial effects or minor antecedent drainage of a trivial volume of drop pipe before starting the pump. Drop pipe drainage would have allowed the pump to start against reduced head momentarily until the pipe refilled. The corresponding transient elevated discharge rate would have resulted in the observed brief increase in drawdown beyond the theoretical response.

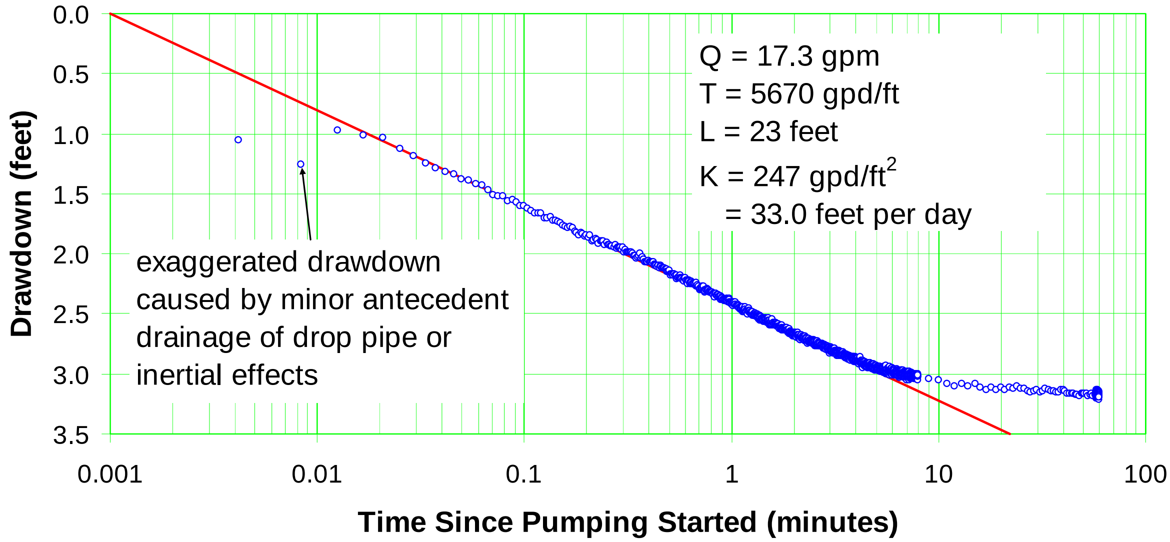


Figure D-7.2-3 Well R-36 trial 2 drawdown

Figure D-7.2-4 shows recovery data after the trial 2 pumping event. The data revealed a transmissivity of 5660 gpd/ft and a hydraulic conductivity of 246 gpd/ft^2, or 32.9 ft/d, consistent with the previous results. The late recovery data showed the aforementioned flattening.

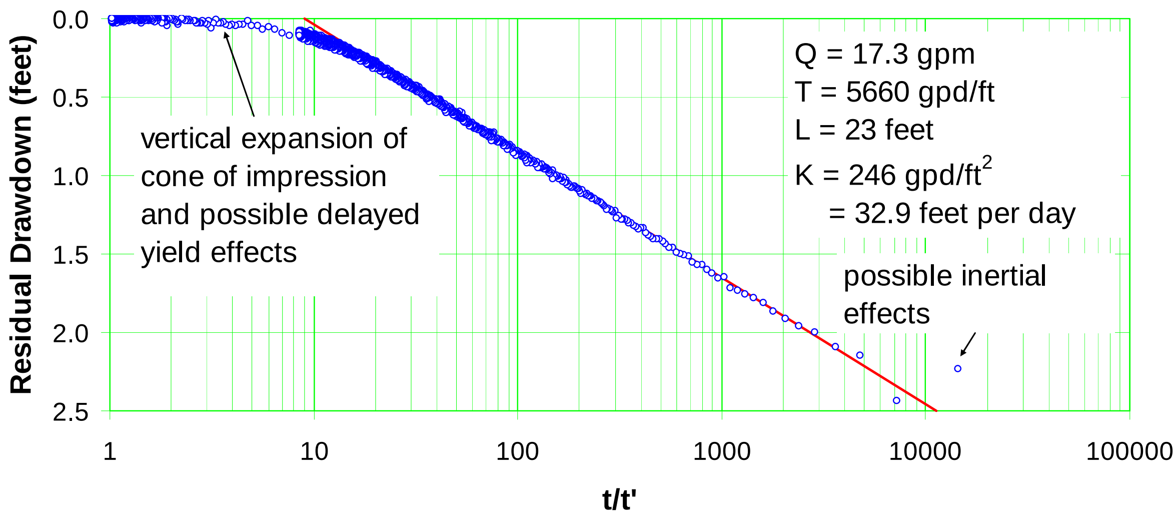


Figure D-7.2-4 Well R-36 trial 2 recovery

Note that the first few recovery data points showed some scatter, including exaggerated recovery at the first data point. Because antecedent drop pipe drainage is not relevant in recovery data, the most likely explanation for this response was inertial effects. This suggested that the early pumping data scatter in Figure D-7.2-3 was probably caused by inertia rather than drop pipe drainage.

Note that this effect was absent on the recovery graph in Figure D-7.2-2. This was because the early data collection interval in Figure D-7.2-2 was 1 s and was ¼ s in Figures D-7.2-3 and D-7.2-4. The inertial effects persisted for less than 1 s and thus were absent in Figure D-7.2-2 but were detected in Figures D-7.2-3 and D-7.2-4.

D-7.3 24-H Constant-Rate Pumping Test

The constant-rate pumping test was started at 8:30 p.m. on February 19, 2008, at a discharge rate of 17.4 gpm. Pumping continued for 24 h until 8:30 p.m. on February 20, 2008. At that time, the pump was shut down and recovery measurements were recorded for 1483 min until 9:13 a.m. on February 21, 2008.

Time-Drawdown Analysis

Figure D-7.3-1 shows the time-drawdown data for the 24-h pumping period. Aquifer parameters calculated from this plot included a transmissivity of 5780 gpd/ft and a hydraulic conductivity of 251 gpd/ft^2, or 33.6 ft/d; these values are in good agreement with those from the trial tests. Data after just a few minutes showed flattening associated with partial penetration effects, lateral changes in transmissivity, and/or possible delayed yield.

