FINAL
COMPLETION REPORT
CHARACTERIZATION WELL R-16r
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
PROJECT NO. 49436

Prepared for:

The US Department of Energy and the
National Nuclear Security Administration through the
US Army Corps of Engineers
Sacramento District

Prepared by:

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LIST OF ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
ARCH	air-rotary casing hammer
ASTM	American Society for Testing and Materials
bgs	below ground surface
BMPs	best management practices
°	degrees
DOE	US Department of Energy
DTW	depth to water
EES-6	Earth and Environmental Sciences Division, Group 6
ft	foot/feet
ft^3	cubic feet
gal.	gallon/gallons
hr	hour
ID	inner diameter
in.	inch/inches
Kleinfelder	Kleinfelder, Inc.
LANL	Los Alamos National Laboratory
µS/cm	microSiemens per centimeter
NM	not measured
NMED	New Mexico Environment Department
NTUs	nephelometric turbidity units
OD	outer diameter
pH	percentage of hydrogen ions
ppm	parts per million
Qal	Quaternary Alluvium
Qbo	Otowi Member of the Bandelier Tuff
RCT	radiation control technician
Ta	Older Alluvium
TD	total depth
TOC	total organic carbon
Tb4	Cerros del Rio basalt
Tpf	Puye Formation
Tpl	Lakebed sediments of the Puye Formation
Tpt	Totavi Lentil
WDC	WDC Exploration and Wells

ABSTRACT

Characterization Well R-16r was installed in accordance with the "Drilling Work Plan for Characterization Wells R-16a and R-23i, Final" (Kleinfelder 2005a); note that well R-16a has been renamed R-16r. Drilling activities were funded and directed by the US Department of Energy and contracted by the US Army Corps of Engineers. Kleinfelder, Inc, conducted the drilling, installation and associated activities at R-16r. Los Alamos National Laboratory personnel provided technical assistance.

R-16r is located south of Cañada del Buey, approximately 1.3 miles east of Los Alamos National Laboratory near the town of White Rock. R-16r is a replacement well for the upper screened interval in characterization well R-16 that was drilled in August 2002. R-16 was sited to provide hydrogeologic information and monitor groundwater between Los Alamos National Laboratory and the Rio Grande. During construction of R-16, 11¾-inch intermediate drill casing could not be retracted and it was cemented in place to 729 ft bgs, blocking the upper screen. The upper screen of R-16 had been intended to monitor the upper portion of the regional aquifer; R-16r was drilled and installed approximately 20 feet north of R-16 for that purpose.

R-16r was drilled to 655 feet below ground surface using air rotary, fluid-assisted air rotary and air rotary casing hammer techniques. The stratigraphy encountered during borehole drilling included, in descending order, Quaternary Alluvium, Otowi Member of the Bandelier Tuff, basaltic sediments, lakebed sediments of the Puye Formation, Cerros del Rio basalt, lakebed sediments, Older Alluvium, Cerros del Rio basalt, Totavi Lentil of the Puye Formation and the Puye Formation fanglomerate. The well was installed with a screened interval from 600 to 617.6 feet below ground surface within the Totavi Lentil. The depth to water after well installation was 563.56 feet below ground surface.

One screening groundwater sample was collected from the regional aquifer in the open borehole and a final groundwater sample was collected after the well was developed. Perchlorate was detected at 0.0021 parts per million in the screening sample, but was not detected in the post-development sample. Nitrate (as nitrogen) was detected in both samples at concentrations of 0.44 and 0.45 parts per million, respectively. Total organic carbon was measured at 0.99 milligrams of carbon per liter near the end of well development on October 17, 2005.

A 32.5-hour aquifer pumping test was conducted at R-16r. The average hydraulic conductivity near the top of the regional aquifer at R-16r was 7.1 feet per day. There was no discernible response in R-16 screen 2 (863.4 to 870.9 feet below ground surface) to pumping at R-16r, which suggests the intervening sediments have a low vertical hydraulic conductivity.

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development and related activities for Characterization Well R-16r, drilled in September 2005 at Los Alamos National Laboratory (LANL). Drilling activities were funded and directed by the US Department of Energy (DOE) and contracted by the US Army Corps of Engineers. Kleinfelder, Inc. (Kleinfelder) was responsible for the drilling, installation and sampling activities, with technical assistance from LANL. Activities were conducted according to the "Drilling Work Plan for Characterization Wells R-16a and R-23i, Final" (Kleinfelder 2005a). Note that well R-16a has been renamed R-16r.

R-16r is a replacement well for the upper screened interval in characterization well R-16, drilled in August 2002. The LANL Hydrogeologic Workplan called for drilling R-16 to provide hydrogeologic information and monitor groundwater between LANL and the Rio Grande (LANL 1998). R-16 was drilled to a depth of 1,287 feet (ft) below ground surface (bgs) and constructed with four screened intervals; one to monitor the top of the regional aquifer and the other three to monitor more productive zones deeper in the regional aquifer. However, during construction, 11¾-inch (in.) intermediate drill casing could not be retracted. It was cemented in place to a depth of 729 ft bgs, blocking the upper screen (LANL 2003).

R-16r was drilled to monitor the upper portion of the regional aquifer, replacing the blocked upper screened interval in R-16. R-16r is located south of Cañada del Buey, approximately 3,000 ft northwest of the Rio Grande and near the town of White Rock, as shown in Figure 1.0-1; it is located approximately 20 ft north of R-16. The drilling plan specified that R-16r would be drilled to 700 ft bgs; the well was drilled to a total depth (TD) of 655 ft bgs and installed with a screened interval from 600 to 617.6 ft bgs. Post-installation activities included well development, groundwater sampling, aquifer testing and wellhead surveying.

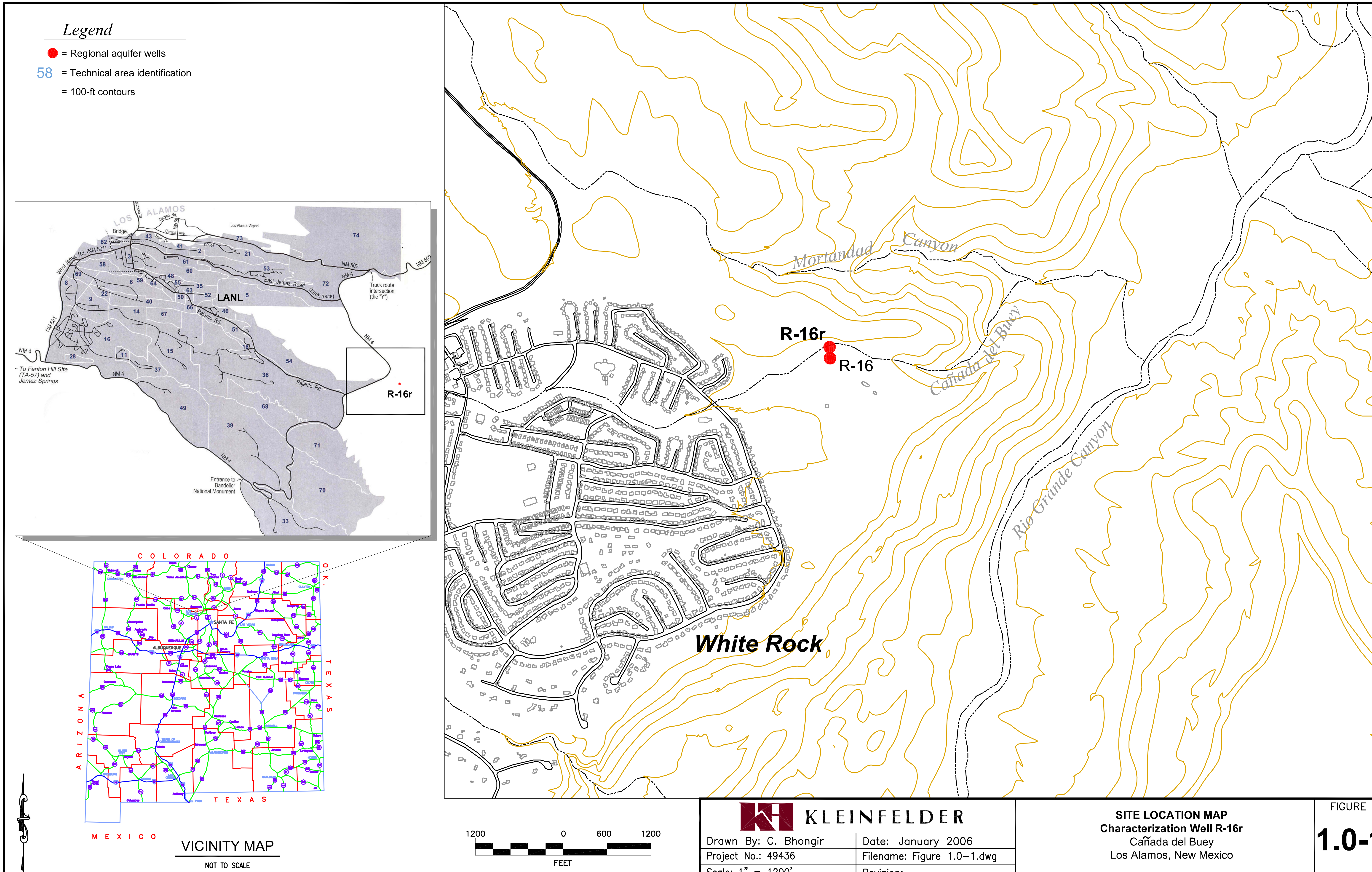
The information presented in this report was compiled from field reports and activity summaries generated by Kleinfelder, LANL and subcontractor personnel. Original records, including field reports, field logs and survey records, are on file in Kleinfelder's Albuquerque office and will be transferred to the LANL Records Processing Facility after completion of the project. This report contains brief descriptions of all activities associated with R-16r as well as supporting figures, tables and appendices. Detailed analysis and interpretation of geologic, geochemical and aquifer data will be included in separate technical documents to be prepared by LANL.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities included preparing administrative planning documents and constructing the drill site.

2.1 Administrative Preparation

Kleinfelder received contractual authorization as a notice to proceed on May 27, 2005. The following documents were prepared to guide the implementation of the scope of work for this well: Drilling Work Plan (Kleinfelder 2005a), Contractor's Quality Management Plan



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Drawn By: C. Bhongir	Date: January 2006
Project No.: 49436	Filename: Figure 1.0-1.dwg
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SITE LOCATION MAP
Characterization Well R-16r
Cañada del Buey
Los Alamos, New Mexico

FIGURE
1.0-1

G:\Environ\49436 – DOE Mortandad Canyon\DOE-LANL_2005-06_Drilling\Project Plans\Fact Sheets\R-16r\Figure 1.0-1.dwg

(Kleinfelder 2005b), Site-Specific Health and Safety Plan (Kleinfelder 2005c), and Storm Water Pollution Prevention Plan (Kleinfelder 2005d).

2.2 Site Preparation

Site preparation consisted of constructing and lining the cuttings pit, installing a steel perimeter fence with a locking gate, erecting silt fencing to prevent erosion and runoff from the drill site, and setting up the exclusion zone. Best management practices, also known as BMPs, were installed as specified in the Storm Water Pollution Prevention Plan (Kleinfelder 2005d). EnviroWorks, Inc. completed these tasks from September 7 through 9, 2005. A radiation control technician (RCT) from LANL's Health, Safety, and Radiation Protection Group-1 screened the site before site preparation activities. A geology trailer, generator, compressor, and safety lighting equipment were moved to the site during the subsequent mobilization of drilling equipment.

3.0 DRILLING ACTIVITIES

WDC Exploration & Wells (WDC) drilled R-16r with a Speedstar 50K rig to a TD of 655 ft bgs between September 13 and 27, 2005. The well was completed with one screened interval in the regional aquifer from 600 to 617.6 ft bgs. Drilling activities were performed generally in one 12-hour shift per day, 7 days per week, by the drill crew and two site geologists. Depth-to-water (DTW) measurements were taken at the beginning and end of most shifts to check for the presence of groundwater. A chronology of drilling and associated activities for R-16r is presented in Table 3.0-1.

The drilling rig was equipped with conventional drilling rods, tri-cone bits, mill-tooth bits, down-the-hole hammer bits, air compressors, and support equipment. Air-rotary, fluid-assisted air-rotary and air-rotary casing hammer (ARCH) drilling techniques were used to drill R-16r. Municipal water mixed with QUIK-FOAM® surfactant and EZ-MUD® polymer was used to improve borehole stability, minimize fluid loss, and help remove cuttings from the borehole. An approximate tally of the total drilling fluids introduced into the borehole, as well as the total drilling fluids recovered, is presented in Table 3.0-2.

On September 12 and 13, 2005, WDC mobilized drilling equipment and supplies to the site. On September 13, WDC drilled to 100 ft bgs using the ARCH technique; the hole was drilled with a 12¼-in. outer diameter (OD) tricone bit and 13⅜-in. drill casing was hammered to 100 ft bgs. On September 14, the borehole was advanced to 182 ft bgs and casing was installed to 120 ft bgs. QUIK-FOAM® surfactant and EZ-MUD® polymer were used from approximately 142 to 162 ft bgs to assist in drilling through lakebed clays in the Puye Formation and the upper portion of the Cerros del Rio basalt.

On September 15, WDC advanced the boring from 182 to 402 ft bgs; no cuttings were recovered from 380 to 400 ft bgs. In order to solve the lost circulation problems, DOE and Kleinfelder representatives decided to install 11¾-in. casing to approximately 630 ft bgs, through the Totavi Lentil. The drill crew left for scheduled days off.

On September 20, the drill crew tripped the drill string and bit out of the borehole and installed 11¾-in. casing to 180 ft bgs. On September 23, the drill crew cleaned out the hole with a 10⅝-in. bit to 203 ft bgs. Casing was installed to 199 ft bgs but could not be advanced further. DOE

Table 3.0-1
Chronology of Activities

TASK	R-16r DATES					
	Sep-05	Oct-05	Nov-05	Dec-05	Jan-06	Feb-06
SITE PREPARATION ACTIVITIES	9/7-9					
BOREHOLE DRILLING/SAMPLING						
Mobilization	9/12-13					
Air Rotary Drilling	9/13 - 27					
Groundwater Screening Sampling	9/26					
BOREHOLE LOGGING						
Geophysical Logging	9/27					
WELL CONSTRUCTION		10/4 - 11				
WELL DEVELOPMENT		10/12 - 17				
GROUNDWATER WELL SAMPLING		10/17				
AQUIFER TESTING		10/21-22				
PUMP INSTALLATION				12/13		
SITE RESTORATION*						

*** Site restoration will begin in Spring 2006 when all analytical data have been received and NMED permission to discharge has been obtained.**

Table 3.0-2
Introduced and Recovered Fluids

Material		**Amount (gallons)**
Introduced	QUIK-FOAM®	25
	Potable Water	5,840
	EZ-MUD®	14
	Total Introduced Fluids[a]	5,879
Recovered	Total Recovered Fluids[b]	21,411

[a]Represents the fluids introduced during drilling.
[b]Represents the estimated fluid volume recovered during drilling, well development and aquifer testing.

representatives decided to use the ARCH technique to install 9⅝-in. casing to approximately 630 ft bgs. WDC installed 9⅝-in. casing to 160 ft bgs.

On September 24, 9⅝-in. casing was installed to 350 ft bgs. Then an 8½-in. tricone button bit was used with the ARCH to advance the borehole and drive casing to 520 ft bgs. On the 25th, the borehole and casing were advanced to 627 ft bgs. The crew tripped out the drill string and water was measured at 582.2 ft bgs; the water level rose to 567.2 ft bgs over a 3-hour (hr) period before personnel left the site for the day.

On September 26, the DTW in the morning was 564.35 ft bgs and the borehole depth was 618 ft bgs, indicating 9 ft of slough had accumulated from the previous day. A screening groundwater sample was collected from approximately 580 ft bgs. The crew was directed to retract the 9⅝-in. casing to 540 ft and run a video log and borehole geophysics; however, once the casing was retracted, slough accumulated in the borehole to 551 ft bgs. The crew was directed to trip the drill string back in the hole and drill/drive the casing to 647 ft bgs. By the end of the day, the hole had been advanced and cased to 575 ft bgs.

On September 27, the casing was advanced to 635 ft bgs and the borehole was drilled to 655 ft bgs. The drill string was tripped out and a natural gamma log was run in the borehole. After logging, the DTW was measured at 565.8 ft bgs.

On September 28, slough had accumulated in the bottom of the borehole, so the drill crew tripped in the drill string and cleaned the hole to approximately 640 ft bgs. On the 29th, well casing and annular materials were brought to the site and the well casing and screen were decontaminated with a steam cleaner. The drill crew departed for days off.

On October 4, the drill crew returned and approximately 8 ft of slough had accumulated in the borehole; the crew cleaned out the borehole to 640 ft bgs prior to installing the well.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling at R-16r. Samples were generally collected in accordance with the Drilling Plan (Kleinfelder 2005a), except for some modifications requested by LANL scientists.

4.1 Cuttings Sampling

In 2002, cuttings samples were collected at R-16 at 5-ft intervals; therefore, in R-16r, the drill plan called for bulk cuttings to be collected in plastic bags at 10-ft intervals from ground surface to 450 ft bgs, and at 5-ft intervals from 450 to 700 ft bgs. Sieved cuttings were to be collected at 5-ft intervals and placed in chip trays from 450 to 700 ft bgs. However, LANL scientists asked that bulk cuttings be collected at 10-ft intervals to 550 ft bgs, and at 5-ft intervals from that point to TD. Sieved samples were also to be collected at 5-ft intervals from 550 ft bgs to TD. Those procedures were followed. There was one zone of lost circulation with no sample recovery between 380 and 400 ft bgs.

4.2 Water Sampling

One screening groundwater sample, EU0507GR16A01, was collected from the open borehole with a disposable bailer from approximately 580 ft bgs during drilling at R-16r. A final groundwater sample, EU0507GR16A02, was collected from approximately 610 ft bgs in the completed well after it was developed. The groundwater samples were submitted to the LANL Earth and Environmental Sciences Division, Group 6 (EES-6) for anions, cations and metals analyses.

5.0 BOREHOLE LOGGING

A full suite of geophysical logs was run at R-16 in 2002, so a natural gamma log was the only geophysical log obtained from R-16r. Table 5.0-1 summarizes the gamma logging information. Appendix C of the report CD contains the geophysical logging spreadsheets and charts. A video log was planned for R-16r, but borehole instability necessitated the use of 9⅝-in. casing to 635 ft bgs, which precluded the use of a video camera.

Table 5.0-1
Borehole Logging

Operator	Date	Tools	Cased Footage (ft bgs)	Open hole Interval (ft bgs)	Logged Interval (ft bgs)	Remarks
Kleinfelder	9/27/05	Natural gamma	0 - 635	635 - 655	0 – 655	DTW after logging was 565.8 ft bgs

6.0 HYDROGEOLOGY

This section contains a description of the hydrogeologic features encountered at R-16r. The stratigraphy section discusses geologic units that were identified during the drilling of R-16. The groundwater description is based on drilling observations and water level measurements at R-16r.

6.1 Stratigraphy

The stratigraphic descriptions in this section are from the June 2003 R-16 report (LANL 2003); only the descriptions to the R-16r total depth of 655 ft bgs are included. R-16r is approximately 100 ft north of R-16, and the ground surface at R-16r is roughly 1.5 in. higher. The following formations were present in descending order: Quaternary Alluvium, Otowi Member of the Bandelier Tuff, basaltic sediments, lakebed sediments of the Puye Formation, Cerros del Rio basalt, lakebed sediments, Older Alluvium, Cerros del Rio basalt, Totavi Lentil of the Puye Formation and the Puye Formation fanglomerate. Figure 6.1-1 summarizes the local stratigraphy at R-16r and Figure 6.1-2 shows the site stratigraphy plotted with the gamma geophysical log. A detailed lithologic log for R-16r is presented in Appendix A.

Quaternary Alluvium, Qal (0 to 5 ft bgs)

Unconsolidated tuffaceous sand and gravel derived from the Bandelier Tuff were noted in the interval from 0 to 5 ft bgs.