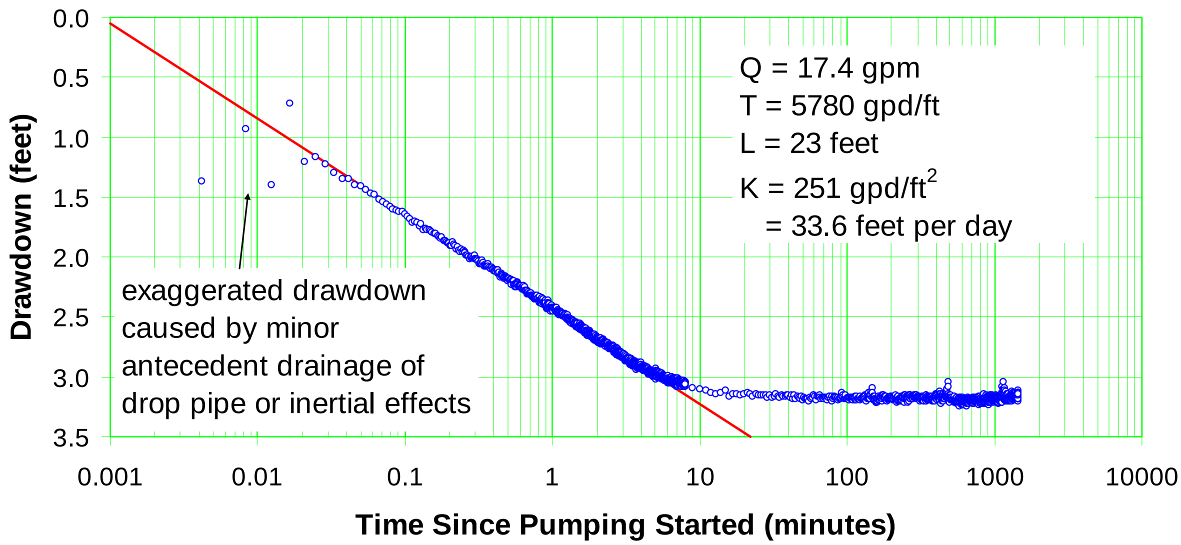


Figure D-7.3-1 Well R-36 drawdown

The very early data showed exaggerated drawdown as well as data scatter for about 1 s after starting the pump. As observed in trial 2, this was probably attributable to inertial effects but also might have been caused by minor drainage of a portion of the drop pipe.

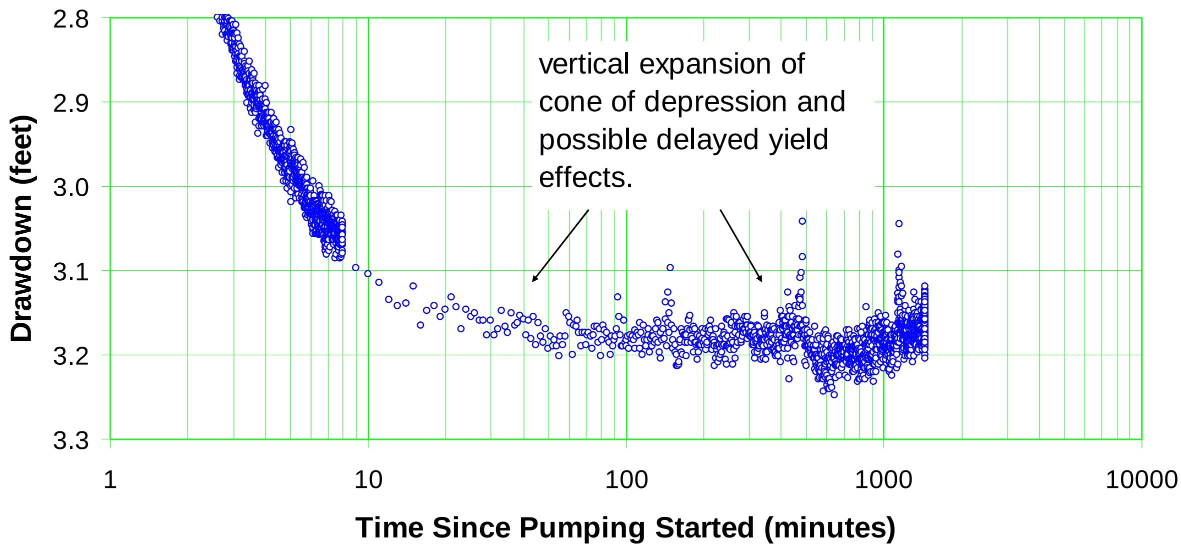


Figure D-7.3-2 Expanded view of well R-36 drawdown

Figure D-7.3-2 shows an expanded-scale graph of the late time-drawdown data from the 24-h pumping test. The slope of the data plot flattened steadily throughout the pumping period, with water levels appearing to stabilize completely. It is unlikely that actual stabilization occurred. Instead, it appears that background water-level fluctuations simply overwhelmed the small incremental water-level changes associated with continued pumping. The background noise precluded analysis of the late slope on the graph.

To account for the effects of partial penetration, the time-drawdown data were analyzed using the Hantush method for partially penetrating wells. This allowed analysis of the entire data set, including the early data and the transition data before apparent stabilization of water levels. Analysis was performed assuming a uniform aquifer penetrated by a 23-ft-long well screen. An arbitrary aquifer thickness of 200 ft was used in the calculations.

Figures D-7.3-3, D-7.3-4, D-7.3-5, and D-7.3-6 show curve-matching results for assumed vertical anisotropy ratios of 1.0, 0.1, 0.01, and 0.001, respectively. A range of assumed vertical anisotropy ratios was used to try to identify an optimum value. According to the figures, better fits were obtained for relatively isotropic conductivity ratios than for severely anisotropic ratios.

Hydraulic conductivity values obtained for anisotropy rations of 1.0, 0.1, 0.01, and 0.001 were 26.4, 33.4, 40.1 and 48.8 ft/d, respectively. The first two values—26.4 and 33.4 ft/d—corresponded to moderate anisotropy, providing better curve matches than the graphs for severe anisotropy.