Otowi Member of the Bandelier Tuff, Qbo (5 to 84 ft bgs)

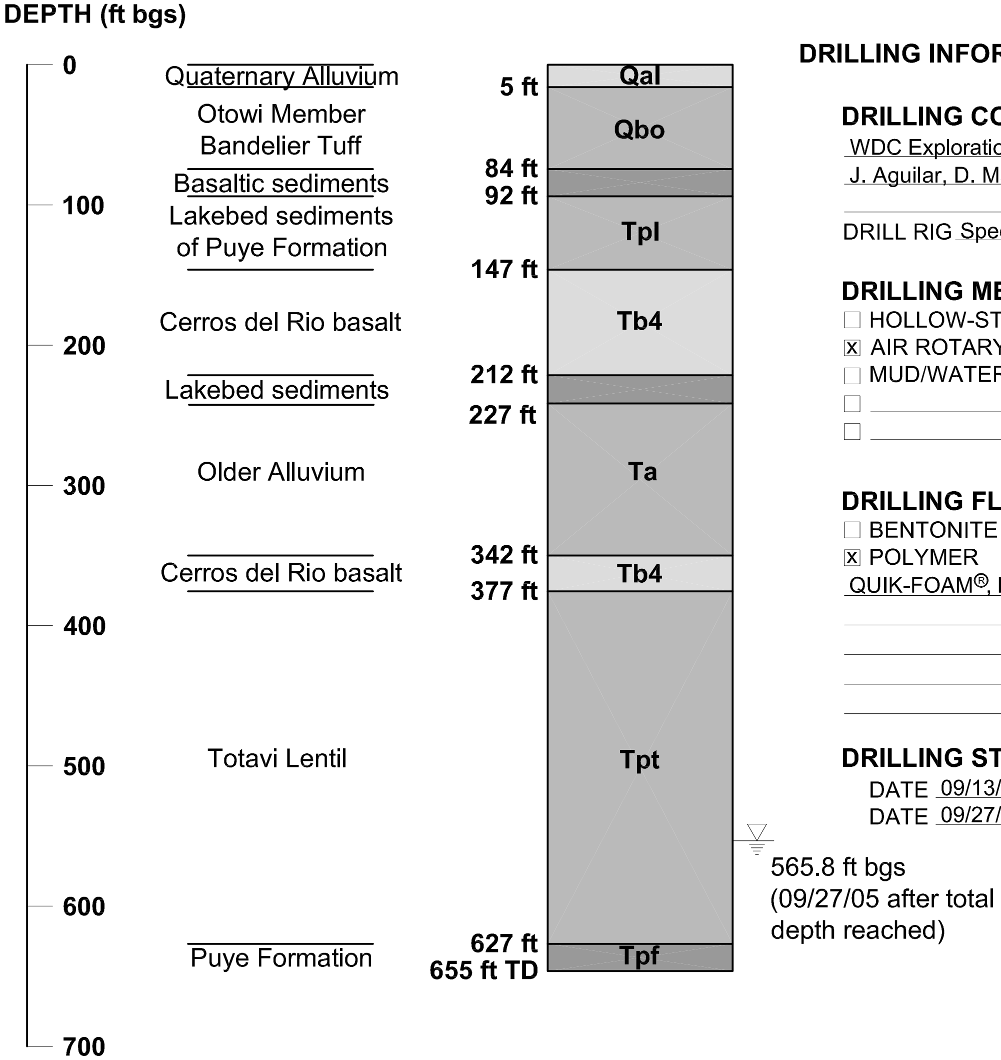
The Quaternary Otowi Member of the Bandelier Tuff was intersected in the R-16 borehole from 5 to 84 ft bgs. Drill cuttings indicate that this unit is composed of vitric pumice, quartz and sanidine crystals, and abundant volcanic xenoliths. Little of the ash matrix is preserved in chip samples, indicating the poorly welded to nonwelded nature of this rhyolithic ash-flow unit. Pumice fragments are generally glassy with a fibrous structure and commonly are stained with iron oxides. Coarse chip samples are frequently 40% to 60% by volume dacite and basalt lithics. Cuttings and geophysical logs leave some uncertainty as to whether the Guaje Pumice Bed of the Otowi Member is present.

Basaltic sediments (84 to 92 ft bgs)

Basalt-rich volcaniclastic gravels and sands were encountered from 84 to 92 ft bgs. This sedimentary interval has not been assigned to any unit in the stratigraphic section in the vicinity of R-16. Up to 50% of the cuttings in this interval contain chips of vesicular and massive basalt that probably derive from Cerros del Rio basalt sources. Other sample components include clasts of dacite, silicified dacite, black vitrophyre, and clay nodules.

Puye Formation—diatomaceous lakebed sediments, Tpf (92 to 147 ft bgs)

An interval of clay and clay-rich sand and gravel occurs from 92 to 147 ft bgs. These sediments are interpreted to represent lakebed deposits associated with a lacustrine depositional environment in the upper part of the Puye Formation. Cuttings are locally (e.g., notably from 92.2 to 107.2 ft bgs) made up of white clay fragments containing microscopic siliceous tubules. Scanning-electron-microscope analysis shows these fragments are the fossil remains of fresh-water diatoms. Basaltic clasts, preserved in the basal part of this unit, exhibit orange-colored, limonite-clay rinds, suggesting palagonite alteration.



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL

WDC Exploration & Wells

J. Aguilar, D. Mathews, Q. Stevens

DRILL RIG Speedstar 50k

DRILLING METHOD

☐ HOLLOW-STEM AUGER

☒ AIR ROTARY

☐ MUD/WATER ROTARY

☐

☐

DRILLING FLUID TYPE

☐ BENTONITE ☒ WATER

☒ POLYMER ☒ AIR

QUIK-FOAM®, EZ-MUD®

DRILLING START / FINISH

DATE 09/13/05 TIME 14:05

DATE 09/27/05 TIME 09:50

Note:
Geologic contacts are preliminary and subject to change.

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Project No.: 49436	Filename: Figure 6.1–1.dwg
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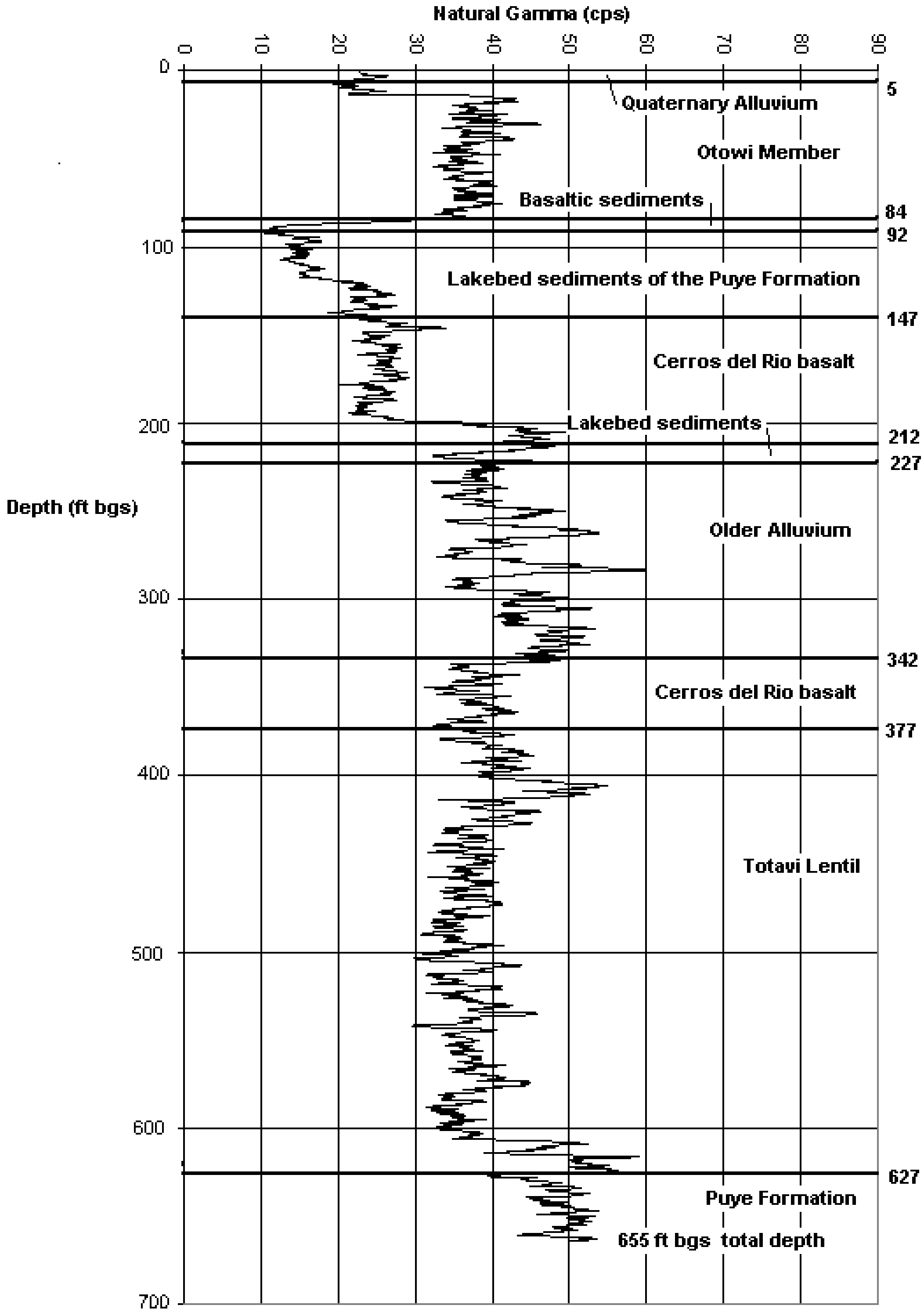
BOREHOLE SUMMARY DATA SHEET
Characterization Well R-16r
Cañada del Buey
Los Alamos, New Mexico

FIGURE
6.1-1



Note: 13 3/8-in. casing to 119 ft bgs, 11 3/4-in. casing to 199 ft bgs and 9 5/8-in. casing to 635 ft bgs during logging.

Figure 6.1-2. Gamma Log and R-16r Stratigraphy

Cerros del Rio basalt, Tb4 (147 to 212 ft bgs)

Two intervals of the Pliocene Cerros del Rio basalt are recognized in R-16. These volcanic units are intercalated with sedimentary deposits of the Puye Formation. The upper basalt occurs in the interval form 147 to 212 ft bgs. Evidence from cuttings suggests that this unit represents a discrete flow made up of massive-to-vesicular, porphyritic olivine basalt with an aphanitic groundmass. In general, this basalt is sparsely altered as characterized by iddingsite replacement of olivine phenocrysts, iron oxide and clay coatings on fractures, and groundmass minerals that are variably altered.

Lakebed sediments with basalt detritus (212 to 227 ft bgs)

Additional lakebed deposits containing basaltic detrital sediments are interpreted to occur in the interval from 212 to 227 ft bgs. Samples in this interval contain abundant altered basalt chips and fragments of clay-cemented sandstone.

Older Alluvium, Ta (227 to 342 ft bgs)

A 115-ft-thick sequence of clastic sediments intersected from 212 to 342 ft bgs is interpreted to be "older" (i.e., pre-Quaternary) alluvium intercalcated within the Puye Formation. Sand and gravel in this interval contain abundant fragments of quartzo-feldspathic sandstone and subrounded coarser clasts dominantly composed of quartz, feldspars, and granitic rocks derived from Precambrian sources.

Cerros del Rio basalt, Tb4 (342 to 377 ft bgs)

The interval from 342 to 377 ft bgs represents a stratigraphically lower flow of the Cerros del Rio basalt. Cuttings indicate that this clay-rich interval is made up of abundant chips (up to 60% by volume) of olivine basalt and fine-to-coarse quartzo-feldspathic detrital sediments. Samples also contain 30% to 40% by volume quartzo-feldspathic detritus, possibly intermixing from the overlying older alluvium.

Totavi Lentil, Tpt (377 to 627 ft bgs)

R-16 encountered a 250-ft-thick section of quartzite-rich sediments in the interval from 377 to 627 ft bgs that represents the Totavi Lentil. The Totavi Lentil consists of axial channel deposits of the ancestral Rio Grande that occur as lenses within the Puye Formation. Totavi deposits are predominantly quartzite, granite, and other Precambrian materials. The interval is locally made up of clay-rich sands and gravels containing subangular to subrounded clasts derived from Precambrian and, to a lesser degree, volcanic sources. The proportion of Precambrian source materials in these sediments typically ranges from 60% to 80% by volume. Clasts are composed of quartzite, quartz, feldspar, granitic and metamorphic lithics, and include abundant fragments of indurated quartzo-feldspathic sandstone. Volcanic detritus (20% to 40% by volume) consists mainly of dacite and minor basalt.

Puye Formation, Tpf (627 to 655 ft bgs)

The interval from 627 to 655 ft bgs is composed Puye Formation fanglomerate. These are fanglomerate deposits in which coarse volcanic detritus occurs as the dominant component, typically in the range of 60% to 80% by volume. The volcanic clasts generally are subrounded to rounded and are composed mainly of pink and grayish dacite with minor basalt.

6.2 Groundwater

Perched intermediate zone groundwater was not encountered at R-16r. Regional groundwater was encountered at R-16r within the Totavi Lentil and the Puye Formation. At the borehole TD of 655 ft bgs (within the Puye Formation) on September 27, 2005, standing water was measured in the open borehole at 565.8 ft bgs. After the well was installed, with a screened interval between 600 and 617.6 (in the Totavi Lentil), the DTW was 563.56 ft bgs on October 11, 2005.

6.3 Preliminary Groundwater Analytical Results

Analytical data for the groundwater samples collected from R-16r are presented and briefly summarized in Appendix B. Perchlorate was detected at 0.0021 parts per million (ppm) in the screening sample, but was not detected in the post-development sample. Nitrate (as nitrogen) was detected in both samples at concentrations of 0.44 and 0.45 ppm, respectively. Total organic carbon (TOC) was measured at 0.99 milligrams of carbon per liter near the end of well development on October 17, 2005.

7.0 WELL INSTALLATION

This section describes the well design process and well construction for R-16r. The well was installed between October 4 and 21, 2005.

7.1 Well Design

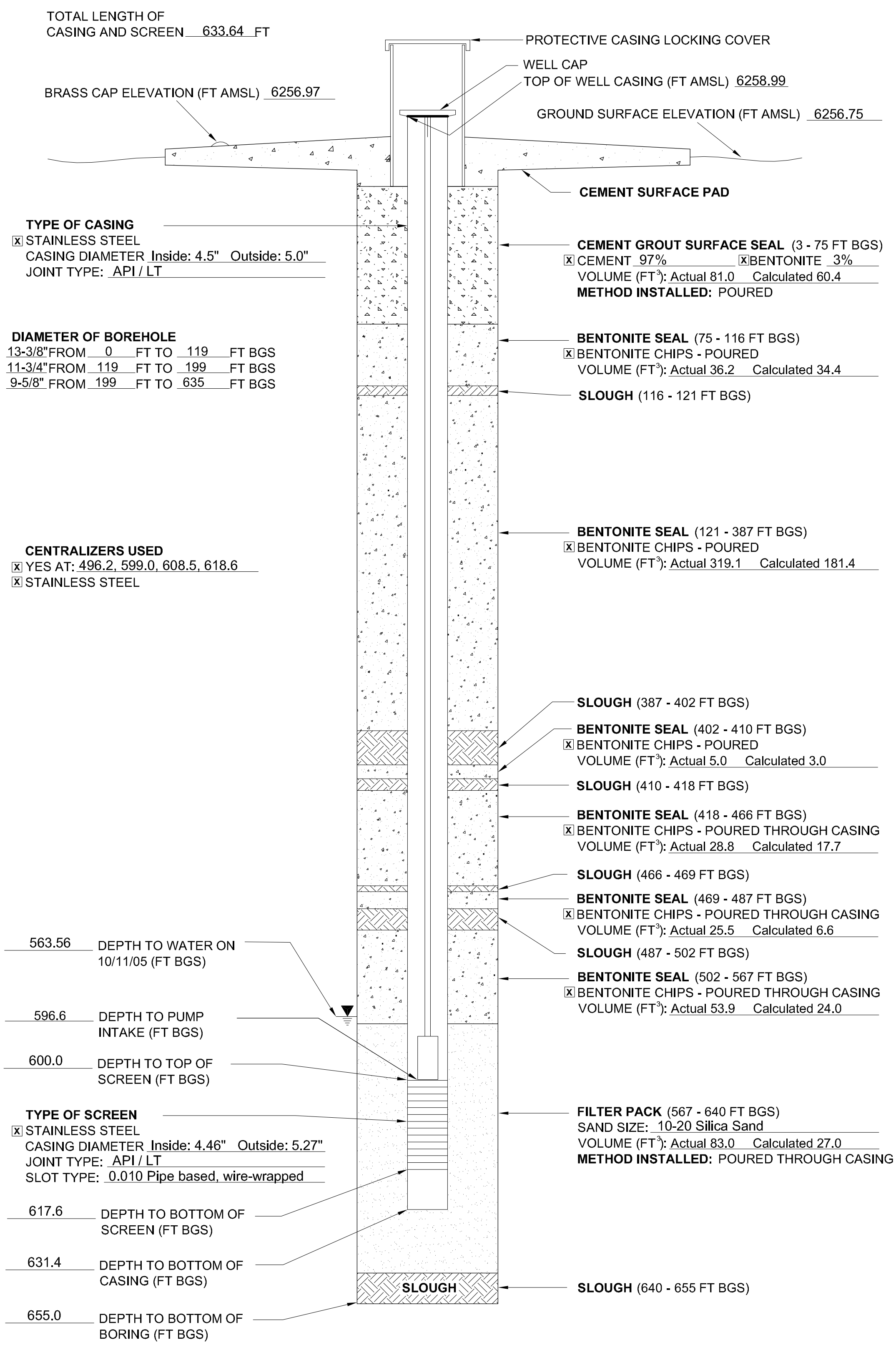
The well was designed in accordance with LANL Standard Operating Procedure for Well Construction, Revision 3 (LANL 2001); DOE and LANL provided an approved well design to Kleinfelder. The design called for a single screened interval from 600 to 623 ft bgs to monitor groundwater quality in the regional aquifer. The New Mexico Environment Department (NMED) reviewed the well design prior to well installation.

7.2 Well Construction

R-16r was constructed of 4.5-in. inner diameter (ID)/5.0-in. OD, type A304 stainless steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. Figure 7.2-1 is an as-built schematic showing construction details for R-16r. Two nominal 7.5-ft lengths of 4.5-in. ID, pipe-based, 0.010-in. wire-wrapped well screen were used. The casing and screen were factory-cleaned before shipment and delivery to the site and also steam cleaned onsite.

Because the two sections of pipe-based screen were only 7.5-ft long, the overall screened interval, including the coupler, was actually 17.6-ft long and extended from 600 to 617.6 ft bgs. A 14-ft-deep sump of stainless steel casing was placed below the well screen.

The borehole depth was tagged at 640 ft bgs prior to well installation. The well casing, screen and sump were then lowered into the borehole and the annular materials were added between the 9⅝-in. drill casing and the stainless steel well casing. Bentonite and sand were not placed at the bottom of the borehole due to the narrow annular space and the presence of centralizers. The primary filter pack of 10/20 silica sand was installed between 640 and 567 ft bgs; the installation crew had a difficulty in accurately tagging the top of the filter pack, resulting in a thicker primary filter pack than had been planned. After emplacement of the filter pack, the drillers used a swabbing tool to settle the filter pack along the screened interval. A transition filter pack of



WELL DEVELOPMENT INFORMATION

WELL COMPLETION BEGAN
DATE 10/04/05 TIME 12:20
WELL COMPLETION FINISHED
DATE 10/11/05 TIME 12:37

WELL DEVELOPMENT BEGAN
DATE 10/12/05 TIME 09:15
WELL DEVELOPMENT FINISHED
DATE 10/17/05 TIME 16:44

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING ☒ PUMPING
TOTAL PURGE VOLUME 20,711 GALLONS

PARAMETER MEASUREMENTS
pH 8.07
TEMPERATURE 20.6 °C
SPECIFIC CONDUCTANCE 176 µS/cm
TURBIDITY 4.28 NTUs

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Project No.: 49436	Filename: Figure 7.2–1.dwg
Scale: not–to–scale	Revision: –

WELL SCHEMATIC
Characterization Well R-16r
Cañada del Buey
Los Alamos, New Mexico

FIGURE
7.2-1

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20/40 silica sand was not placed above the primary filter pack because the primary filter pack extended 33 ft above the screened interval. Bentonite chips were added above the primary filter pack to a depth of 502 ft bgs.

As the annular materials were added, the 9⅝-in. drill casing was removed incrementally. Between 502 and 387 ft within the Totavi Lentil sediments, four intervals of sloughing ranging from 3 to 15 ft thick were noted as the casing was removed. Figure 7.2-1 shows the four zones of slough in that interval. Above 387 ft bgs, bentonite chips were added to 121 ft bgs with no sloughing. At that point, 5 ft of slough accumulated in the annulus. Bentonite chips were added from 116 to 75 ft bgs. The cement grout surface seal, consisting of 97% cement and 3% bentonite, was added to 3 ft bgs. From 640 to 121 ft bgs, the actual annular fill volumes were roughly twice the calculated volumes because washouts (e.g., oversized borehole) developed in sedimentary units encountered in that interval. Table 7.2-1 summarizes the volumes of annular fill materials used at R-16r.

Table 7.2-1
Annular Fill Materials

Material	Volume
Surface seal: cement grout slurry	81.0 ft^3
Bentonite seal: bentonite chips	468.5 ft^3
Primary Filter: 10/20 silica sand	83.0 ft^3
Potable Water	540 gallons

ft^3 = cubic ft

8.0 POST-INSTALLATION ACTIVITIES

Following well installation, R-16r was developed, the wellhead was installed and the wellhead components were surveyed. Site restoration activities will commence when NMED permission to discharge fluids has been received.

8.1 Well Development

R-16r was developed between October 10 and 17, 2005. The development crew initially bailed and swabbed the screened interval to help remove formation fines and filter pack sand from the well. Approximately 245 gallons (gal.) of water were removed during swabbing and bailing. A Grundfos submersible pump was used for the final stage of well development. The pump intake was set within the screened interval and 20,466 gal. of water were removed.

Turbidity, pH, temperature, specific conductance, and TOC were measured during development; these parameters were required to stabilize before terminating well development. The final turbidity reading was 4.28 and the TOC level was 0.99 ppm, below the target TOC concentration of 2.0 ppm. Table 8.1-1 shows the volume of water removed during well development and the resultant water quality parameters and TOC levels. Figure 8.1-1 shows the water quality parameters measured during the course of well development.

Table 8.1-1
Final Water Quality Parameters

Method	Water Removed (gal.)	pH	Temper-ature (°Celsius)	Specific Conductance (µS/cm)	Turbidity (NTUs)	Total Organic Carbon (ppm)
Bailing/Swabbing	245	7.99	20.2	2.35	Off scale	NM
Pumping	20,466	8.07	20.6	176	4.28	0.99
Aquifer testing	9,378.5	NM	NM	NM	NM	NM

µS/cm = microSiemens per centimeter
NM = not measured
NTUs = nephelometric turbidity units

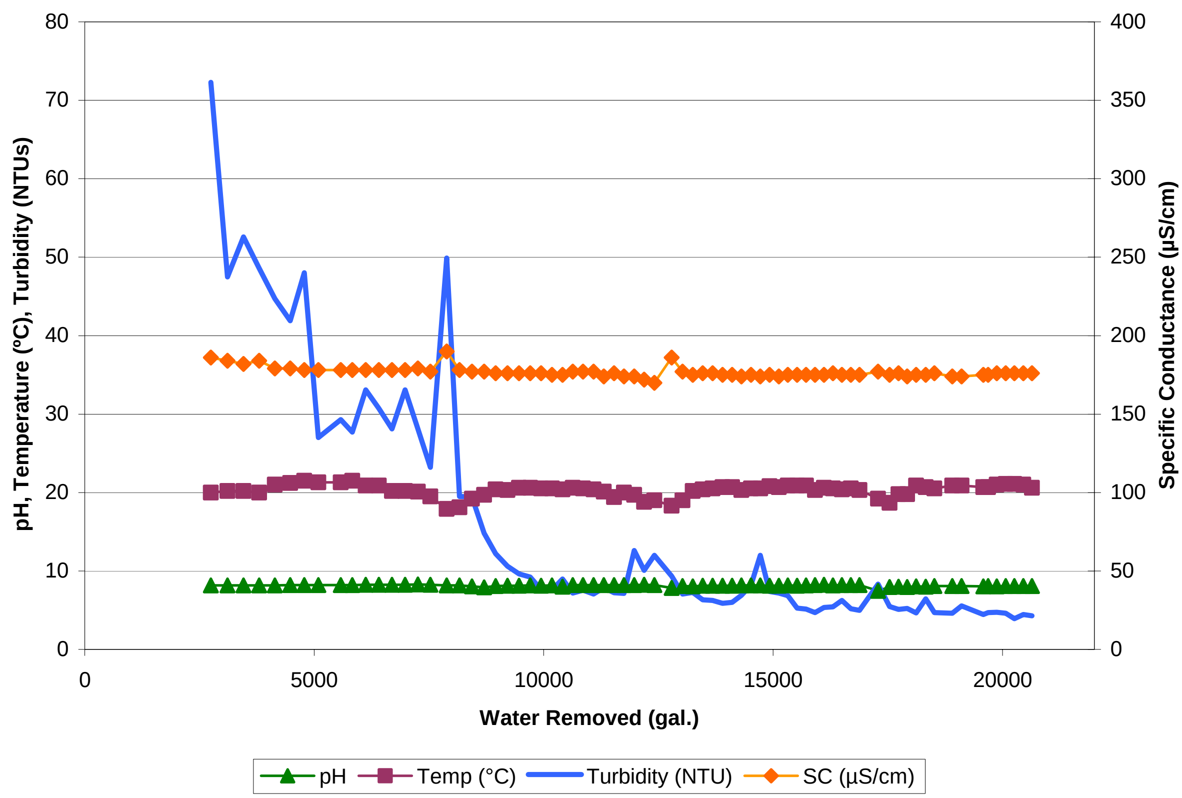

Figure 8.1-1. Water Quality Parameters During Development

8.2 Aquifer Testing

A 32.5-hr aquifer pumping test was conducted at R-16r on October 21 and 22, 2005. The complete report and associated figures are presented in Appendix D. The key results from the test are as follows:

- Test data were affected profoundly by air trapped or dissolved in the formation. During testing, the air was able to come out of solution and/or expand and contract in response to pumping and recovery. The air affected performance by clogging formation pores and entering the well and pump, resulting in very unusual data sets.

- In contrast to most of the regional wells on the Pajarito Plateau, which are nearly 100% barometrically efficient, R-16r appears to have a moderate barometric efficiency, although a precise measurement was not possible because of poor data quality obtained from the pump test. Based upon test results at R-10a/R-10, R-16r and R-16 screen 2, it appears that wells closer to the Rio Grande may have lower barometric efficiencies than those farther away.
- Storage effects were not completely eliminated by use of the inflatable packer in R-16r. The presence of air in the well caused a storage-like effect because of expansion and contraction of the air.
- The average hydraulic conductivity at R-16r near the top of the regional aquifer was 7.1 ft per day.
- There was no discernible response in R-16 screen 2 (863.4 to 870.9 ft bgs) from pumping at R-16r, which suggests the intervening sediments have a low vertical hydraulic conductivity – likely orders of magnitude less than the horizontal hydraulic conductivity.

8.3 Dedicated Sampling System Installation

A dedicated 3⅜-in. OD, 2-horsepower Grundfos submersible pump (Model 5S20-39DS) was installed at R-16r on December 13, 2005. The pump intake was set at 596.6 ft bgs. A ⅞-in. ID polyvinyl chloride transducer tube was installed to 595.3 ft bgs, with a slotted interval from 594.8 to 584.8 ft bgs.

8.4 Wellhead Completion

A reinforced 2,500 pounds per square in. concrete pad, 5 ft by 5 ft by 6 in. thick, was installed around the well casing to provide long-term structural integrity for the well and to prevent surface water from flowing down the outside of the casing. A brass survey pin was embedded in the northwest corner of the pad. A 10.75-in. diameter steel casing with a locking lid was installed to protect the well riser. The concrete pad was elevated slightly above the ground surface, with base-course gravel graded up around the edges.

8.5 Geodetic Survey

Table 8.5-1 presents the geodetic survey data for R-16r.

Table 8.5-1
Geodetic Data

Description	Northing	Easting	Elevation[a]
Brass cap in R-16r pad	1756730.68	1659289.39	6256.97
Top of stainless steel casing	1756728.91	1659290.46	6258.99
Ground surface beside pad	1756732.34	1659288.51	6256.75

[a] Measured in ft above mean sea level relative to the National Geodetic Vertical Datum of 1929.

8.6 Site Restoration

Fluids produced during drilling and development were containerized and sampled in accordance with the July 12, 2005 "Waste Characterization Strategy Form" prepared for the 2005 well drilling program at LANL (Appendix C in Kleinfelder 2005a). Fluid sample results will be compared to the State of New Mexico Water Quality Control Commission Regulation 3103 groundwater standards and applicable Resource Conservation and Recovery Act regulatory limits. Water generated during drilling, development and aquifer testing will be discharged in accordance with the "Workplan Notice of Intent Decision Tree," revised July 15, 2002, and in coordination with NMED. Site restoration will include removing the silt fencing and reseeding the site.

The groundwater samples required by NMED for waste characterization have been collected, but some of the analytical results have not been received. Once the data are received and permission to discharge has been obtained, a separate memorandum will be issued to document the analytical results and discharge approval.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Appendix E compares the actual drilling and well construction activities at R-16r with the planned activities described in the Drilling Work Plan. In general, drilling, sampling, and well construction were performed as specified in the Drilling Work Plan. The main deviations from planned activities were:

- Planned Borehole Depth – The Drilling Work Plan called for the borehole to be drilled to a target TD of approximately 700 ft bgs; it was drilled to 655 ft bgs.
- Cuttings Collection – The work plan called for bulk samples to be collected at 10-ft intervals to 450 ft bgs, and 5-ft intervals thereafter. Sieved samples were to be collected at 5-ft intervals below 450 ft bgs as well. LANL scientists decided that bulk and sieved samples could be collected at 5-ft intervals beginning at 550 ft bgs rather than 450 ft bgs, and that approach was followed.
- Well Screen and Sump – The well design called for an overall 23-ft screened interval with a 10-ft sump; however, the pipe-based screens were only 7.5-ft long, making the screened interval 17.6-ft long. A 14-ft sump was installed beneath the well screen.
- Bentonite and Sand Mix – Bentonite and sand were not added to the bottom of the borehole because of the narrow annular space and the presence of centralizers.
- Filter Pack – The well design called for the primary filter pack to extend 10 ft above the well screen; however, due to difficulties with accurate tagging of the filter pack, it was installed to 33 ft above the top of the well screen. Therefore, a transition filter pack was not installed above the primary filter pack.

10.0 ACKNOWLEDGEMENTS

EnviroWorks, Inc. prepared the drill site.

P. Longmire of LANL evaluated the hydrochemistry.

WDC drilled and installed the monitoring well.

11.0 REFERENCES

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Appendix A

Lithologic Log

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
Qal, Quaternary Alluvium	Unconsolidated sediments, clay (CH) with sand and gravel, light brown (5YR 6/4). +12F (i.e., plus No. 12 seize sieved sample fraction): clay-coated clasts of volcanic tuff, quartz and sanidine crystals, and dacite lithic fragments.	0-5	6256.9-6251.9
Qbo, Otowi Member of the Bandelier Tuff	Rhyolite tuff, light brownish (5YR 6/4), lithic-rich. +12F: 15%-25% pumice fragments; 1%-3% basalt fragments; 75%-85% dacitic fragments that are strongly oxidized. WR sample (i.e., unsieved cuttings sample) is clay-rich.	5-10	6251.9-6246.9
	Rhyolite tuff, medium light gray (N6), poorly welded to nonwelded, lithic-rich. +12F: 1%-3% pumice fragments; 2%-3% quartz and sanidine crystals; 90%-95% abundant dacitic and lesser basalt fragments that are strongly oxidized.	10-14	6246.9-6242.9
	Rhyolite tuff, yellowish-gray (5YR 6/1), poorly welded to nonwelded. +12F: 60%-70% vitric pumice fragments; 25%-30% dacitic and basalt fragments in equal proportions. +40F (i.e., plus No. 40 size sieved sample fraction): contains 50% pumice, 40% quartz and sanidine crystals, and 10% volcanic lithics.	14-15	6242.9-6241.9
	Rhyolite tuff, medium light gray (N6), poorly welded to nonwelded, lithic-rich. +12F: 15%-20% oxidized pumice fragments; 75%-85% abundant basalt and lesser dacite volcanic lithics.	15-20	6241.9-6236.9
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumiceous. +12F: 80%-90% glassy fibrous pumice lapilli (up to 1 cm), light limonite-staining; 2%-4% quartz and sanidine crystals; 5%-15% volcanic lithics (basalt and lesser dacite). +40F: contains 60%-70% quartz and sanidine crystals.	20-28.5	6236.9-6228.4
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded. +12F: 25%-30% white, unaltered, vitric pumice fragments (up to 1.5 cm); 20%-40% quartz and sanidine crystals; 20%-40% volcanic lithic fragments (dacite with lesser basalt).	28.5-43.5	6228.4-6213.4
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded. +12F: 20%-25% white vitric pumice fragments; 15%-20% quartz and sanidine crystals; 50%-60% volcanic lithic fragments (up to 0.7 cm) made up of dacite, basalt, rhyodacite, and latite.	43.5-48.2	6213.4-6208.7

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
Qbo, Otowi Member of the Bandelier Tuff	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice-rich. +12F: 70%-75% white vitric pumice fragments (up to 1.0 cm) that are partly limonite-stained; 5%-10% quartz and sanidine crystals; 10%-15% volcanic lithic fragments made up of pink and gray dacite with minor basalt.	48.2-63.2	6208.7-6193.7
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice and lithic-rich. +12F: 50% white vitric, fibrous pumice fragments (up to 0.6 cm); 5%-10% quartz and sanidine crystals; 35%-40% volcanic lithic fragments made up of intermediate to felsic lithologies. +40F: contains 97%-98% quartz and sanidine crystals.	63.2-68.2	6193.7-6188.7
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice-rich. +12F: 90%-95% white vitric, fibrous pumice fragments; 5%-10% quartz and sanidine crystals; 2%-3% volcanic lithic fragments made up of intermediate to felsic lithologies.	68.2-83	6188.7-6173.9
Basaltic sediments	Rhyolite tuff, grayish-orange pink (5YR) 7/2), poorly welded to nonwelded, pumice-rich. +12F: 95%-97% white vitric, fibrous and limonite-stained pumice fragments (up to 1.0 cm); <1% quartz and sanidine crystals; 2%-3% dacitic, lithic fragments. +40F: contains 75%-80% quartz and sanidine crystals.	83-88	6173.9-6168.9
	Basalt-rich sediments, gravel (GW) with sand, varicolored light tan (10 YR 6/2) to dark gray (N3), subangular to subrounded clasts (up to 0.5 cm). +12F: contains mixed volcanic lithologies including 30%-50% vesicular to massive basalt, 20%-30% dacite and silicified dacite, 5%-20% white to light tan clay nodules and fragments; and 1%-2% black vitrophyre. Basalt and dacite clasts have clay or iron-oxide/clay coatings. +40F: orange-colored limonite cementing clasts/chips; 40% clay particles/nodules. Note: top of this unit is estimated at 84 ft bgs; its base is estimated at 92 ft bgs.	88-92.2	6168.9-6164.7
Tpl, Puye lakebed sediments	Lakebed sediments, yellowish-gray (5Y 8/1), clay (CH) with broken gravel chips and subrounded pebble-size clasts. +12F: 10%-15% vesicular basalt chips and pebbles; 3%-5% dacite; 80%-85% whitish-tan chips of soft clay containing microscopic tubules that appear siliceous, locally limonite-stained; Mn-oxides common.	92.2-102.2	6164.7-6154.7

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Lakebed sediments, yellowish-gray (5Y 8/1) to medium-dark gray (N4), clayey gravel (GC), broken chips and subrounded pebble-size clasts (up to 1.0 cm). +12F: 7%-10% vesicular basalt clasts with strong clay and/or limonite coatings; 90%-93% whitish fragments of clay that are subrounded (milled), clays contain abundant silica tubules (diatomaceous clay); 1%-2% dacite chips.	102.2-107.2	6154.7-6149.7
	Lakebed sediments, yellowish-gray (5Y 8/1), clay (CH). WR: whole rock sample only collected. 100% clay of high plasticity.	107.2-127.2	6149.7-6129.7
	Lakebed sediments, very pale yellowish-orange (10YR 8/2), clay (CH) with gravel. WR: whole rock sample only collected. 10%-15% angular vesicular basalt fragments (up to 0.7 cm); 85%-95% clay of high plasticity.	127.2-142.2	6129.7-6114.7
	Transition Tpl/Tb interval, very pale orange (10YR 921), clay (CH) with gravel, broken chips (up to 0.5 cm) in clay matrix. +12F: 85%-90% vesicular, olivine-basalt chips; 10%-15% clay-cemented sandstone clasts; 1%-2% bright-orange, altered volcanic lithics (possible palagonite). Note: base of lakebed sediments is estimated at 147 ft bgs.	142.2-152.2	6114.7-6104.7
Tb4, Cerros del Rio basalt	Basalt with clay (CH), light gray (N6), sparsely porphyritic with aphanitic groundmass, massive to sparsely vesicular. +12F: chips finely ground and clay coated, textures obscured. Groundmass is unaltered or very weakly altered. Local clay nodules suggest amygdaloidal fillings.	152.2-162.2	6104.7-6094.7
	Basalt, medium gray (N5), porphyritic with aphanitic groundmass, sparsely vesicular. +12F: brownish-olivine phenocrysts (up to 1.0 mm) are oxidized, groundmass altered and bleached; 3%-5% clay nodules, partly limonite-stained and yellowish. WR sample moderately clay-rich.	162.2-172.2	6094.7-6084.7
	Basalt, light brownish-gray (5YR 6/1), porphyritic with aphanitic groundmass, sparsely vesicular. +12F: 85%-95% basalt chips that are partially altered, clay coatings obscure textures; 5%-15% whitish clay fragments and clay-cemented sandstone. WR sample clay-rich.	172.2-177.2	6084.7-6079.7
	Basalt, light brownish-gray (5YR 6/1), porphyritic with aphanitic groundmass, sparsely vesicular. +12F: olivine phenocrysts (up to 2 mm) are replaced by iddingsite, chips clay-coated obscuring textures, slight Fe-oxide/clay coating on some fractures. WR sample contains clay-binding chips.	177.2-187.2	6079.7-6069.7

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Basalt, medium-light gray (N5), slightly porphyritic with aphanitic groundmass, vesicular. +12F: olivine phenocrysts (1%-3% of volume, up to 3 mm) commonly rounded and wholly replaced by iddingsite; groundmass is bleached and partially altered; some vesicles contain yellowish clay.	187.2-197.2	6069.7-6059.7
	Basalt, medium-light gray (N5), slightly porphyritic with aphanitic groundmass, vesicular. +12F: pale green olivine phenocrysts (2%-3% of volume, up to 2 mm) are unaltered; groundmass partially altered, bleached, trace light tan clay fragments. Note: basal Tb4 contact estimated at 212 ft bgs.	197.2-212.2	6059.7-6044.7
Tpl Puye Formation, Lakebed sediments	Transitional Tb4/lakebed sediments, light gray (N7) to grayish orange (10YR 7/4), slightly porphyritic with aphanitic groundmass, vesicular. +12F: olivine phenocrysts (1%-2% of volume, up to 2 mm) mostly replaced by iddingsite; groundmass strongly altered, strongly bleached; yellowish clay chips, angular, hard, locally limonite-stained.	212.2-222	6044.7-6034.9
	Lakebed sediments, pale reddish-brown (10YR 5/4), basalt chips in clay matrix. +12F: 80%-85% angular altered basalt chips, mostly clay-coated; 10%-15% reddish-brown, fine-grained sandstone clasts; 2%-3% clay nodules locally containing sand grains. WR sample clay-rich. +40F: contains 40%-50% sandstone, 1% granitic grains. Note: Base of lakebed sediments is 227 ft bgs.	222-227	6034.9-6029.9
Ta Older Alluvium	Clastic sediments, gravel (GW) with sand and clay, pale reddish-brown (10R 5/4). +12F: 20%-25% angular basalt chips, clay-coated; 60%-70% clay-cemented, fine-grained sandstone fragments (up to 0.5 cm) composed of quartz, granite, and volcanic grains; 5 – 10% angular granitic clasts. WR sample clay-rich.	227-232	6029.9-6024.9
	Clastic sediments, gravel (GW) with sand and clay, light brown (5YR 6/4). +12F: 15%-30% angular basalt chips, clay-coated; 20%-25% clay-cemented, fine-grained sandstone and clay; 50%-60% subrounded quartz, microcline, and granitic clasts (up to 0.5 cm).	232-242	6024.9-6014.9
	Clastic sediments, clayey gravel (GC) with sand, light brown (5YR 6/4). +12F: 15%-20% basalt and other volcanic lithics; 25%-30% whitish claystone and clay-cemented sandstone; 40%-50% broken to subrounded quartz, microcline, and granitic clasts (up to 0.5 cm). WR sample clay-rich.	242-252	6014.9-6004.9