A critical examination of the Hantush plots shows that although there was a range of goodness-of-fit qualities, none of the matches were particularly good. This suggested that the conceptual model of a homogeneous, uniformly anisotropic aquifer was not an adequate description of the hydrogeologic regime.

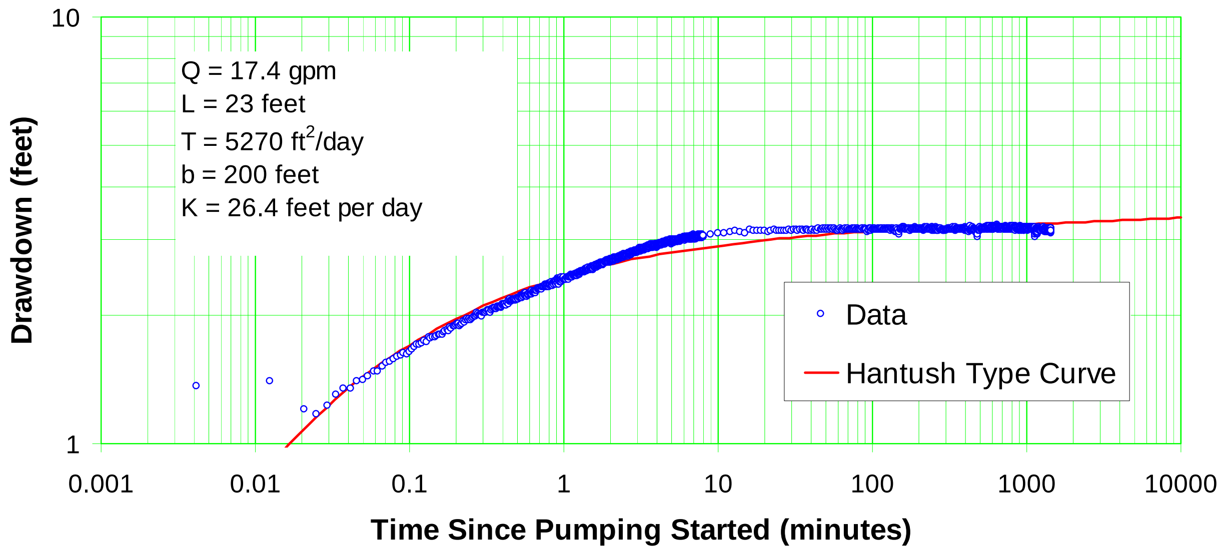


Figure D-7.3-3 Well R-36 drawdown Hantush solution for anisotropy of 1.0

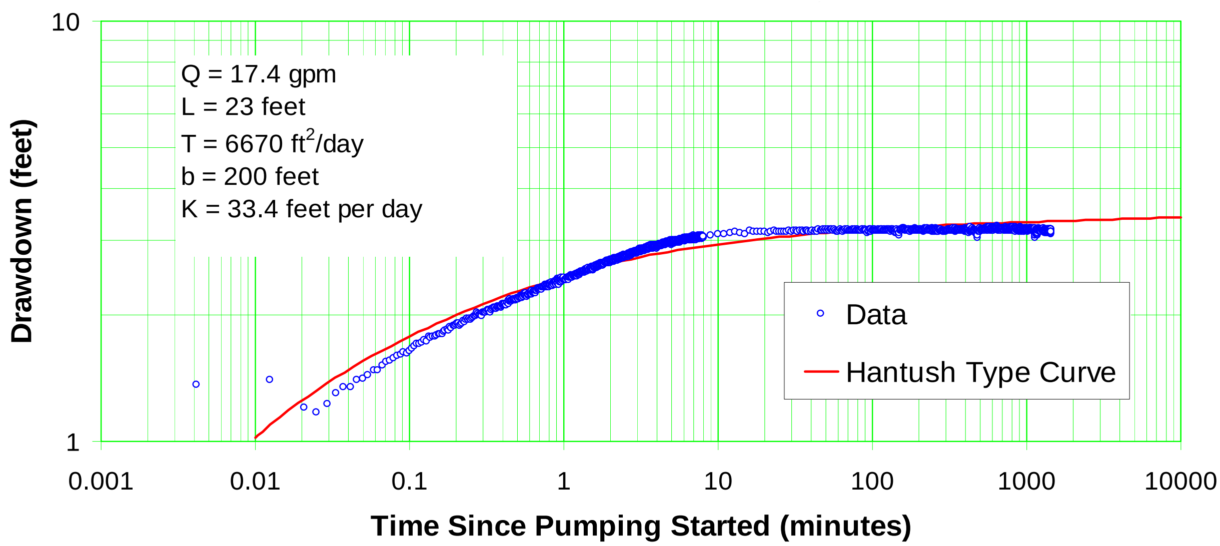


Figure D-7.3-4 Well R-36 drawdown Hantush solution for anisotropy of 0.1

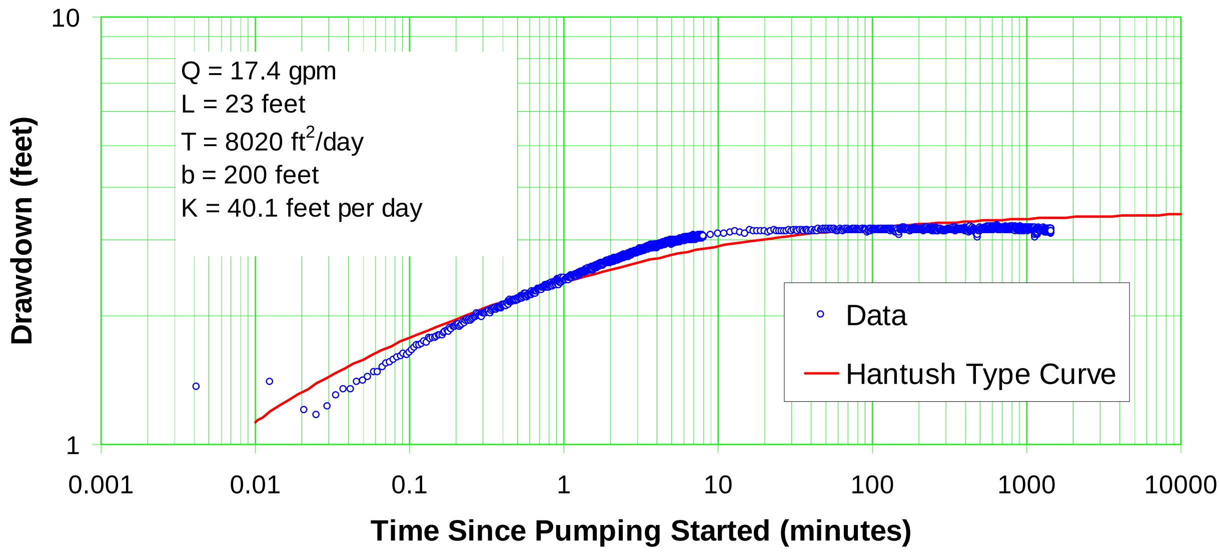


Figure D-7.3-5 Well R-36 drawdown Hantush solution for anisotropy of 0.01

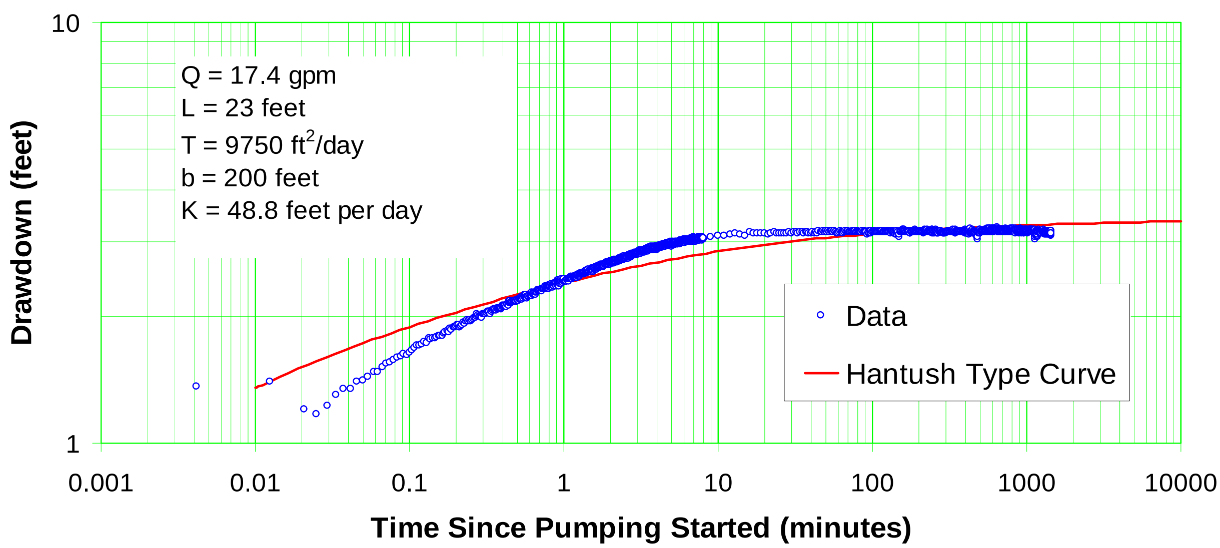


Figure D-7.3-6 Well R-36 drawdown Hantush solution for anisotropy of 0.001

The poor curve matches for the homogeneous model of aquifer conditions suggested that a layered model of the aquifer might be more representative of the hydrogeologic conditions. To test this idea, the time-drawdown data were analyzed using the Hantush-Jacob leaky aquifer method (1955, 070091), as modified by Hantush for partial penetration effects. In this analysis, an aquifer thickness of 50.9 ft was assumed, and leakage from the balance of the deeper saturated sediments was simulated.

Figures D-7.3-7, D-7.3-8, D-7.3-9, and D-7.3-10 show leaky curve-matching results for assumed vertical anisotropy ratios of 1.0, 0.1, 0.01, and 0.001, respectively. A range of assumed vertical anisotropy ratios was used to try to identify an optimum value.