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Clastic sediments, gravel (GW) with clay, light brown (5YR 6/4). +12F: 5%-7% angular basalt chips; 15%-20% quartzo-feldspathic sandstone fragments; 70%-75% coarse sand granules composed of quartz, microcline, chert, Precambrian granite, and quartzite. WR sample clay-rich.	252-262	6004.9-5994.9
	Clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 6/2), subangular to subrounded pebbles (up to 0.7 cm). +12F: 60%-70% clasts of various granitic rocks, 5%-10% quartzo-feldspathic sandstone fragments; 5%-10% quartzite; 5%-10% white clay nodules; rare basalt fragments. Clasts commonly clay-coated.	262-272	5994.9-5984.9
	Clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 6/2). +12F: 50%-80% clasts made up of quartz, pink microcline, metamorphic and granitic rocks, and quartzite; 20%-50% fine-grained sandstone; 1%-2% basalt.	272-287	5984.9-5969.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 50%-80% subangular to subrounded clasts (up to 0.7 cm) made up of pink microcline, quartz, and metamorphic and granitic rocks; 20%-50% micaceous sandstone and siltstone; 1%-2% basalt.	287-302	5969.9-5954.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 60%-70% clay-cemented tuffaceous sandstone and siltstone; 30%-40% coarse sand and granules (up to 0.5 cm) made up of pink microcline, quartz, and metamorphic and granitic rocks, minor basalt, and dacite; clasts commonly clay-coated.	302-312	5954.9-5944.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 90%-95% clay-cemented, quartz-bearing tuffaceous sandstone and siltstone; 5%-10% granitic and minor volcanic fragments.	312-317	5944.9-5939.9
	Clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 6/2). +12F: 10%-30% clay-cemented, quartz-feldspar-mica-volcanic sandstone; 70%-80% subangular to subrounded clasts (up to 0.5 cm) made up of pink microcline, quartz, and granitic rocks; 3%-5% dacitic volcanic clasts.	317-322	5939.9-5934.9

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 30%-50% fine-grained, quartz-volcanic sandstone and siltstone; 50%-60% subangular to subrounded clasts (up to 0.5 cm) made up of clay-coated pink microcline, quartz, and granitic rocks; 2%-3% light gray dacitic volcanic clasts. WR sample clay-rich.	322-332	5934.9-5924.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2), coarse sand to granules (up to 0.5 cm), subrounded to angular. +12F: 40%-50% indurated fragments of quartz-volcanic and hornblende-volcanic sandstone; 50%-60% subrounded clasts made up of pink microcline, white feldspar, quartz, and granitic rocks; 3%-5% light gray dacitic volcanic clasts. WR sample clay-rich. Note: Base of Older Alluvium is 342 ft bgs.	332-342	5924.9-5914.9
Tb4 Cerros del Rio basalt	Basalt/clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1). +12F: 40%-60% angular chips of olivine-basalt; 30%-40% fine-grained, quartz-feldspar sandstone fragments; 10%-30% subrounded clasts made up of pink and white feldspar, quartz, and granitic rocks. WR sample clay-rich. Top of Cerros del Rio basalt is 342 ft bgs.	342-352	5914.9-5904.9
	Basalt/clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1). +12F: 70%-80% angular chips of olivine-basalt, commonly clay-coated; 30%-40% subrounded coarse sand and granules (up to 0.9 cm) composed of quartz, feldspar, and granitic and metamorphic rocks; 10%-15% fragments of fine-grained sandstone and siltstone. WR sample clay-rich.	352-367	5904.9-5889.9
	Basalt/clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1). +12F: 50%-60% angular/broken chips of olivine-basalt, commonly clay-coated; 40%-50% subrounded/broken clasts composed of quartz, feldspar, and granitic lithics; 10%-15% fragments of fine-grained sandstone and siltstone. WR sample clay-rich. Note: Base of Cerros del Rio basalt is 377 ft bgs.	367-377	5889.9-5879.9
Tpt Totavi Lentil	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1). +12F: 35%-45% angular/broken chips of clay-coated basalt, minor rounded hornblende dacite; 10%-20% light tan fragments of fine-grained, quartzo-feldspathic sandstone/siltstone; 50%-60% subrounded -broken clasts (up to 0.5 cm) pink and white feldspar, quartz, quartzite, and granitic lithics. WR sample clay-rich.	377-392	5879.9-5864.9

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1). +12F: 30%-40% angular/broken chips of basalt and subrounded hornblende-bearing dacite; 10%-20% light tan fragments of sandstone and siltstone; 50%-60% subrounded/broken clasts (up to 0.4 cm) pink and white feldspar, quartz, quartzite, and granitic lithics. WR sample clay-rich.	392-407	5864.9-5849.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1). +12F: 35%-45% angular/broken chips of basalt and subrounded hornblende-bearing dacite; 10%-15% light tan fragments of sandstone and siltstone; 50%-60% subrounded/broken clasts (up to 0.5 cm) pink microcline, plagioclase, quartz, quartzite, and meta-granitic lithics.	407-422	5849.9-5834.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), medium to coarse sand with pebbles (up to 0.5 cm) +12F: 30%-40% angular/broken chips basalt and subangular/subrounded clasts dacite; 10%-15% fragments of fine-grained sandstone; 50%-60% subrounded/broken clasts pink and white feldspar, quartz, quartzite, and granitic lithics. WR sample clay-rich.	422-432	5834.9-5824.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), broken to rounded clasts, pebbles (up to 0.5 cm). +12F: 50%-60% volcanic lithics (dacite, basalt, and possible pumice); 30%-40% clasts pink microcline, quartz, and quartzite of Precambrian sources; 5%-10% siltstone fragments. WR sample clay-rich.	432-442	5824.9-5814.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), broken to rounded clasts, pebbles (up to 0.5 cm). +12F: 25%-35% mixed clay-coated dacite and basalt chips; 10%-15% whitish clay fragments; 60%-70% subrounded/broken clasts of pink microcline, quartz, granite, and quartzite of Precambrian sources. WR sample clay-rich.	442-457	5814.9-5799.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), medium to coarse sand with pebbles (up to 0.5 cm). +12F: 35%-45% clay-coated dacite and minor basalt chips; 15%-20% fine-grained sandstone and clay fragments; 40%-60% subrounded/broken clasts of pink microcline, quartz, granite, and quartzite of Precambrian sources. WR sample clay-rich.	457-472	5799.9-5784.9

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), medium to coarse sand with pebbles (up to 0.5 cm). +12F: 25%-35% clay-coated dacite and minor basalt chips; 10%-15% fine-grained sandstone and claystone fragments; 50%-60% subrounded/broken clasts of pink microcline, quartz, chert, granite, and quartzite. WR sample clay-rich.	472-482	5784.9-5774.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), broken and subrounded clasts (up to 1.0 cm). +12F: 10%-20% rounded dacite and minor basalt chips; 15%-20% fine-grained quartzo-feldspathic sandstone fragments; 65%-75% subrounded to rounded clasts of quartzite, pink microcline, and granitic lithics. WR sample clay-rich.	482-492	5774.9-8764.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), broken and subrounded clasts (up to 1.0 cm). +12F: 10%-20% dacite clasts and minor basalt chips; 15%-25% fine-grained quartzo-feldspathic sandstone fragments; 60%-70% subrounded to rounded clasts (up to 1.0 cm) of quartzite, pink microcline, chert, granite, and meta-granite lithics. WR sample clay-rich.	492-507	5764.9-5749.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), subrounded and broken clasts. +12F: 15%-25% volcanic lithic clasts, mostly dacite with minor basalt chips; 5%-7% indurated siltstone fragments; 70%-80% subangular to subrounded clasts (up to 1.5 cm) of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	507-522	5749.9-5734.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), subrounded and broken clasts. +12F: 15%-25% volcanic lithic clasts, mostly dacite with minor basalt chips; 3%-5% indurated fine-grained sandstone; 75%-80% subangular to subrounded clasts (up to 0.7 cm) of quartzite, pink microcline, chert, granite, and metamorphic lithics.	522-537	5734.9-5719.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), subrounded and broken clasts. +12F: 15%-25% rounded to broken dacite clasts; 3%-5% indurated fine-grained quartzo-feldspathic sandstone; 70%-80% subrounded and broken clasts (up to 0.7 cm) of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	537-547	5719.9-5709.9

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), subrounded and broken clasts. +12F: 15%-25% dacite clasts; 10%-20% indurated fine-grained quartzo-feldspathic sandstone; 60%-70% clasts of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	547-562	5709.9-5694.9
	Clastic sediments, gravel (GW) with sand, grayish-orange pink (5YR 7/2). +12F: 15%-20% dacite clasts; 5%-10% indurated fine-grained sandstone; 60%-70% clasts of quartzite, quartz, pink microcline, granite, and metamorphic lithics.	562-577	5694.9-5679.9
	Clastic sediments, clayey sand (SC), grayish-orange pink (5YR 7/2). +12F: 15%-25% dacite clasts; 85%-90% clasts of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	577-602	5679.9-5654.9
	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: clay-rich matrix binding chips and obscuring composition. +40F: 10%-20% dacite clasts; 80%-90% grains of quartzite, quartz, pink microcline, granite, and metamorphic lithics in clayey matrix. WR sample contains 40-50% clay.	602-612	5654.9-5644.9
	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: 60%-70% volcanic clasts with clay-rich matrix. +40F: 35%-45% grains of dacite lithics; 45%-55% grains of quartzite, quartz, pink microcline, granite, and metamorphic lithics in clayey matrix; 5%-10% fragments of white clay. WR sample contains more than 50% clay.	612-617	5644.9-5639.9
	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: unidentified volcanic clasts in clay-rich matrix. +40F: 30%-35% grains of dacite lithics; 60%-70% grains of quartzite, quartz, pink microcline, and granite lithics. WR sample contains 30-50% clay matrix. Note: Tpt extends from 377 to 627 ft bgs.	617-627	5639.9-5629.9
Tpf, Puye Formation	Clastic sediments, clayey sand (SC), yellowish-gray (5Y 8/1). +12F: 80%-95% subrounded to rounded granules/pebbles (4-7 mm) of pink and gray dacite lithics; 5%-7% clasts of quartzite and rare granitic and metamorphic lithics, 5%-15% sandstone clasts. WR sample contains 30-50% clay matrix binding fine to very fine coarse sand. Top of Tpf is 627 ft bgs.	627-642	5629.9-5614.9

Geologic Unit	Lithologic Description NOTE: This log is from the R-16 Well Completion Report (LANL 2003) and covers the interval from 0 to 655 ft bgs.	Sample Interval (ft bgs)	Elevation Range (ft amsl)
	Clastic sediments, clayey sand (SC), yellowish-gray (5Y 8/1), fine to very coarse sand, 30%-35% clay/silt. +12F: 97%-98% subrounded to rounded granules/pebbles (up to 0.5 mm) of pink and gray dacite lithics; 2%-3% clasts of quartzite and rare granitic lithics.	642-647	5614.9-5609.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), fine to very coarse sand/granules, 20%-25% clay matrix. +12F: 60%-70% broken and subrounded to rounded clasts (up to 1.0 cm) of pink and gray dacite lithics; 15%-20% clasts of quartzite, granite, and chert lithics, 10%-15% fine-grained sandstone and siltstone fragments.	647-655	5609.9-5601.9

R-16r Borehole Total Depth = 655 ft bgs

Notes: This log was obtained from the R-16 Well Completion Report (LANL 2003) with a total depth of 1,287 ft bgs. Only the portion to 655 ft bgs, the total depth of R-16r, is shown here.

1. American Society for Testing Materials (ASTM) standards (D 2488-90: Standard Practice and Identification of Soils [Visual-Manual Procedure]) were used to describe the texture of drill chip samples for sedimentary rocks such as alluvium and the Puye Formation. ASTM method D 2488-90 incorporates the Unified Soil Classification System (USCS) as a standard for field examination and description of soils. The following standard USCS symbols were used in the R-16 lithologic log:

   SC = clayey sand, GC = clayey gravel, CH = clay, high plasticity, GP = poorly graded gravel

2. Cuttings at R-16 were collected at nominal 5-ft intervals and divided into three sample splits: (1) unsieved, or whole rock (WR) sample; (2) +12F sieved fraction (No. 12 sieve equivalent to 1.75 mm); and (3) +40F sieved fraction (No. 40 sieve equivalent to 0.425 mm).
3. The term *percent*, as used in the above descriptions, refers to percent by volume for a given sample component.
4. Color designations such as hue, value, and chroma (e.g., 5YR 5/2) are from the Geological Society of America's Rock Color Chart.

Source of this lithologic log: LANL 2003, Characterization Well R-16 Completion Report, LA-UR-03-1841, ER2003-0198, Los Alamos National Laboratory, Los Alamos, New Mexico, June 2003.

Appendix B

Groundwater Analytical Results

1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-16R

Shallow and perched intermediate zone groundwater were not encountered at R-16r. The regional aquifer was encountered at approximately 564 to 565 feet (ft) below ground surface (bgs). One screening groundwater sample was collected from the open borehole at approximately 580 ft bgs during drilling. A final groundwater sample was collected from approximately 611 ft bgs after well development was complete. Both samples were analyzed for anions, including perchlorate, and metals. During development, water samples were also submitted for total organic carbon (TOC) analysis.

1.1 Analytical Techniques

Groundwater samples were filtered prior to analysis for metals, trace elements, and major cations and anions. Aliquots of the samples were filtered through a 0.45-micrometer Gelman filter. Samples were acidified with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses. Alkalinity was measured at Los Alamos National Laboratory's Earth and Environmental Sciences (EES) Group 6 using standard titration techniques. Samples collected for TOC analyses were not filtered.

Groundwater samples were analyzed by EES-6 using techniques specified in the US Environmental Protection Agency SW-846 manual. Ion chromatography was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limits for perchlorate analyses were 0.001 and 0.0005 parts per million (ppm).

Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was used for calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, 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% using ICPOES and ICPMS.

1.2 Analytical Results

Analytical results for groundwater samples collected at R-16r are provided in Table 1.2-1. Perchlorate was detected at 0.0021 ppm in the screening sample, but was not detected in the post-development sample. Nitrate (as nitrogen) was detected in both samples at concentrations of 0.44 and 0.45 ppm, respectively. TOC was measured at 0.99 milligrams of carbon per liter near the end of well development on October 17, 2005.

Table 1.2-1. Hydrochemistry of Groundwater Samples Collected from the Regional Aquifer at R-16r (filtered samples)

SAMPLE ID	**EU0507 GR16A01**	**EU0507 GR16A02**
SAMPLE TYPE	During drilling	After development
DEPTH (ft bgs)	580	611
GEOLOGIC UNIT	Totavi Lentil	Totavi Lentil
DATE	09/26/05	10/17/05
Charge Balance (%)	+6.08	-1.10
pH (Lab)	7.37	7.99
Ag (ppm)	U [0.001]	U [0.001]
Al (ppm)	0.009	0.012
Alkalinity (ppm $CaCO_3$/L)	67.9	82.0
As (ppm)	0.0005	0.0029
B (ppm)	0.083	0.083
Ba (ppm)	0.24	0.34
Be (ppm)	U [0.001]	U [0.001]
Br (ppm)	0.07	0.03
Ca (ppm)	15.0	19.4
Cd (ppm)	U [0.001]	U [0.001]
Cl (ppm)	2.36	2.39
ClO_4 (ppm)	0.0021	U [0.0005]
Co (ppm)	U [0.001]	U [0.001]
CO_3 (ppm)	0	0
Cr (ppm)	0.0012	0.0038
Cs (ppm)	U [0.001]	U [0.001]
Cu (ppm)	0.0012	0.0027
F (ppm)	0.44	0.43
Fe (ppm)	U [0.01]	U [0.01]
HCO_3 (ppm)	82.8	100.0
Hg (ppm)	U [0.00005]	0.00012
K (ppm)	2.06	1.69
Li (ppm)	0.032	0.029
Mg (ppm)	0.68	0.94
Mn (ppm)	0.055	0.017
Mo (ppm)	0.051	0.0025
Na (ppm)	20.9	16.4
Ni (ppm)	0.0019	U [0.01]
NO_2(as N) (ppm)	U [0.002]	U [0.002]
NO_3(as N) (ppm)	0.44	0.45
C_2O_4 (ppm)(oxalate)	U [0.01]	U [0.01]
Pb (ppm)	U [0.0002]	U [0.0002]
PO_4 (ppm)	U [0.01]	U [0.01]
Rb (ppm)	0.0015	0.0015
Sb (ppm)	U [0.001]	U [0.001]
Se (ppm)	U [0.001]	U [0.001]
SiO_2 (ppm)	12.5	20.5
SO_4 (ppm)	4.49	4.57
Sn (ppm)	U [0.001]	U [0.001]
Sr (ppm)	0.15	0.17
Th (ppm)	U [0.001]	U [0.001]
Ti (ppm)	0.001	U [0.001]
Tl (ppm)	U [0.001]	U [0.001]
U (ppm)	0.0006	0.0012
V (ppm)	0.002	0.011
Zn (ppm)	0.018	0.057
TDS (calculated)	158.3	192.6

Note: U = Undetected at the detection limit shown in brackets. Bicarbonate concentrations (HCO_3) were calculated from measured alkalinity.

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[CC1]Please do not delete the word “determined” in any of the reports for LANL. It has been used for a long time w/o any problems. I am curious as to why this was not shown as a tracked change. Pls show ALL of your changes in track changes mode.

Appendix C

Geophysical Logging Files

Geophysical logging spreadsheets and charts are located on the final report CD.

Appendix D

Aquifer Test Report

TABLE OF CONENTS

R-16r PUMPING TEST ANALYSIS

INTRODUCTION

This section describes the analysis of constant-rate test pumping conducted in late October 2005 on R-16r located in White Rock. The primary objective of the analysis was to determine the hydraulic properties of the screened sediments, as well as the hydraulic interconnection between R-16r and R-16, an adjacent multi-screened well. Consistent with the protocol used in most of the R-well pumping tests, the R-16r testing incorporated an inflatable packer above the pump to try to eliminate the effects of casing storage on the measured data.

R-16r is completed with a 17.6-ft (ft) long screen within the Totavi Lentil sediments, set between 600 and 617.6 ft below land surface. R-16r was drilled as a replacement for R-16 screen 1 (upper screen), which was left isolated behind stuck drill casing during the well construction of R-16.

At the time of testing, the static water level in R-16r was 563.25 ft below land surface. The water levels in adjacent R-16 screens 2, 3 and 4 were approximately 615 ft, 700 ft, and 711 ft below land surface, respectively. Thus, there is a strong downward gradient at the site, with the R-16r water level roughly 52 ft higher than that in R-16 screen 2. The steep downward gradient between R-16r and R-16 screen 2 implies a very low vertical hydraulic conductivity of the intervening sediments. Similar conditions were observed during the testing of R-10 and R-10a in Sandia Canyon. Testing at that location showed the vertical hydraulic conductivity of the regional aquifer to be a minimum of two and a half to three orders of magnitude less than the horizontal conductivity. It was surmised that similar conditions existed at the R-16r location.

Testing

Because of difficulty with air entrainment in the aquifer and groundwater (described below), testing occurred in two phases. In the first phase, testing consisted of brief trial pumping on October 19, followed by a 32.5-hour constant-rate pumping test that was begun on October 21. Two trial tests were conducted. Trial 1 was conducted at a discharge rate of 3.6 gallons per minute (gpm) for 60 minutes from 11:00 A.M. until 12:00 P.M. and was followed by 210 minutes of recovery until 3:30 P.M. Trial 2 was conducted at 3.6 gpm for 150 minutes from 3:30 P.M. until 6:00 P.M. Following shutdown, recovery was monitored for nearly 38 hours until 7:50 A.M. on October 21. The extended recovery period was expected to provide background water level data as well.

Constant-rate pumping test 1 was started at 7:50 A.M. on October 21 at a discharge rate of 3.6 gpm. Pumping continued for 32.5 hours until 4:20 A.M. on October 22. At that time, the discharge rate began dropping significantly because of air entrainment and the pump was shut down. Recovery measurements were recorded for about 38 hours until 6:24 A.M. on October 24.

Following the premature termination of the first test, a second phase of testing was performed. A larger pump was installed so that the aquifer could be stressed more heavily, in hopes of inducing an observable water level change in adjacent well R-16. Testing consisted of brief trial testing (trial 3), followed by a 198-minute constant-rate pumping test (test 2), on October 24.

Trial 3 consisted of pumping at 9.1 gpm for 9 minutes from 1:40 P.M. to 1:49 P.M. to fill the drop pipe. Following pump shutoff, recovery was recorded for 91 minutes until 3:20 P.M.

During trial 3, the packer was left deflated so that casing storage water above the packer would be available to help fill the drop pipe.

The second constant-rate pumping test was conducted at 7.7 gpm for 198 minutes from 3:20 P.M.until 6:38 P.M. The test was terminated at that time because of unacceptable discharge rate fluctuations caused by air entrainment. Following premature termination of pumping, recovery data were recorded for 866 minutes until 9:04 A.M. on October 25.

In addition to monitoring water levels in R-16r, water level data were collected from existing well R-16 so that a determination could be made of whether pumping R-16r affect water levels in R-16. The existing transducers in R-16 screens 2, 3, and 4 were set to record data at one-minute intervals throughout the R-16r testing program.

Air Entrainment

The sudden discharge rate fluctuations that occurred during testing, as well as other data anomalies presented below, were attributed to substantial trapped air in the formation. It was likely that compressed air entered the formation during drilling and remained there, with perhaps a portion of it dissolving into the groundwater. Once pumping began, air could come out of solution, or trapped gas-phase air could expand, in response to the pressure reduction caused by pumping. Accumulation of air volume in the formation pores and entry of air into the well and pump caused flow rate fluctuations and well efficiency and drawdown changes during the tests.

Indeed, when the pump was removed from the well, as each joint of drop pipe was disconnected, air bubbles were observed rising to the top of the freshly exposed section of drop pipe and escaping to the atmosphere. This was similar to observations made during the testing of R-34 a year earlier, where trapped and/or dissolved air in the formation resulted in unusual hydraulic response. As discussed below, this phenomenon had a significant effect on well and pump operation.

BACKGROUND DATA

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

Background water level fluctuations have several causes, among them barometric pressure changes, operation of other wells in the aquifer, earth tides, and long-term trends related to weather patterns. The background data hydrographs from the R-16r tests were compared to barometric pressure data from the area to determine if a correlation existed.

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

Subsequent pumping tests, including those at R-16r, have utilized *non-vented* transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an *increase* in barometric pressure of 1 unit causes a *decrease* in recorded down-hole pressure of 0.9 units, because the water level is forced downward 0.9 units by the barometric pressure change. However, using a non-vented transducer, the total measured pressure *increases* by 0.1 units (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 Los Alamos National Laboratory Technical Area (TA)-54 tower site from Environmental Division-Meteorology and Air Quality (ENV-MAQ). The TA-54 measurement location is at an elevation of 6,548 ft above mean sea level (amsl), whereas the wellhead elevation is 6,257 ft amsl. The static water level in R-16r was about 563 ft below land surface, making the water table elevation approximately 5,694 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-16r.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R16r}-E_{TA54}}{T_{TA54}}+\frac{E_{WT}-E_{R16r}}{T_{WELL}}\right)\right] \qquad (1)$$

where,

P_{WT} = barometric pressure at the water table inside R-16r
P_{TA54} = barometric pressure measured at TA-54
g = acceleration of gravity, in m/sec^2 (9.80665 m/sec^2)
R = gas constant, in J/Kg/degree Kelvin (287.04 J/Kg/degree Kelvin)
E_{R16r} = land surface elevation at R-16r, in ft (6257 ft)
E_{TA54} = elevation of barometric pressure measuring point at TA-54, in ft (6548 ft)
E_{WT} = elevation of the water level in R-16r, in ft (approximately 5694 ft)
T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 46.7 degrees Fahrenheit, or 281.3 degrees Kelvin)
T_{WELL} = air temperature inside R-16r, in degrees Kelvin (assigned a value of 65 degrees Fahrenheit, or 291.5degrees Kelvin)

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. Similar calculations were made for data collected from R-16.

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

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 often offer the best opportunity to obtain hydraulic conductivity information, because conductivity would equal the earliest-time transmissivity divided by the well screen length.

Unfortunately, in 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).

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

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

In some instances, it may be possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval prior to conducting the test. Therefore, this option has been implemented for the R-well testing program, including the R-16r pumping tests. Using the packer was not totally successful in eliminating casing storage effects in the R-16r pumping test. The presence of trapped air in the formation and filter pack caused a storage-like effect because of expansion and contraction of the air during pumping and recovery.

TIME-DRAWDOWN METHODS

Time-drawdown data can be analyzed using a variety of methods. Among them is the Cooper-Jacob method (1946), a simplification of the Theis equation (1935) that is mathematically equivalent to the Theis equation for pumped well data. The Cooper-Jacob equation describes drawdown around a pumping well as follows:

$$s = \frac{264Q}{T} \log \frac{0.3Tt}{r^2 S} \qquad (3)$$

where,

s = drawdown, in ft
Q = discharge rate, in gpm
T = transmissivity, in gallons per day per foot (gpd/ft)
t = pumping time, in days
r = distance from center of pumpage, in ft
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:

(4)

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

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:

(5)

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

where,

T = transmissivity, in gpd/ft
Q = discharge rate, in gpm
Δs = change in head over one log cycle of the graph, in ft

RECOVERY METHODS

Recovery data were analyzed using the Theis Recovery Method. This is a semi-log analysis method similar to the Cooper-Jacob procedure.

In this method, residual drawdown is plotted on a semi-log 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:

(6)

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

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

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. The permeable interval penetrated by R-16r was considered to be fully penetrating and, thus, this approach was used.

To apply this procedure, a storage coefficient value must be assigned. Storage coefficient values for confined conditions, as observed in R-16r, can be expected to range from about 10^{-5} to 10^{-3} (Driscoll, 1986). Typically, a value of 5×10^{-4} 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.

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

R-16R DATA ANALYSIS

This section presents the data obtained from the R-16r pump testing and the results of the analytical interpretations. Analyses were applied to recovery data following trial 1, pumping and recovery data from trial 2 and trial 3, the test 1 constant-rate pumping and recovery data, and the subsequent test 2 pumping recovery data. There also is a discussion of the background data recorded before and after the constant-rate pumping tests.

Background Data

Water level data were plotted along with barometric pressure data for R-16r. Figure 1 shows the apparent water level hydrograph for R-16r and the barometric pressure data recorded before, during and after the constant-rate pumping tests.

As is evident on the graph, the recorded water level data were extremely unusual, with nearly instantaneous “jumps” in level of about half an inch to an inch in magnitude occurring at regular intervals. It was assumed that this resulted from equipment malfunction, with the transducer mechanism perhaps “sticking” and then moving suddenly in increments and overshooting the ambient pressure. The data were sent to In-Situ, Inc., the transducer manufacturer, for examination. In-Situ, Inc. concluded that the measured data were accurate and that the equipment had not malfunctioned. There was no apparent explanation for the unusual data output. Even when considering the presence and accumulation of air in the well and formation, it is difficult to envision a physical scenario that could produce the reported pressure response.

The data, such as they are, suggested moderate to low, rather than high, barometric efficiency. For example, the data segment crossing the noon gridline for October 23 showed an initial flat slope, followed by a steep portion and then a flat portion. The steep portion coincided with an abrupt drop in barometric pressure. In a 100% barometrically efficient well, the total aquifer pressure would remain unchanged during barometric pressure changes. The apparent response suggested a more moderate barometric efficiency, such as observed previously in R-10 and R-10a in Sandia Canyon, where roughly 30 to 40% barometric efficiencies were computed.

The data from R-16 screen 2 also were compared to barometric pressure data. Figure 2 shows the comparative plot for October 19 to 25. The similarity of the curves suggested a low to moderate barometric efficiency. Because of the scatter in the hydrograph data, a rolling average was calculated to smooth the curve and make comparison easier.

Figure 3 shows a comparison of the rolling average apparent hydrograph for R-16 screen 2 and the barometric pressure data. Two adjustments were incorporated on the graph. First, the barometric pressure curve was adjusted by plotting barometric pressure change multiplied by a constant factor (100% minus the barometric efficiency) that allowed the trace to match the shape of the hydrograph. Second, a linear trend was removed from the hydrograph data. By adjusting the water level trend for a linear decline of 0.01 ft per day and by adjusting the barometric pressure curve for an assumed barometric efficiency in R-16 screen 2 of 30%, the resulting curves matched fairly well.

The match on Figure 3 showed very good correlation, with one exception. The hydrograph showed a cyclic decline and recovery, independent of the barometric pressure curve, with a period of one day, lasting from October 20 to 23. Each day, toward late evening, the water level began dropping, continued to decline until the following morning (with a decline of just a few hundredths of a ft), and then rebounded. Coincidentally, the Los Alamos County water supply wells are generally pumped during the night, so it is possible that the observed cyclic response was related to ongoing production well operation.

The modified hydrograph on Figure 3 was examined for possible effects of pumping R-16r. The square wave shown at the bottom of the graph shows the times when R-16r was pumped – both the trial tests and constant-rate tests. Inspection of the graph shows no consistent separation of the adjusted hydrograph and barometric pressure curves at times of pumping, as would occur if operation of R-16r had affected water levels in R-16 screen 2. It was concluded that pumping R-16r did not have a discernable effect on water levels in R-16 screen 2.

Similar analyses for R-16 screens 3 and 4 were not necessary, because the effect in the deeper screens would be expected to be even less than that in screen 2.

The lack of observable response in R-16 screen 2 to pumping R-16r was similar to what was observed in R-10 and R-10a in Sandia Canyon. At that location, modeling of the pumping test data suggested a lower-bound vertical anisotropy of two and a half to three orders of magnitude. It is probable that similar anisotropy applies to the intervening sediments between R-16r and R-16 screen 2.

Phase 1 Trial Testing

Following pump installation, the well was pumped briefly (trial testing) to evaluate capacity, fill the drop pipe in preparation for the long-term test, and generate some useful data. Trial pumping was begun at 11:00 A.M. on October 19. Trial 1 lasted 60 minutes until 12:00 P.M., followed by 210 minutes of recovery until 3:30 P.M.. The pumping rate during trial 1 was 3.6 gpm.

Trial 2 began at 3:30 P.M. and continued 150 minutes until 6:00 P.M., after which recovery was monitored for nearly 38 hours until the start of the constant-rate test. The discharge rate during trial 2 was 3.6 gpm.

Figure 4 shows the trial 1 recovery data. Evident on the graph is a substantial storage effect, caused by compression of trapped air in the filter pack and formation pores during head buildup. The late data revealed a transmissivity estimate of 1,020 gpd/ft and a hydraulic conductivity of 58 gpd/ft^2, or 7.7 ft per day.

Figure 5 shows the trial 2 drawdown data. Two anomalies are evident on the plot. First, the storage effect is prominent in the early data, caused by expansion of trapped air, and dissolved air coming out of solution, during pressure reduction. Second, the early storage curve has an initial depression (excess drawdown) likely caused by antecedent drainage of the drop pipe prior to pumping. With a portion of the drop pipe empty, initial pumping occurred against reduced head briefly, resulting in a greater discharge rate for a short time. (Indeed, when the pump was pulled, some sections of the drop pipe were empty and a defective thread was identified that had allowed leakage of water from the drop pipe into the annular space above the inflatable packer.

The transmissivity calculated from Figure 5 was 580 gpd/ft, making the hydraulic conductivity 33 gpd/ft^2, or 4.4 ft per day. This was a little over half the value obtained from the trial 1 recovery data. In general, recovery data are more reliable than drawdown data because they are immune to transient, dynamic effects such as changes in discharge rate or well efficiency. It is possible that ongoing accumulation of air in the formation pores gradually reduced the well efficiency over time, resulting in an exaggerated slope on the graph and an underestimate of transmissivity.

Figure 6 shows the trial 2 recovery data. Evident on the graph is a substantial storage effect, caused by compression of trapped air in the filter pack and formation pores during head buildup. The late data revealed a transmissivity estimate of 1,010 gpd/ft and a hydraulic conductivity of 57 gpd/ft^2, or 7.7 ft per day, in good agreement with the trial 1 recovery analysis.

Figure 7 shows an expanded-scale plot of the late recovery data. The very late data show a flattening of the curve, likely related to leakage from adjacent sediments or possibly barometric effects.

Phase 1 Constant-Rate Pumping Test

The first constant-rate pumping test was started at 7:50 A.M. on October 21 at a discharge rate of 3.6 gpm. Pumping continued for 32.5 hours until 4:20 P.M. on October 22. At that time, the pump was shut down and recovery measurements were recorded for 38 hours until 6:24 A.M. on October 24.

Time-Drawdown Analysis

Figure 8 shows the drawdown data from test 1. Numerous anomalies are present in the data – most associated with the formation air problem.

The early data showed the storage effect caused by trapped air in the formation as well as the drawdown "spike" caused by antecedent drainage of a portion of the drop pipe. The middle data yielded a transmissivity of 540 gpd/ft and a hydraulic conductivity of 31 gpd/ft^2, or 4.1 ft per day, similar to values obtained from the trial 2 drawdown data. Again, it is likely that a gradual well efficiency reduction caused by ongoing accumulation of air in the formation pores around the well could have caused the low calculated transmissivity.

The late data showed very unusual response – a steepening of the curve, followed by a water level rise, followed again by a steepening and then an abrupt rise. Formation air was responsible for this erratic response. The initial steep segment was likely caused by continued efficiency reduction caused by accumulation of air in the formation around the well.

The water level rise between 550 and 850 minutes probably resulted from air exiting the formation pores and moving into the well, thus improving the permeability of the air-laden sediments. The pumping rate was constant through this interval and, thus, the water level rise could not be explained by a change in discharge rate.

The subsequent water level decline was probably a result of resumed accumulation of air in the formation pores around the well. Again, the discharge rate remained constant through this period.

At the end of the test, the discharge rate became erratic, declining briefly at first, and then dropping drastically, at which time the test was terminated. The drastic rate reduction is evidenced by the huge rise in water level at the end of the test. Such flow rate reduction can occur when air is run through the pump. It is possible that the formation began producing more air to the well and this interfered with the pump. Also possible is that, throughout the test, air entering the well accumulated in the well casing above the pump, trapped beneath the inflatable packer. Once enough air had accumulated to displace all of the water between the packer and the pump intake, the pump began surging wildly.

Recovery Analysis

After pump shutoff, recovery data were recorded from 4:20 am on October 22 until 6:24 am on October 24. Figure 9 shows the corresponding recovery plot. The early data show the storage-like effect seen on all other plots from the testing. The late data were very unusual, actually inexplicable, in that measured water levels rose to a position about 0.6 ft above the original static water level.

Figure 10 shows the recovery data on an expanded-scale plot, illustrating the apparent head buildup above static. It is likely that equipment malfunction caused this anomalous data trend. Perhaps this was related to the water level "jumps" that were recorded by the transducer. These discontinuities can be discerned on Figure 10. As indicated on the graph, a line of fit was drawn through a portion of the curve yielding a transmissivity of 860 gpd/ft. However, it is difficult to defend the position of the straight line in light of the obvious data anomalies and multiple slopes on the graph. This transmissivity calculation can't necessarily be considered reliable.

Packer Deflation

Following 38 hours of recovery, the inflatable packer was deflated in preparation for pump removal. When this occurred, the head above the transducer increased significantly for a couple of minutes, as shown on Figure 11. The effect was caused by water above the packer in the annulus between the drop pipe and the well casing. As shown on Figure 11, the annular water height above the static water level was at least 24 ft. Using an annular volume of 0.76 gallons per lineal ft between the 4.5-inch inner diameter (ID) well casing and the 1-inch drop pipe, the computed water volume in the annulus above the static water level was at least 18 gallons. This volume of water must have leaked from the drop pipe into the annulus through damaged threads during the course of testing.

Figure 12 shows an extended-scale plot of the head buildup, while Figure 13 shows an expanded-scale plot. Amazingly, even though the head prior to packer deflation was measured as being 0.6 ft above the static level, after the slug event caused by packer deflation, the level approached the original static level. Apparently the accuracy of the transducer had somehow been restored. Again, this unusual response was attributed to equipment malfunction, as there was no other explanation for these water level measurements.

Phase 2 Trial Testing

Following premature termination of test 1, the decision was made to rerun the pumping test using a larger pump that could provide a greater hydraulic stress to the aquifer. The initial pump was pulled from the well and its replacement was installed.

Following installation of the replacement pump, the well was pumped briefly (trial testing) to evaluate capacity, fill the drop pipe in preparation for the longer constant-rate test, and generate some useful data. Because of the greater pump capacity, trial testing was performed with the packer deflated so that casing storage water would be available to supply a portion of the volume needed to fill the drop pipe. Trial pumping (trial 3) was begun at 1:40 P.M. on October 24. The trial lasted 9 minutes until 1:49 P.M., followed by 91 minutes of recovery until 3:20 P.M. The pumping rate during trial 3 was 9.1 gpm.

Figure 14 shows the recovery data recorded following trial 3. Evident on the graph is a long casing storage effect. This resulted from not using the inflatable packer. Casing storage calculations predicted a casing storage duration of about 22 minutes, corresponding to a *t/t'* value of 1.4 as indicated on the graph.

Figure 15 shows an expanded-scale plot for ease of analysis. The predicted casing storage time seems to fit the data well. The transmissivity calculated from the line of fit shown on the graph was 850 gpd/ft, yielding a hydraulic conductivity of 48 gpd/ft^2, or 6.4 ft per day. This value was in good agreement with previous results.

Phase 2 Constant-Rate Pumping Test

The second constant-rate pumping test was started at 3:20 P.M. on October 24 at a discharge rate of 7.7 gpm. Pumping continued for 198 minutes until 6:38 P.M.. At that time, the pump was shut down and recovery measurements were recorded for 866 minutes until 9:04 A.M. on October 25

Time-Drawdown Analysis

Figure 16 shows the test 2 drawdown data. The early data reflected the storage effect associated with trapped air in the formation. However, instead of flattening out, the data trace continued on the same slope, likely a result of an ongoing loss of efficiency associated with air buildup in the formation pores around the well. As shown on the figure, the computed transmissivity was 270 gpd/ft – impossibly low, and a result of the exaggerated drawdown slope caused by the efficiency reduction.

Late in the test, the water level rose, even though the pumping rate remained stable, likely indicating that built up air had exited the formation and entered the well, thereby temporarily improving the permeability of the sediments around the well bore. After a period of water level rise, continued air buildup in the formation again caused a steep drawdown slope.

Recovery Analysis

After pump shutoff, recovery data were recorded from 6:38 P.M. on October 24 until 9:04 A.M. on October 25. Figure 17 shows the corresponding recovery plot. The early data show the storage effect seen on all other plots from the testing, while the late data show formation properties.

Figure 18 shows an expanded-scale plot of the recovery data for ease of analysis. The transmissivity computed from the line of fit was 840 gpd/ft, yielding a hydraulic conductivity of 48 gpd/ft^2, or 6.4 ft per day – consistent with previous results.

The very late data show a slight flattening of the recovery curve, possibly indicating a subtle leakage effect. The “jumps” in water level are apparent on the expanded-scale plot for test 2. However, following the test, the water level appeared to approach the original static level, unlike what was observed following test 1.