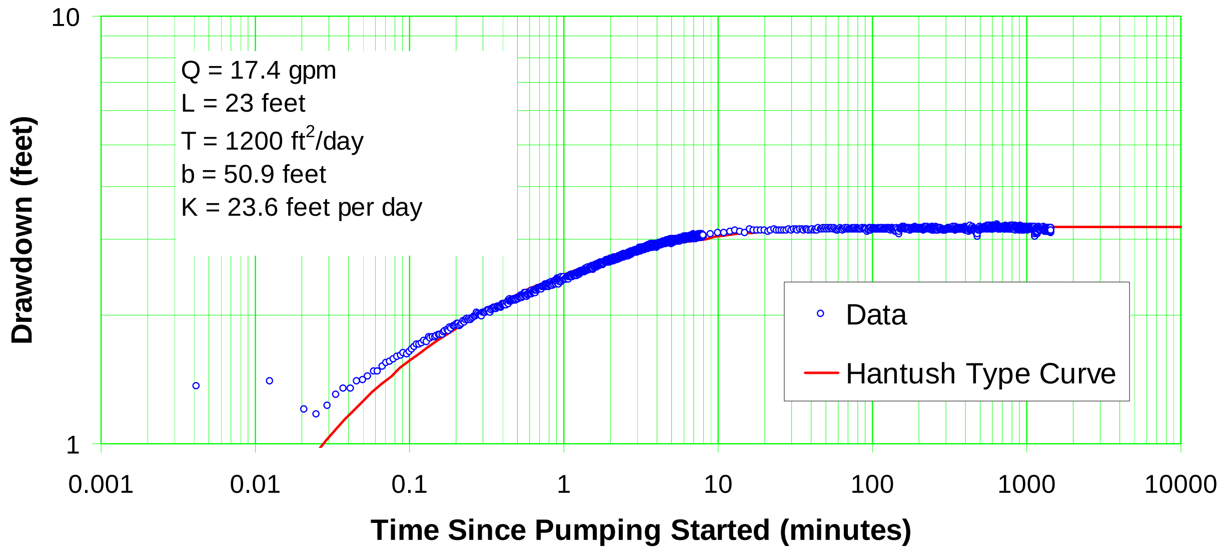


Figure D-7.3-7 Well R-36 drawdown leaky solution for anisotropy of 1.0

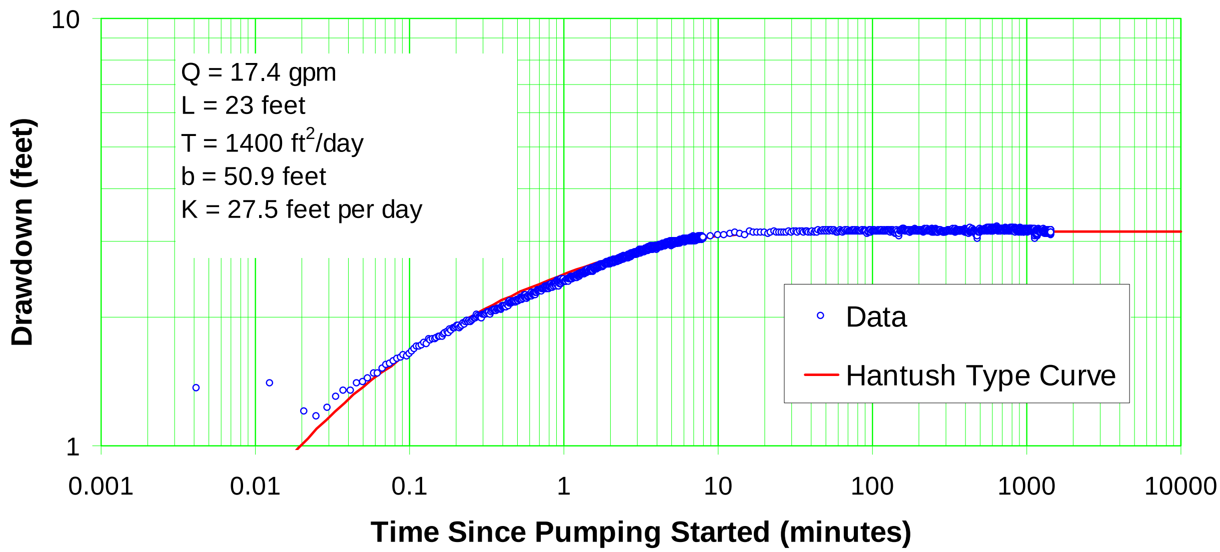


Figure D-7.3-8 Well R-36 drawdown leaky solution for anisotropy of 0.1

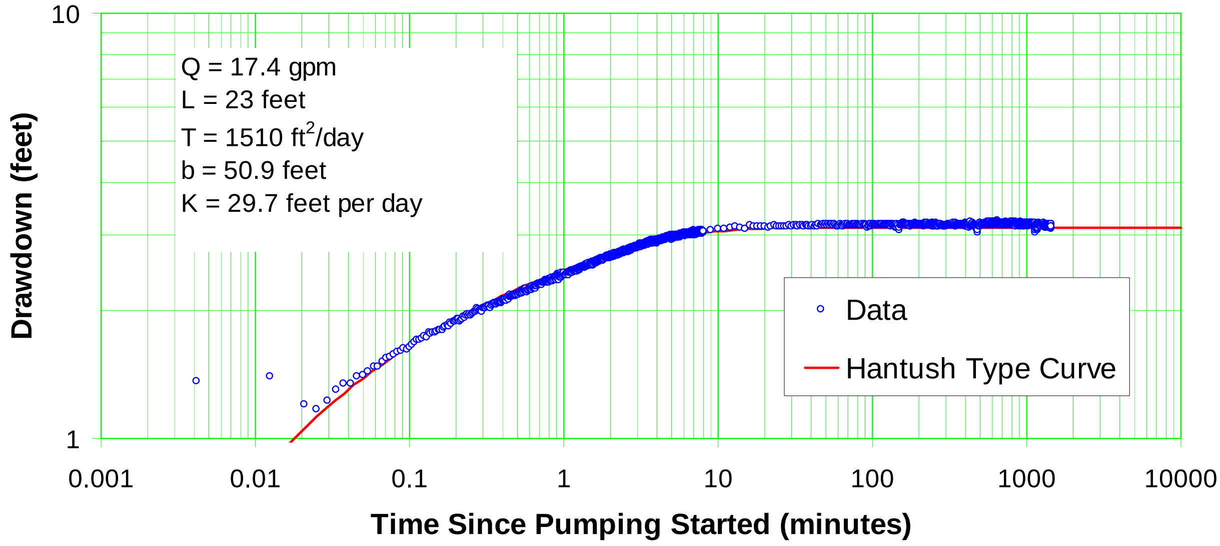


Figure D-7.3-9 Well R-36 drawdown leaky solution for anisotropy of 0.01

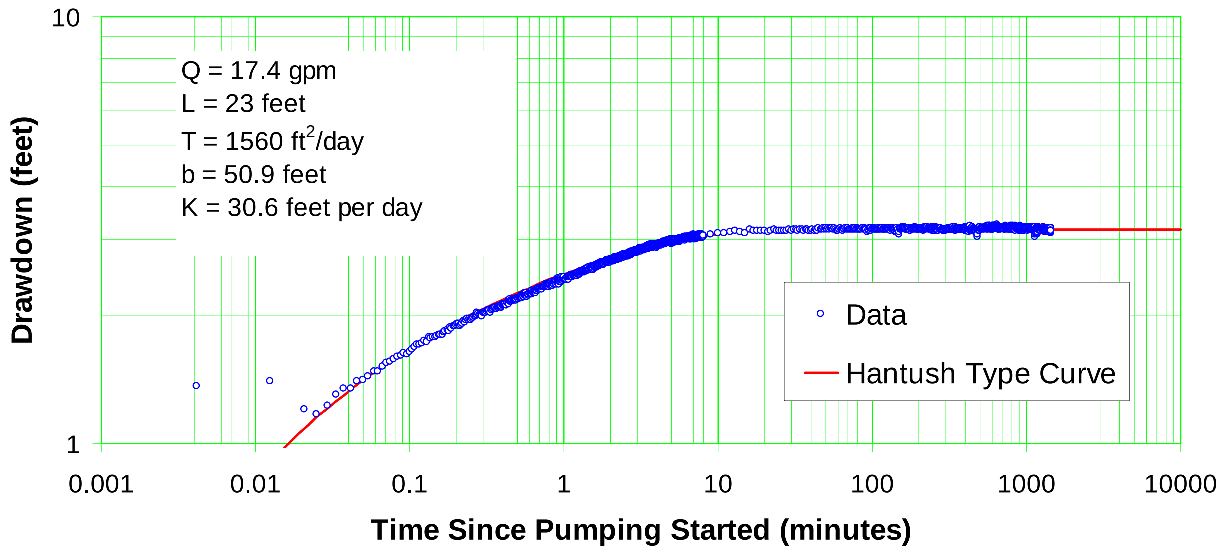


Figure D-7.3-10 Well R-36 drawdown leaky solution for anisotropy of 0.001

An inspection of the plots shows that the curve matches were substantially better than those for the homogeneous, nonleaky model. The best results were obtained for severe, rather than moderate, anisotropy. Hydraulic conductivity values obtained for anisotropy rations of 1.0, 0.1, 0.01, and 0.001 were 25.6, 27.5, 29.7, and 30.6 ft/d, respectively. The last two values—29.7 and 30.6 ft/d—corresponded to relatively more severe anisotropy, providing better curve matches than the graphs for moderate anisotropy.

Curiously, the leakance value associated with the above curve matches was quite large and therefore contradicted the idea of severe vertical anisotropy. This cast doubt on the model of a 50.9-ft-thick aquifer with leakage. Therefore, a final leaky analysis was performed for the assumption of full penetration, that is, a 23-ft-thick fully penetrating aquifer receiving leakage from above and/or below. Figure D-7.3-11 shows the resulting curve matching, revealing an excellent fit between the drawdown data and the leaky type curve.