Packer Deflation

Following 866 minutes of recovery, the inflatable packer was deflated in preparation for pump removal. When this occurred, the head above the transducer increased significantly for a couple of minutes, as shown on Figure 19. As before, the effect was caused by water above the packer in the annulus between the drop pipe and the well casing. Also as before, this was attributable to leaky threaded joints in the drop pipe.

The extended-scale plot on Figure 20 shows that, at late time, the head approached that measured prior to packer deflation. This response was normal – unlike what had been observed following packer deflation during phase 1 testing.

Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound conductivity value for the screened interval. In addition to specific capacity, other input values used in the calculations included a well screen length of 17.6 ft, a saturated zone thickness of 17.6 ft, a storage coefficient of 5 x 10^{-4} and a borehole radius of 0.51 ft.

During test 1, R-16r produced 3.6 gpm with a drawdown of 12.98 ft after 1,440 minutes of pumping. Applying the Cooper-Jacob method to these data yielded a lower-bound transmissivity of 440 gpd/ft. Similarly, during test 2, the well produced 7.7 gpm with a drawdown of 23.25 ft after 198 minutes of pumping. Applying the Cooper-Jacob method to these data yielded a lower-bound transmissivity of 450 gpd/ft. Keep in mind that during each of these pumping events, transient well efficiency degradation had taken place, thus exaggerating the measured drawdown and reducing the specific capacity below what it would have been had air entrainment problems not occurred. This had the effect of reducing the computed lower-bound transmissivity estimates. Had there been no air entrainment, the computed lower-bound values would have been greater.

The average transmissivity obtained using conventional analysis of the pumping test data was approximately 930 gpd/ft. The lower-bound values averaged about half of this, suggesting a well efficiency of about 50% and consistent with (not contradictory to) the conventional analysis. Had air entrainment not occurred, the agreement between the lower-bound values and conventionally derived values would have been even better.

Vertical Hydraulic Conductivity

The lack of a discernable response in R-16 screen 2 while pumping R-16r was similar to that reported on previously for R-10 and R-10a in Sandia Canyon. Also, the head difference between the two zones was similar in magnitude to that observed at R-10. Therefore, it is likely that the vertical resistance to flow is analogous.

Modeling of the pumping test data at R-10 and R-10a suggested a vertical anisotropy of at least two and a half to three orders of magnitude at that location. It is expected that a similar anisotropy may apply to the R-16r site.

SUMMARY

The following information summarizes the results of the pumping and recovery tests on R-16r:

1. In contrast to most of the R-wells on the Pajarito Plateau, which are nearly 100% barometrically efficient, R-16r appeared to have a moderate barometric efficiency. Data collected from adjacent R-16 screen 2 showed a barometric efficiency of 30%. It appears that wells closer to the Rio Grande may have lower barometric efficiencies than those farther away. Recently, testing has shown low to moderate barometric efficiencies for wells R-10, R-10a, R-16r and R-16 screen 2, whereas previous testing of wells farther from the river have tended to show much higher barometric efficiencies. Lower barometric efficiency means that barometric effects are more effective in reaching the saturated zone. The lower efficiencies observed in wells closer to the Rio Grande may be related to the proximity to the cliffs above the river and/or the shorter distance between land surface and the static water levels.

2. The background data obtained from R-16 screen 2 showed a subtle indication of response that might be related to water supply pumping in the area.

3. Test data were affected profoundly by air trapped or dissolved in the formation. During testing, the air was able to come out of solution and/or expand and contract in response to

pumping and recovery. The air affected performance by clogging formation pores and entering the well and pump, resulting in very unusual data sets.

4. Storage effects were not completely eliminated by use of the inflatable packer in R-16r. The presence of air in the well caused a storage-like effect because of expansion and contraction of the air.

5. The transducer appeared to yield erroneous data in some cases, although it may be possible that the air present in the well may have contributed in some way to the apparent equipment malfunction.

6. The average transmissivity obtained from the testing was 930 gpd/ft, corresponding to a hydraulic conductivity of 53 gpd/ft^2, or 7.1 ft per day. As a comparison, the hydraulic conductivities measured in R-16 screens 2, 3 and 4 ranged from about 1 to 2 ft per day (although these values were obtained from brief injection tests, rather than pumping tests, and did not utilize an inflatable packer).

7. Specific capacity data predicted a lower-bound hydraulic about half that obtained by conventional analysis. Had air entrainment not occurred, the specific capacities would have been greater, producing a greater lower-bound estimate. The result was consistent with the conventional results and suggested a well efficiency of more than 50%.

8. The lack of a discernable response in R-16 screen 2 caused by pumping R-16r suggested a low vertical hydraulic conductivity of the intervening sediments – likely orders of magnitude less than the horizontal conductivity.

9. Consistent with the idea of low vertical hydraulic conductivity and decreasing head values with depth, the static water level in R-16r was 52 ft higher than that in R-16 screen 2.

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Figure 1. Comparison of R-16r Apparent Hydrograph and Adjusted TA-54 Barometric Pressure

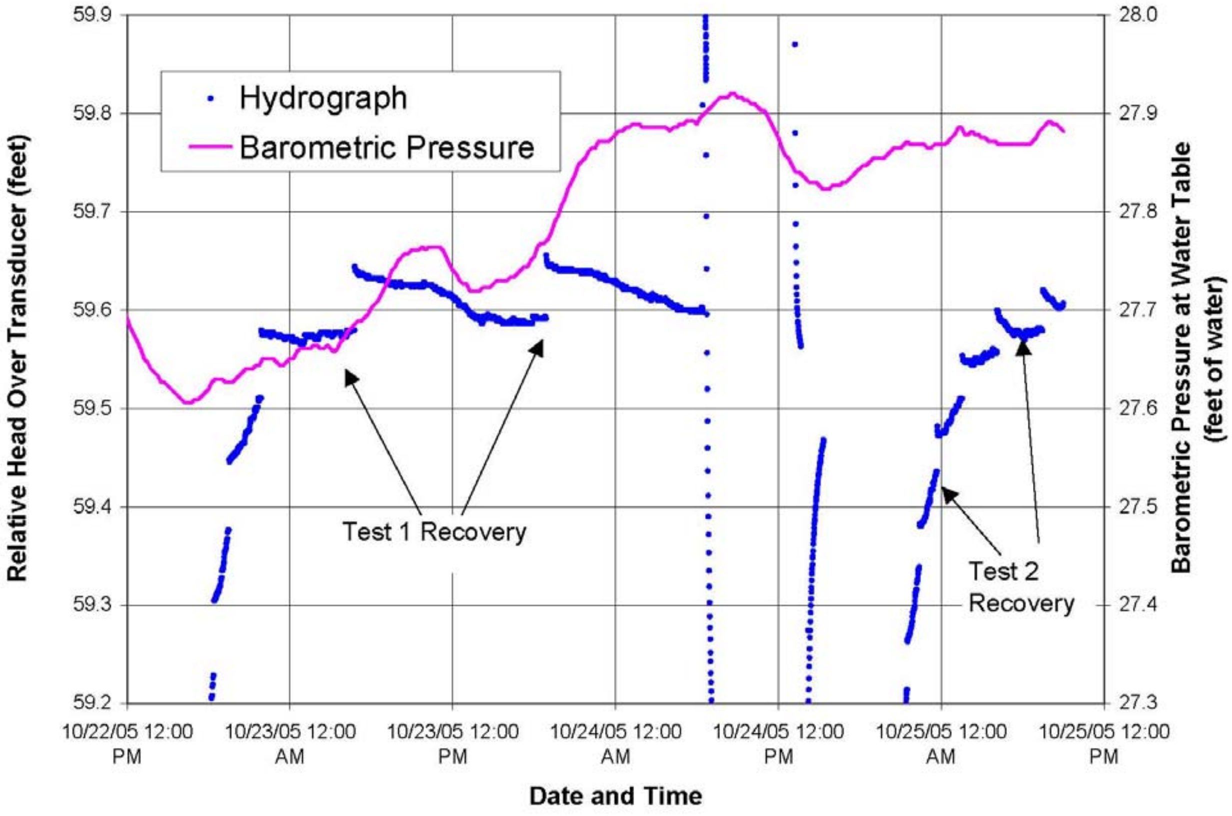


Figure 2. Comparison of R-16 Screen 2 Apparent Hydrograph and Adjusted TA 54 Barometric Pressure

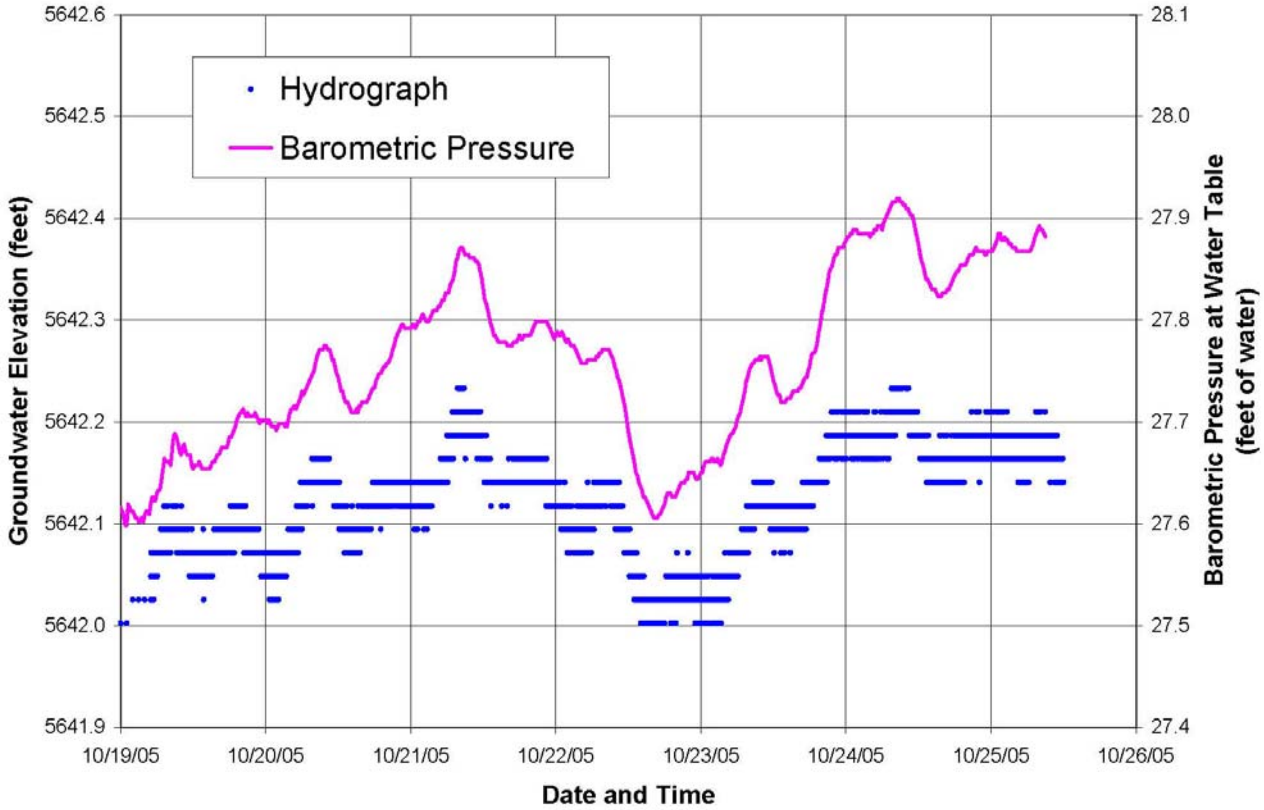


Figure 3. Comparison of R-16 Screen 2 Rolling Average Apparent Hydrograph and Adjusted TA-54 Barometric Pressure Change