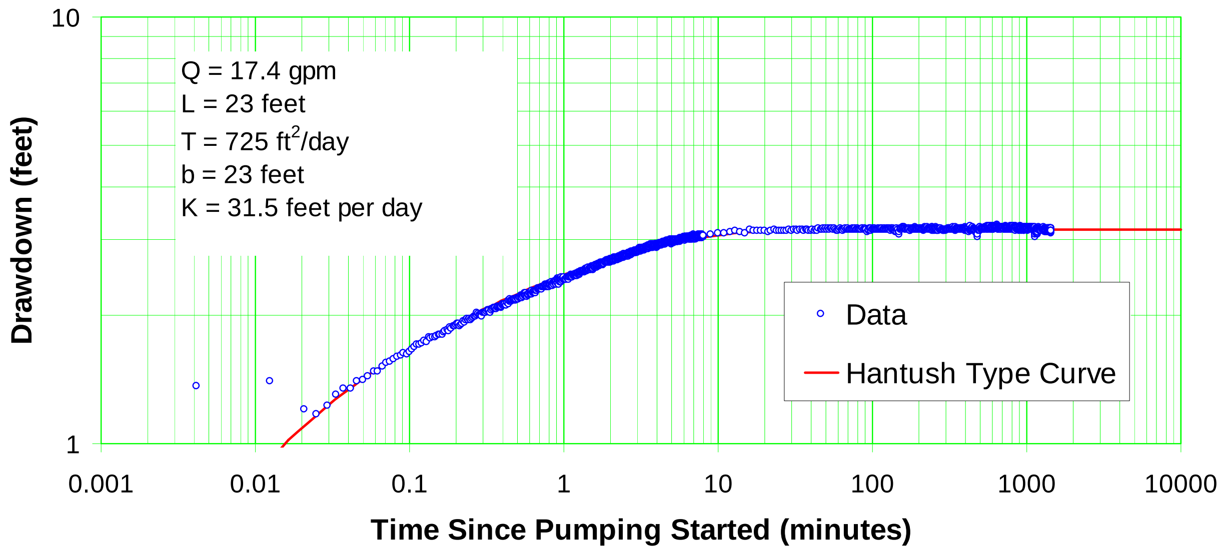


Figure D-7.3-11 Well R-36 drawdown leaky solution for full penetration

The analysis shown in Figure D-7.3-11 revealed a transmissivity value of 725 ft^2/d for the assumed 23-ft-thick aquifer, yielding a hydraulic conductivity of 31.5 ft/d. Again, the computed leakance value was rather large, implying strong leakage from the adjacent sediments into the screened horizon. Of the three-dimensional (3-D) solutions that were examined, the results in Figure D-7.3-11 provided the best match to the data. Although this analysis was based on vertical leakage (partial penetration and 3-D effects), it must be remembered that the observed response may also have included effects of delayed yield and lateral changes in transmissivity.

A derivative plot of the information from Figure D-7.3-11 was created to see if it would provide insight into further improving the curve match. Figure D-7.3-12 shows a plot of the drawdown derivative versus pumping time. Because of scatter in the drawdown data, a smoothing algorithm was applied to the data. Even with smoothing, there was substantial scatter and variation in the derivative plot. The type curve shown in Figure D-7.3-12 is for the solution parameters determined from the previous analysis. Adjusting the aquifer parameters from the indicated values did not produce a better data fit than the one shown in the figure.

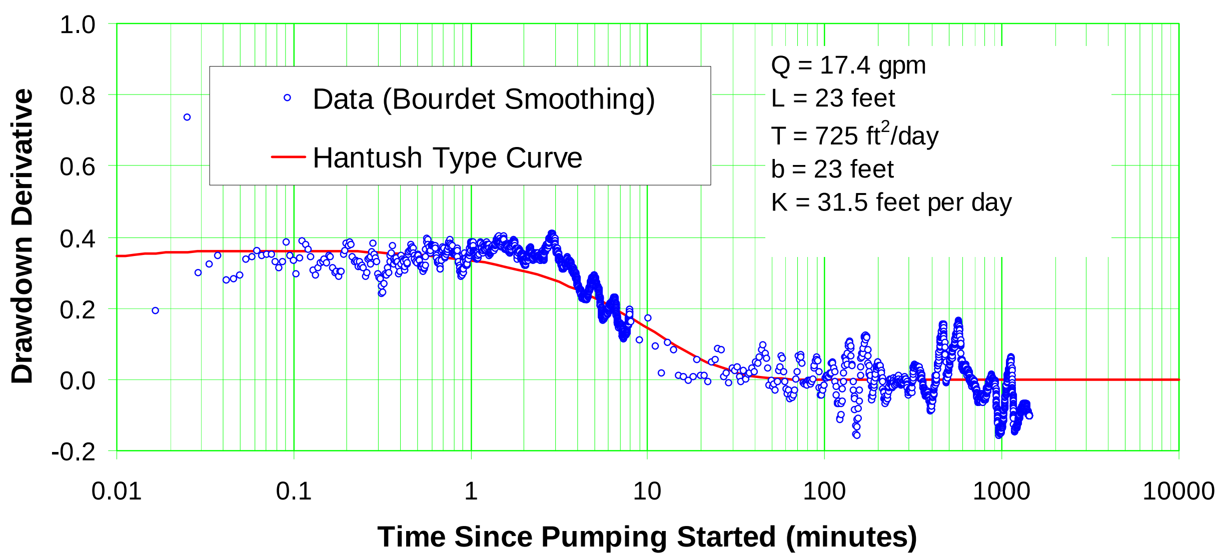


Figure D-7.3-12 Well R-36 drawdown derivative leaky solution for full penentration

Recovery Analysis

After 24 h of continuous pumping, the pump was shut off and recovery data were recorded for 1483 min from 8:30 p.m. on February 20, 2008, to 9:13 a.m. on February 21, 2008. Figure D-7.3-13 shows the resulting Theis recovery analysis. The calculations shown on the graph produced a transmissivity of 6200 gpd/ft and a hydraulic conductivity of 270 gpd/ft^2, or 36.0 ft/d. This result was consistent with, although inexplicably greater than, previous calculations. The first three data points (less than 1 s of recovery) showed the possibility of subtle inertial effects. The late data showed the flattening consistent with partial penetration of the aquifer, possible lateral changes in transmissivity, and/or delayed yield effects.

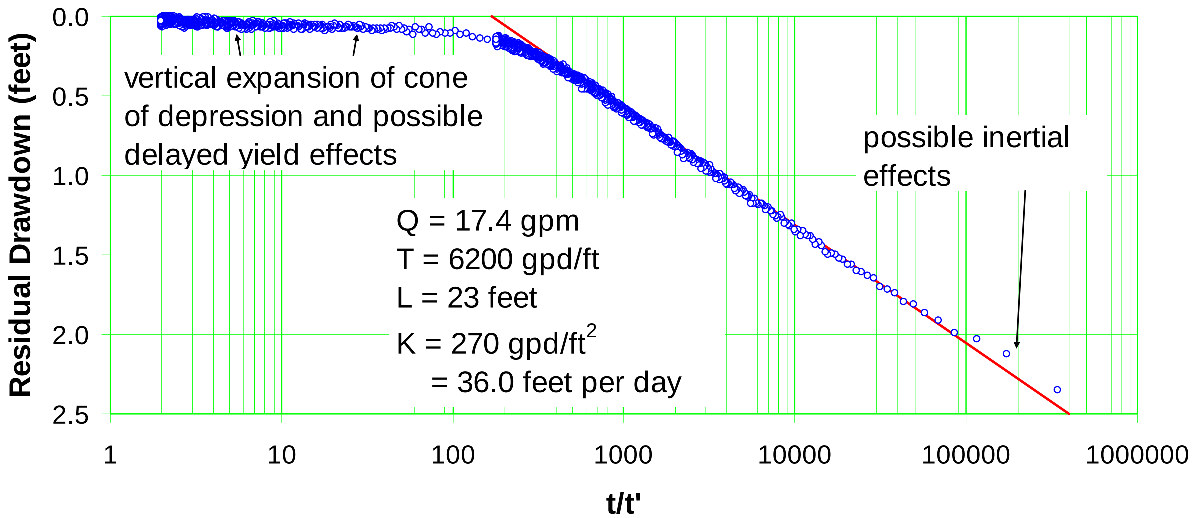


Figure D-7.3-13 Well R-36 recovery

Figure D-7.3-14 shows an expanded-scale plot of the late recovery data from R-36. A rolling average plot was prepared to minimize the scatter in the data plot. Several points of interest are on the graph.

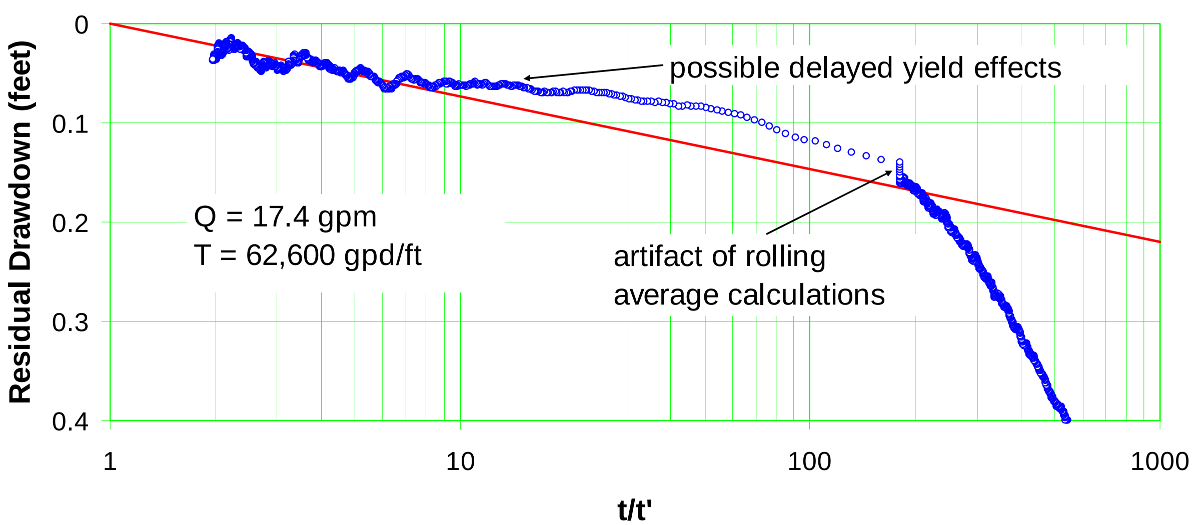


Figure D-7.3-14 Rolling average of late well R-36 recovery

First, an abrupt water-level rise could be seen around a *t/t'* value of about 180. This apparent anomaly was an artifact of the rolling average calculation algorithm in the transition area where the data collection frequency changed from ¼ s to 1 min.