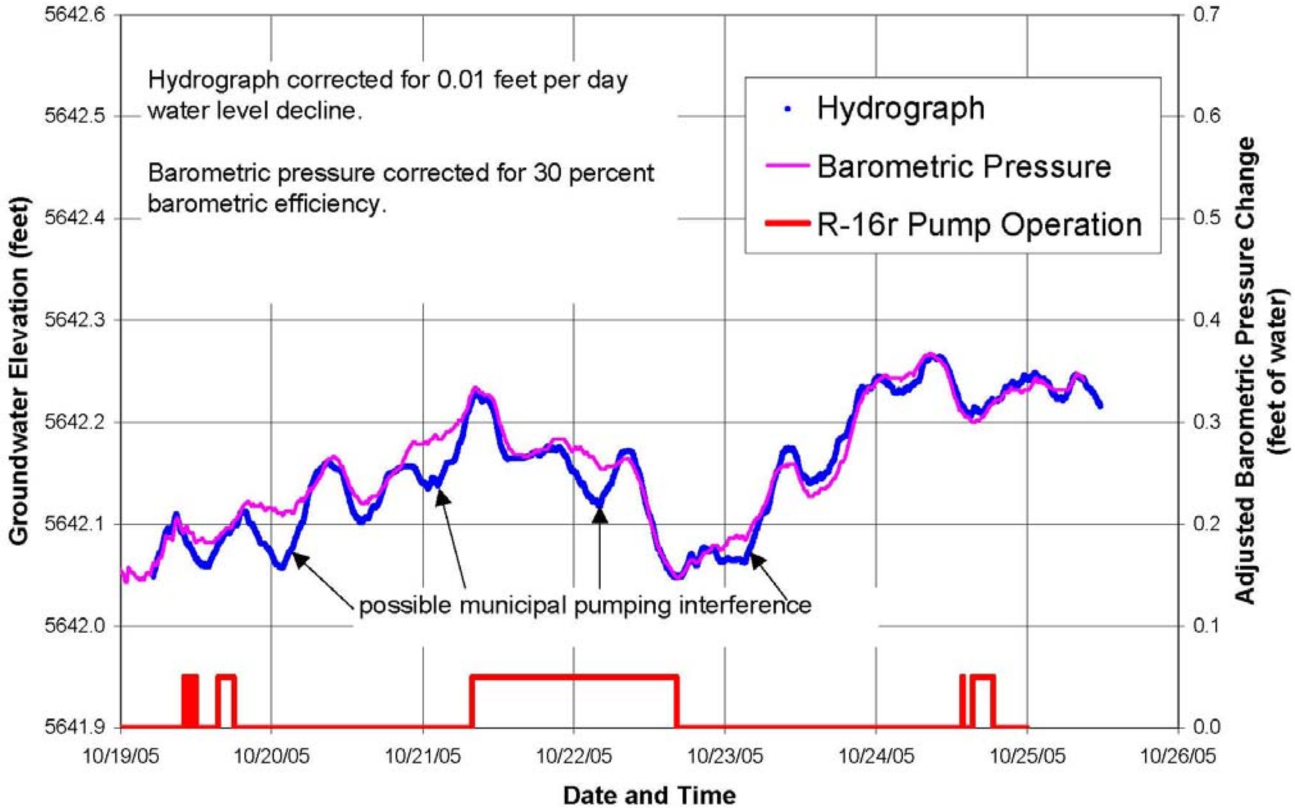


Figure 4. Well R-16r Trial 1 Recovery

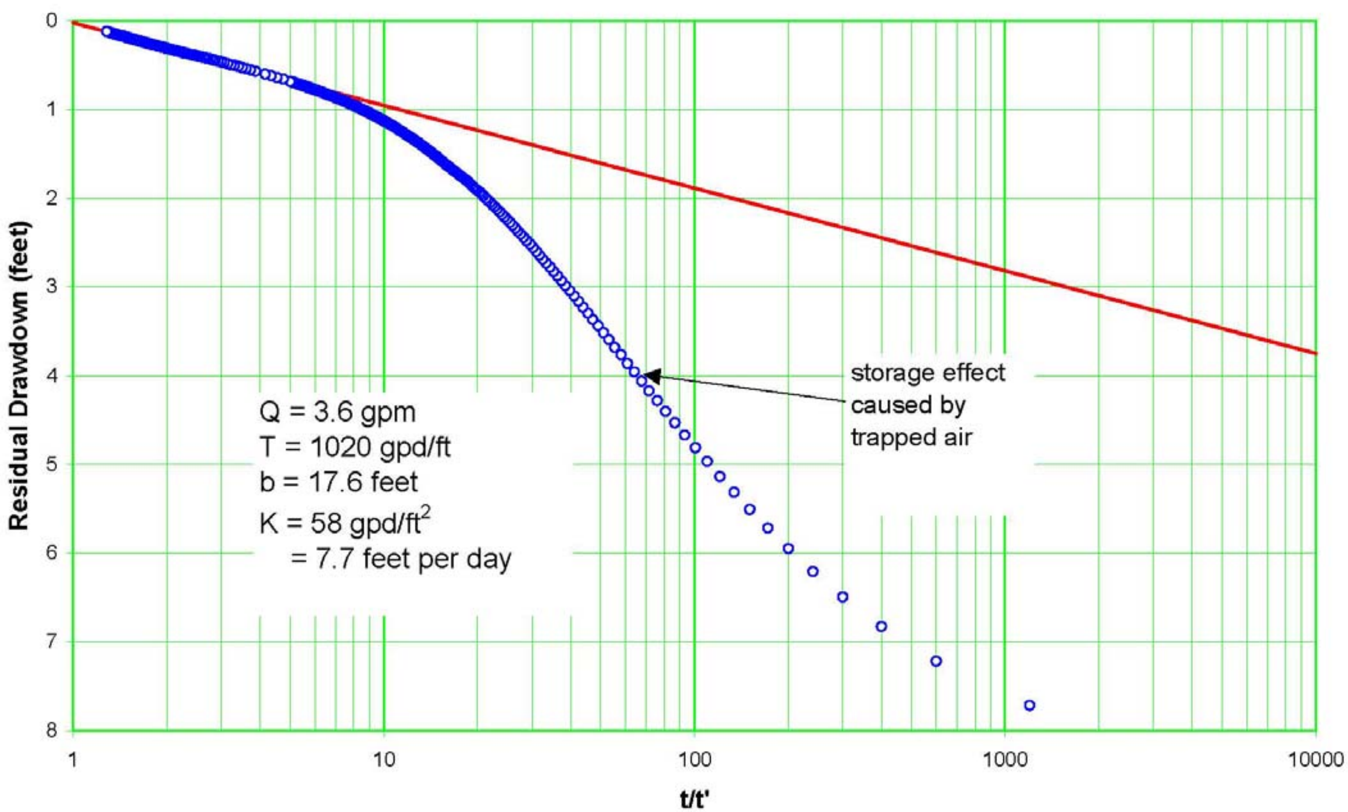


Figure 5. Well R-16r Trial 2 Drawdown

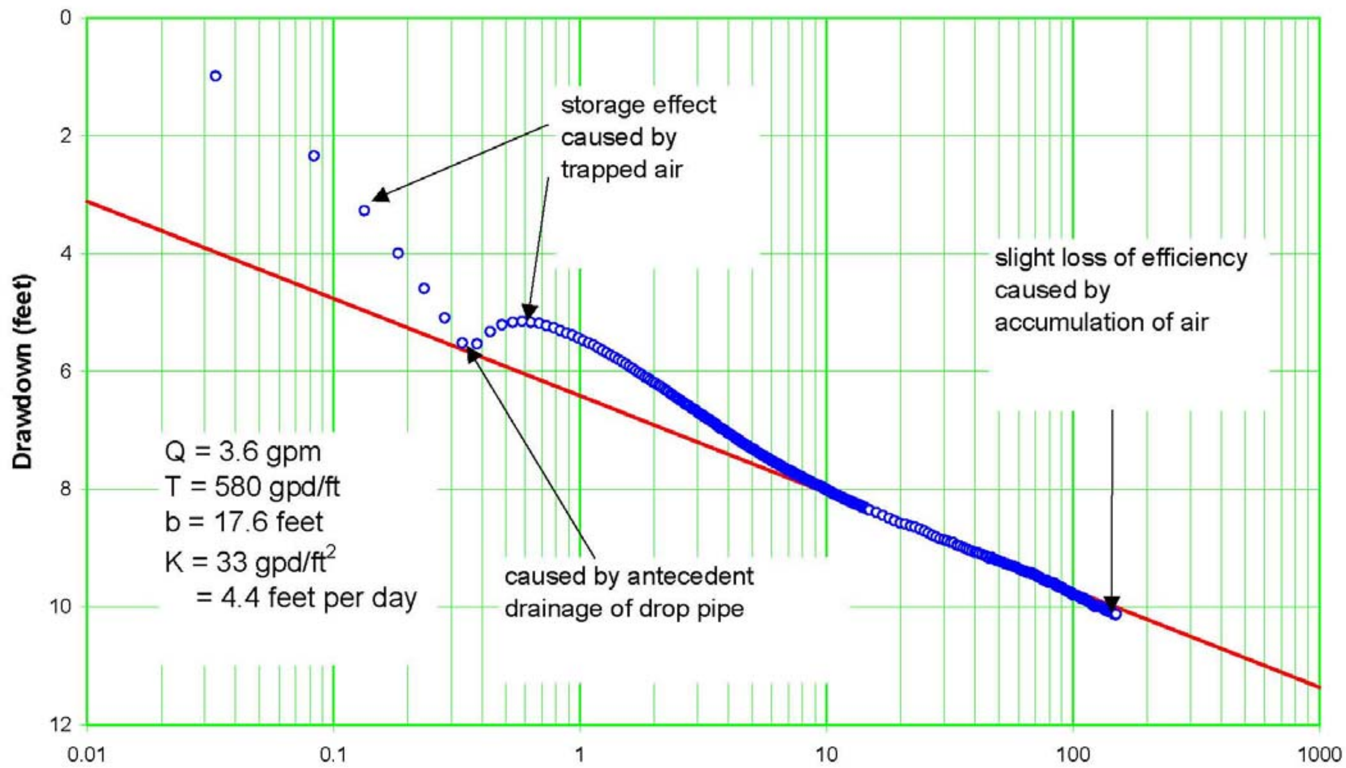


Figure 6. Well R-16r Trial 2 Recovery

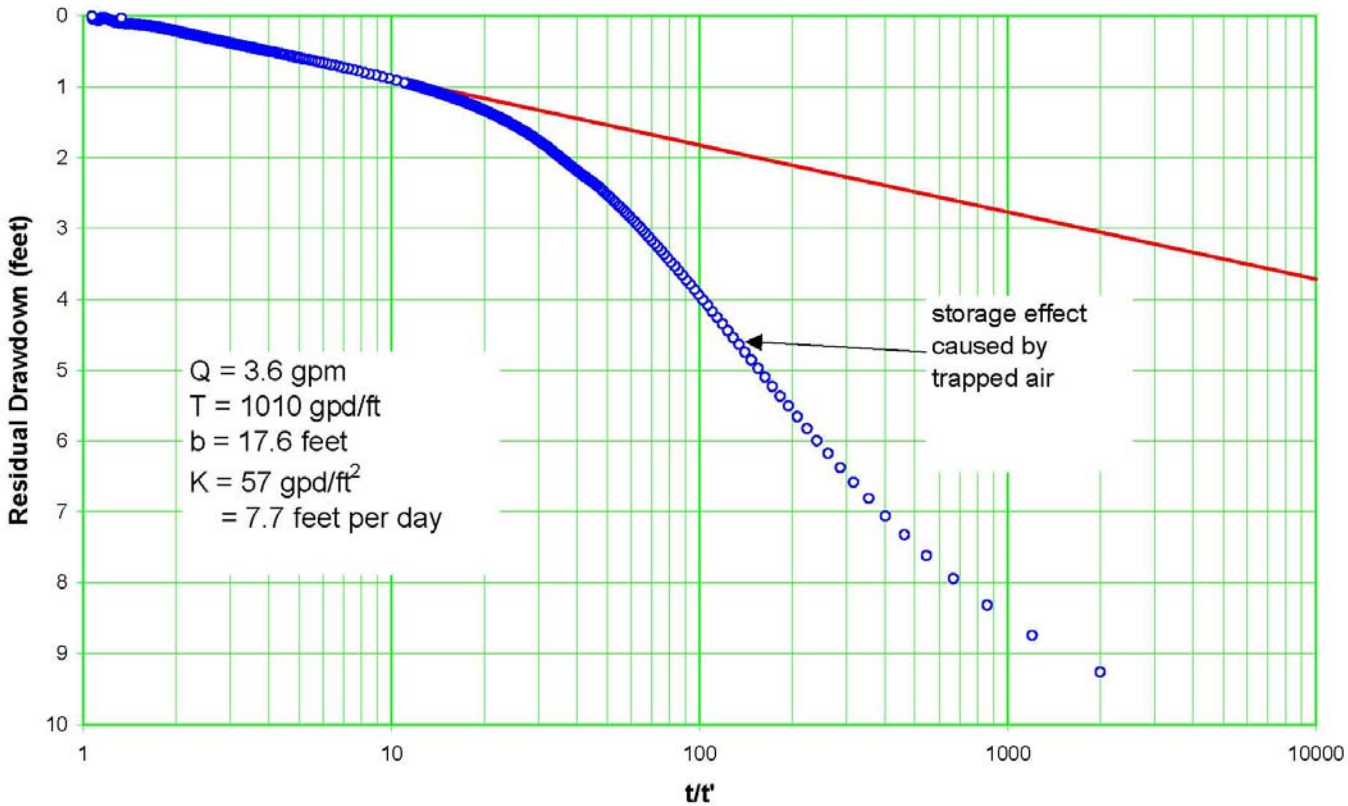


Figure 7. Well R-16r Trial 2 Recovery - Expanded Scale

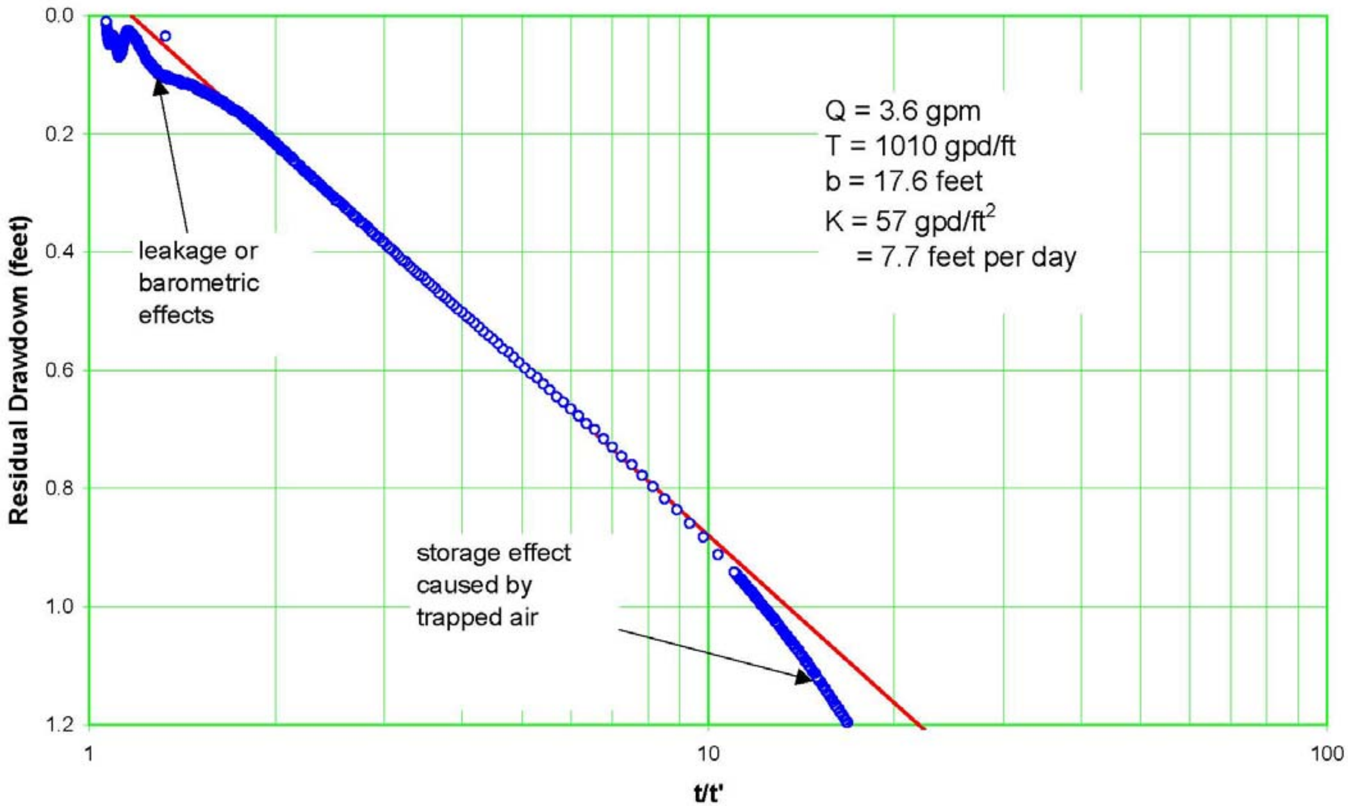


Figure 8. Well R-16r Test 1 Drawdown

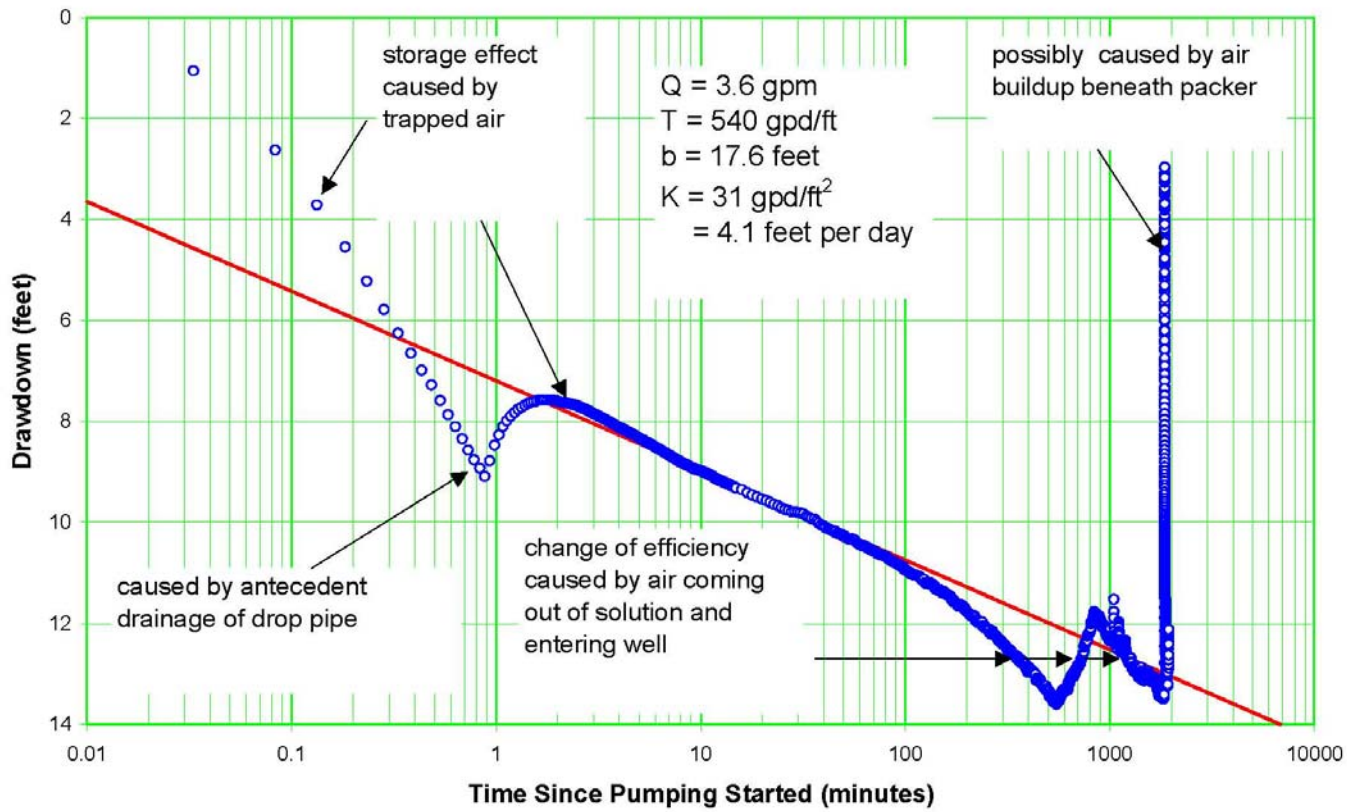


Figure 9. Well R-16r Test 1 Recovery

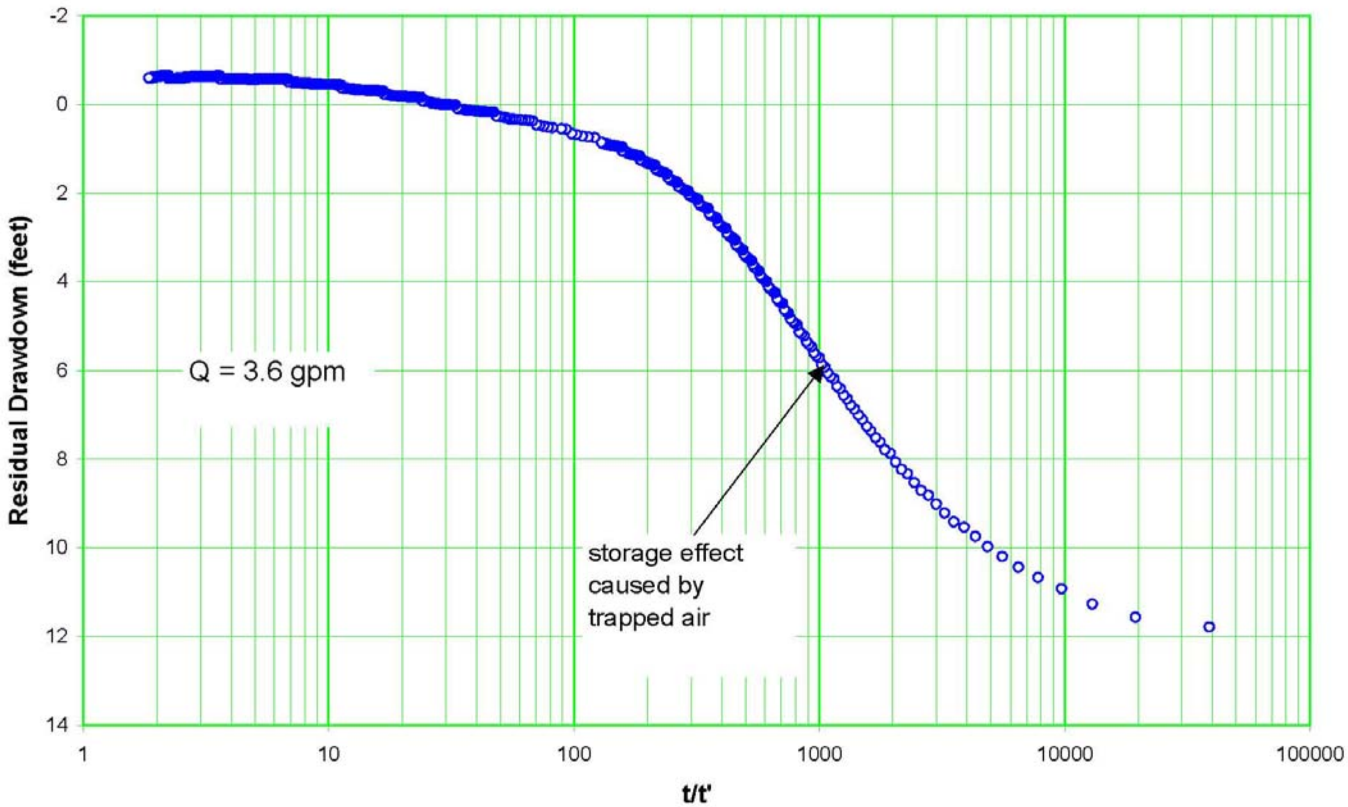


Figure 10. Well R-16r Test 1 Recovery Expanded Scale

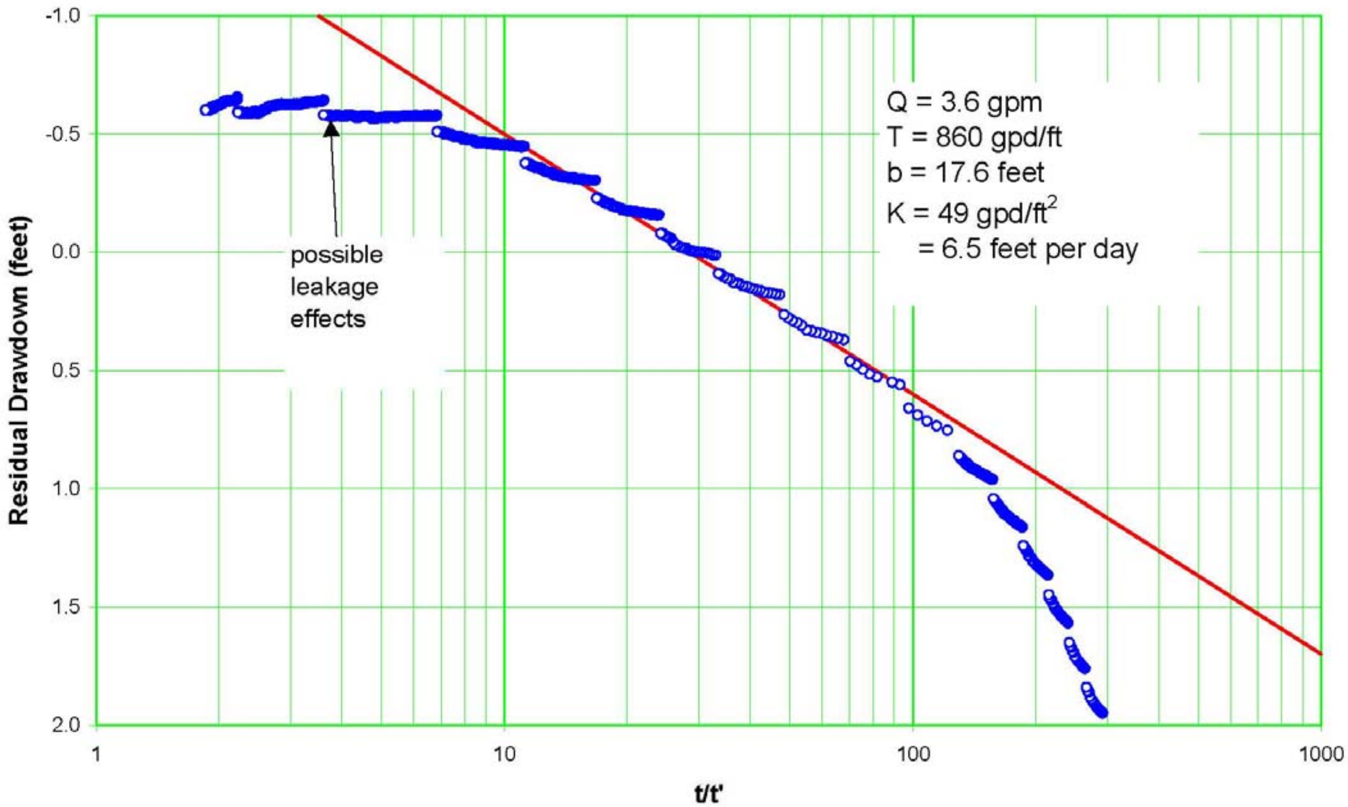