Second, the slope of the recovery data flattened considerably between *t/t'* values of about 25 and 5 and then increased slightly. This may have been an indication of delayed yield effects associated with delayed drainage (actually, resaturation) of the unconfined aquifer. It also might have been caused by background water-level fluctuations in the aquifer.

Finally, the last slope on the plot yielded a calculated transmissivity value of 62,600 gpd/ft, implying that the cone of impression had sufficient vertical and/or horizontal expansion to intercept sediments having substantial transmissivity. The sediment thickness corresponding to this transmissivity value was not known; thus, it was not possible to compute a corresponding hydraulic conductivity value.

Regardless, the computed transmissivity value itself could include substantial error. Note that the residual drawdown change on which the transmissivity calculation was based was only a few hundredths of a foot. Minor background water-level fluctuations would have had a significant effect on the computed transmissivity value.

To emphasize this, the late time-drawdown data shown in Figure D-7.3-12 can be considered analogous to the late recovery data and in theory should have produced the same transmissivity value. Yet the late data in Figure D-7.3-2 showed essentially complete stabilization (even water-level reversal), meaning that background noise obscured whatever water-level change occurred because of pumping. Thus, the late-time slopes in both Figures D-7.3-2 and D-7.3-14 imply high transmissivity but cannot be used to quantify its magnitude accurately.

Because the late-time water-level changes induced by pumping were obscured by background fluctuations, it would have been necessary to conduct a pumping test with a discharge rate of hundreds of gallons per minute to elevate the incremental drawdown over time to a level that could be discerned from the background noise. This would have allowed evaluation of the hydraulic properties of the nonscreened sediments that provide leakage to the R-36 screened zone. Such an approach would require a large diameter well and pump. It was not possible in this particular instance to make this evaluation using the small diameter R-36 monitoring well and the limited discharge rate.

D-7.4 Hydraulic Conductivity Summary

The hydraulic conductivity values determined from the various analyses of the R-36 pumping test data were in good agreement, spanning a relatively narrow range. Table D-7.4-1 lists the values obtained from the straight line analysis methods, as well as the leaky aquifer analysis for the assumption of full penetration.

As shown below in Table D-1, the hydraulic conductivity values ranged from 31.5 to 36.0 ft/d, averaging 33.5 ft/d. This is a reasonable estimate of the conductivity of the sediments within the screened interval in R-36.

Table D-7.4-1
R-36 Hydraulic Conductivity Summary

Test	Data	Analytical Method	Hydraulic Conductivity (ft/d)
Trial 1	Recovery	Theis Recovery	33.9
Trial 2	Drawdown	Cooper-Jacob	33.0
Trial 2	Recovery	Theis Recovery	32.9
24-H	Drawdown	Cooper-Jacob	33.6
24-Hr	Drawdown	Leaky Aquifer	31.5
24-H	Recovery	Theis Recovery	36.0
Average			33.5

D-7.5 Specific Capacity Data

Specific capacity data were used to estimate a lower bound conductivity value for the aquifer sediments in R-36 to provide a comparison to the values determined from the pumping tests. Input values used in the calculations included a well screen length of 23 ft, an arbitrary aquifer thickness of 200 ft, an assumed storage coefficient of 0.1, and a borehole radius of 0.51 ft.

During the 24-h pumping test, R-36 produced 17.4 gpm with 3.15 ft of drawdown. The lower-bound hydraulic conductivity computed from this information was 29.8 ft/d. This value was consistent with the estimate of 33.5 ft/d obtained from the pumping test analyses.

As a rough approximation, the well efficiency can be estimated as the ratio of the lower-bound hydraulic conductivity to the actual conductivity. This implied a well efficiency for R-36 of roughly 90%.

D-8.0 SUMMARY

The results of the pumping and recovery tests on R-36 are summarized below.

- The hydrograph data suggested barometric efficiency for R-36 of nearly 100%, consistent with other observations on the Pajarito Plateau.
- Monitoring of nearby well R-35b by the use of a vented transducer confirmed a similarly high barometric efficiency in agreement with conclusions drawn from 2007 testing of this well using a nonvented transducer.
- Casing storage effects were successfully eliminated by use of the inflatable packer in R-36. This permitted the use of very early data that were instrumental in quantifying aquifer properties.
- After just a few minutes of pumping (or recovery), the effects of vertical expansion of the cone of depression were evident, represented by a flattening of the data curve. The curve continued to flatten over time as a result of continued vertical growth of the drawdown cone, lateral changes in transmissivity, and/or delayed yield effects.
- R-35b showed no response to pumping R-36 (or any other wells). R-35a showed a strong response to pumping PM-3 and a subtle response to pumping O-4. The timing of the O-4 pumping was such that it would have masked any miniscule response that may have occurred in R-35a due to the pumping of R-36. There was no discernible response in R-35a associated with pumping R-36.

- The 3-D effects of partial penetration of the pumped well screen were best represented using a fully penetrating, leaky aquifer model.
- Late-time data showed miniscule water-level change that could not be quantified accurately because of minor background water-level fluctuations. This implied great transmissivity of the sediments above and/or below the screened interval in R-36 or laterally juxtaposed sediments. Note that if the greater transmissivity was caused by overlying or underlying sediments, it does not necessarily imply high hydraulic conductivity. Well log information suggested that the underlying and overlying sediments looked less permeable than the screened zone. The large transmissivity could arise from the combination of moderate sediment hydraulic conductivity and great thickness.
- The average hydraulic conductivity value for the screened interval in R-36 determined from the pumping test analysis was 33.5 ft/d.
- Specific capacity data suggested a lower-bound hydraulic conductivity of 29.8 ft/d, in excellent agreement and consistent with the pumping test value. The lower-bound value suggested a well efficiency of about 90%.

D-9.0 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 number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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