Figure 11. Head Buildup Following Test 1 Packer Deflation

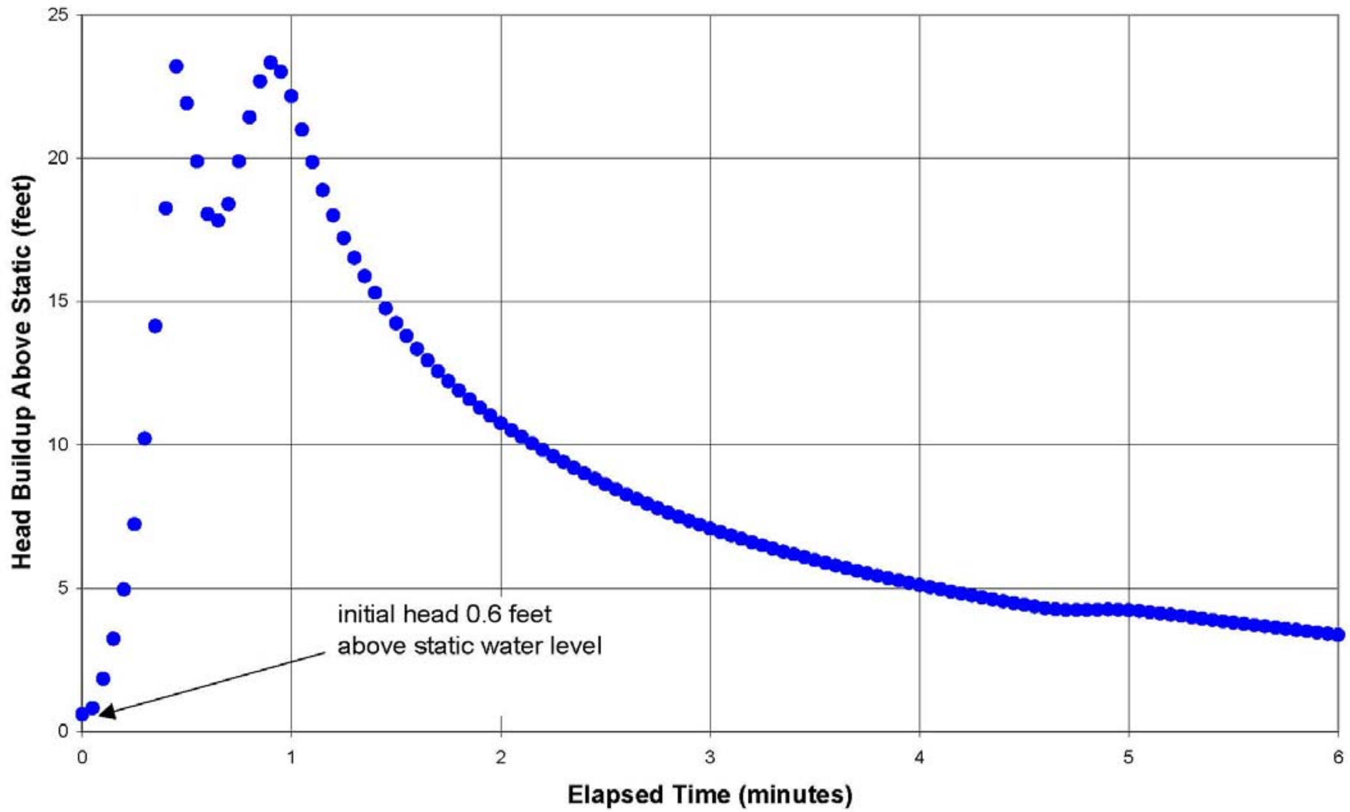


Figure 12. Head Buildup Following Test 1 Packer Deflation - Extended Scale

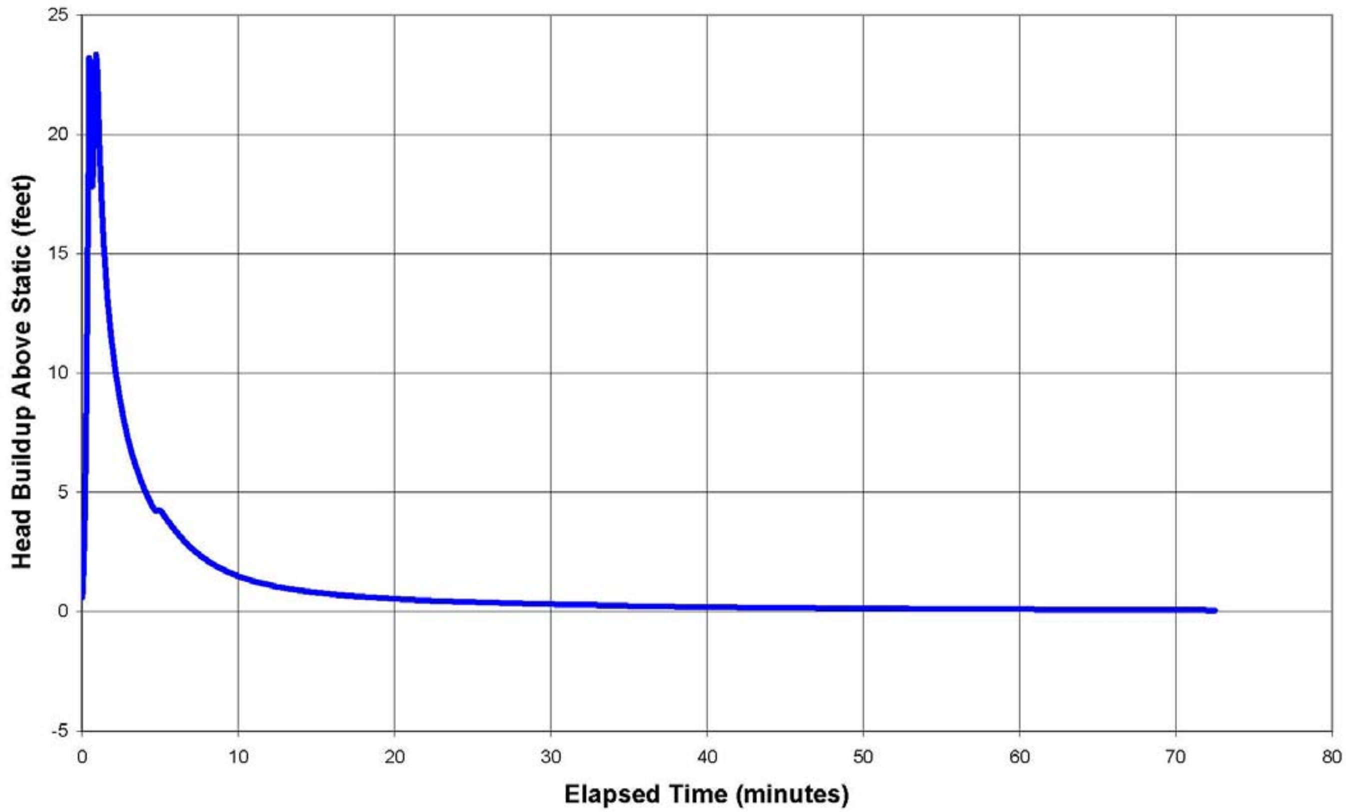


Figure 13. Head Buildup Following Test 1 Packer Deflation - Expanded Scale

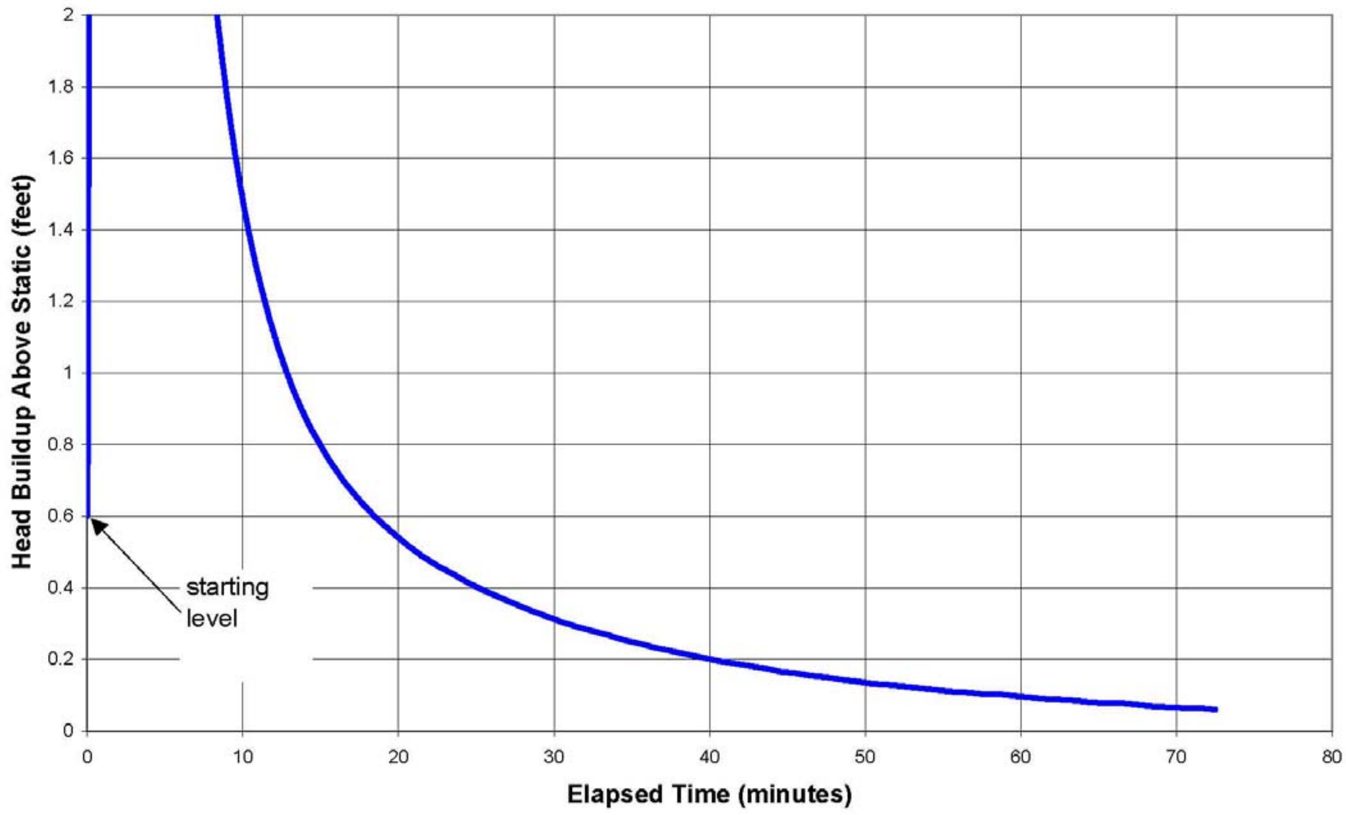


Figure 14. Well R-16r Trial 3 Recovery

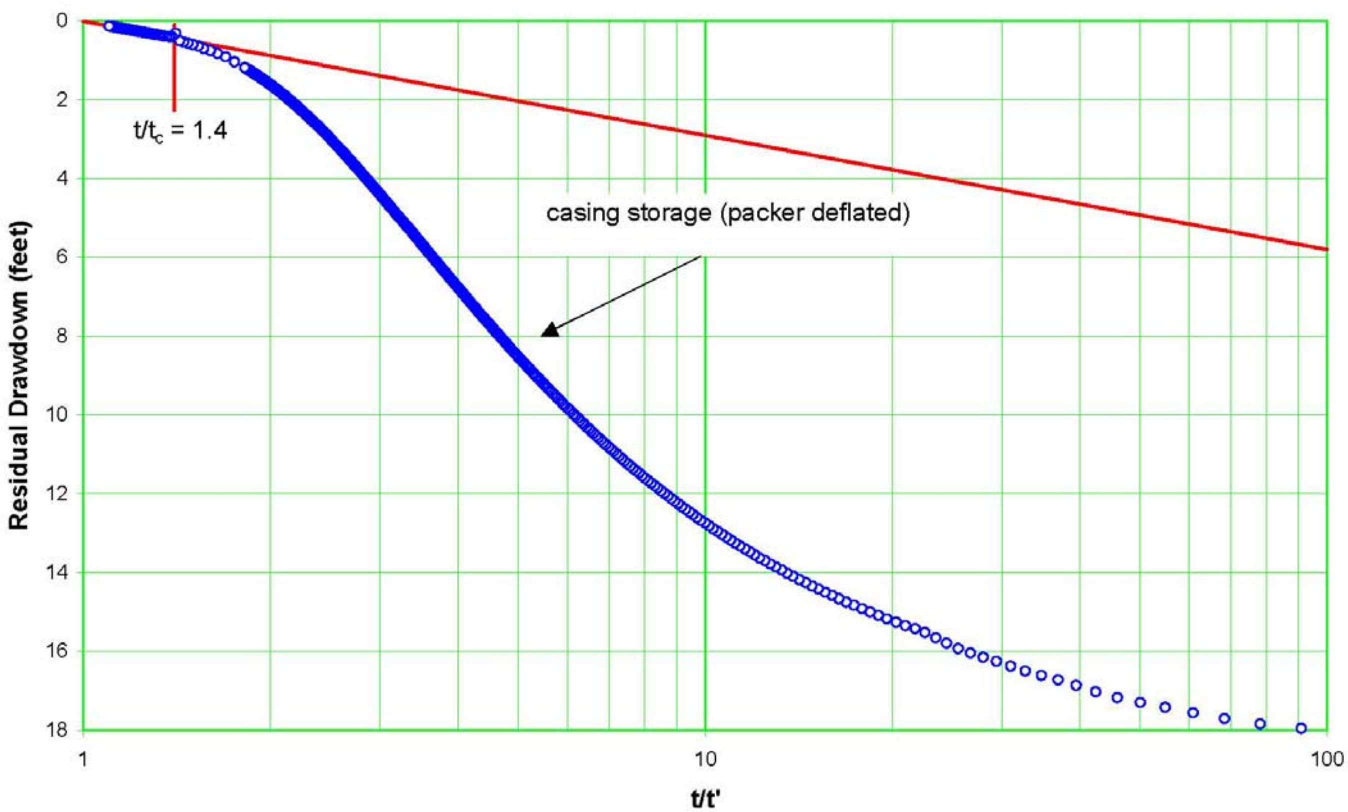


Figure 15. Well R-16r Trial 3 Recovery - Expanded Scale

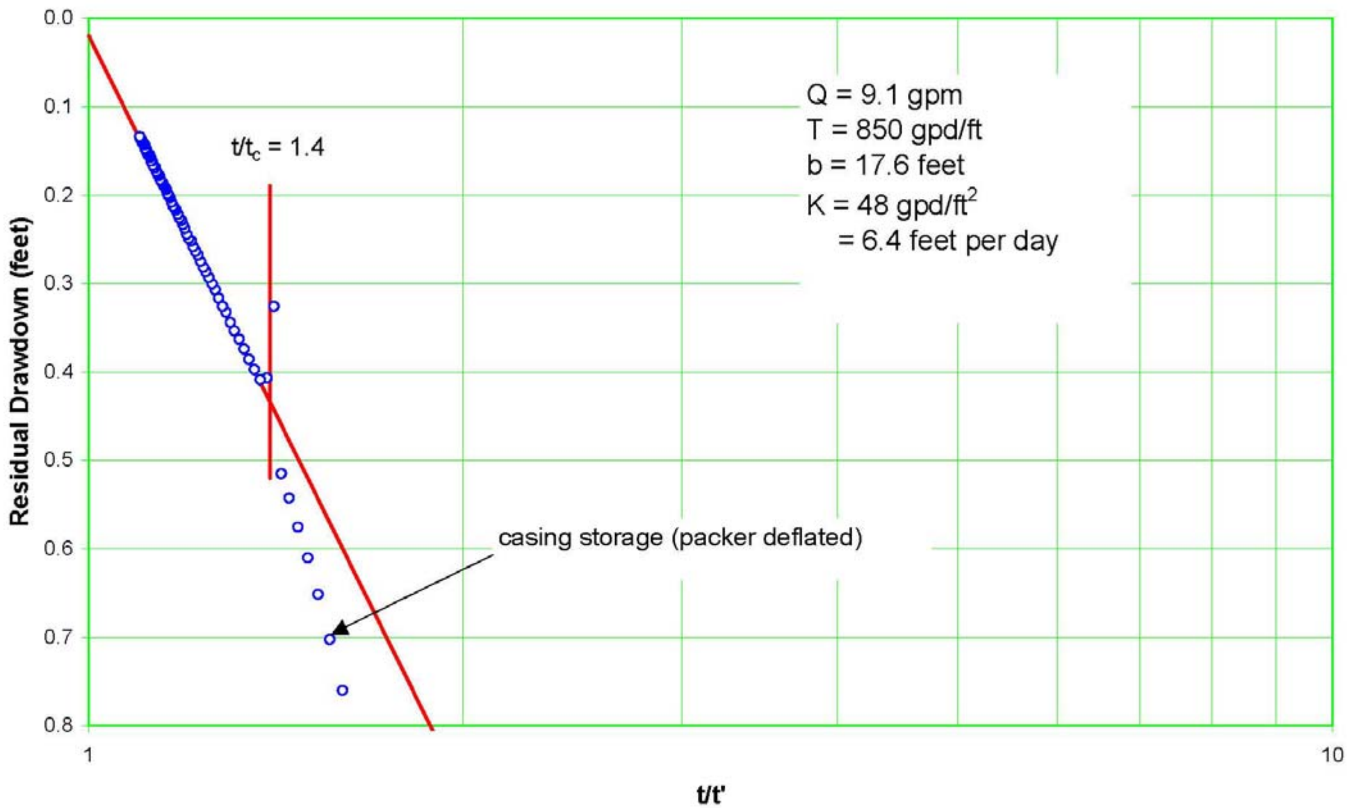


Figure 16. Well R-16r Test 2 Drawdown

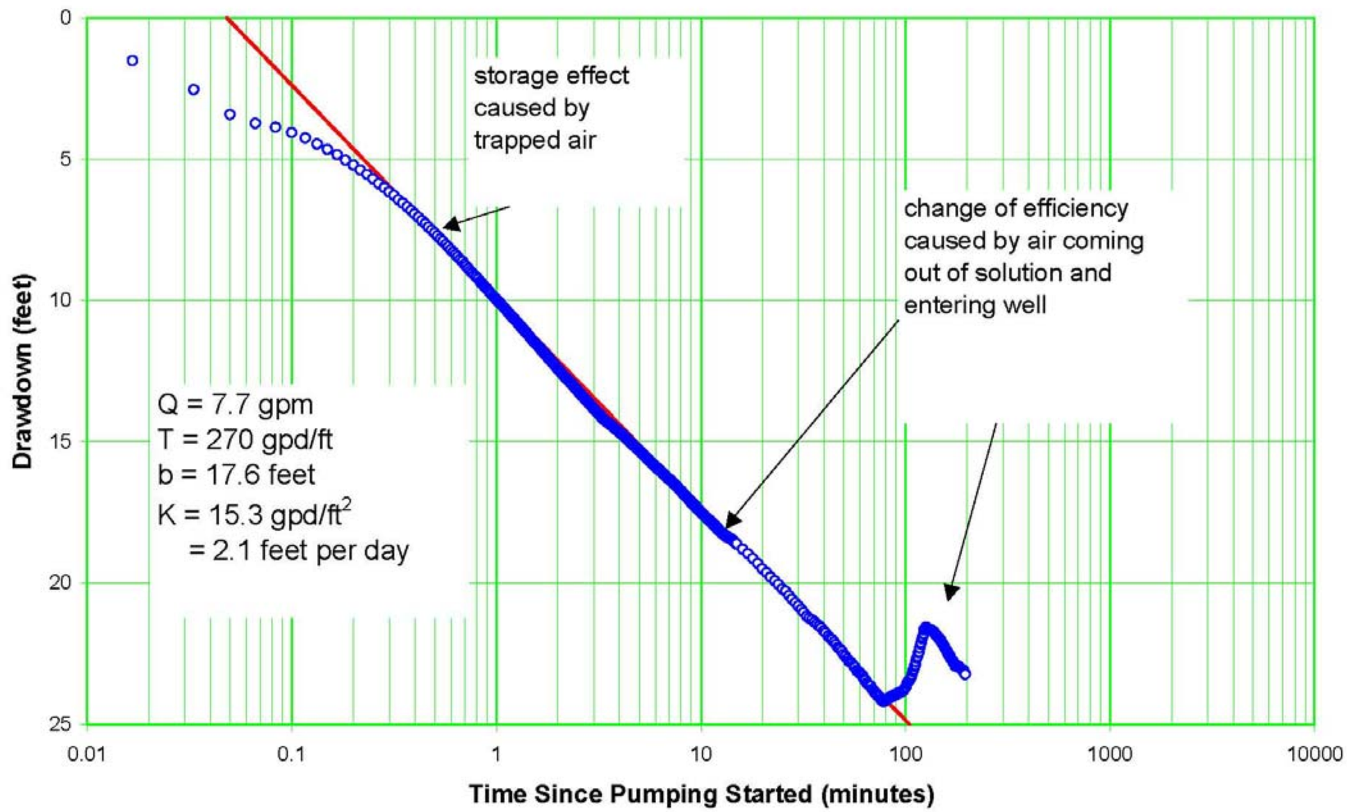


Figure 17. Well R-16r Test 2 Recovery

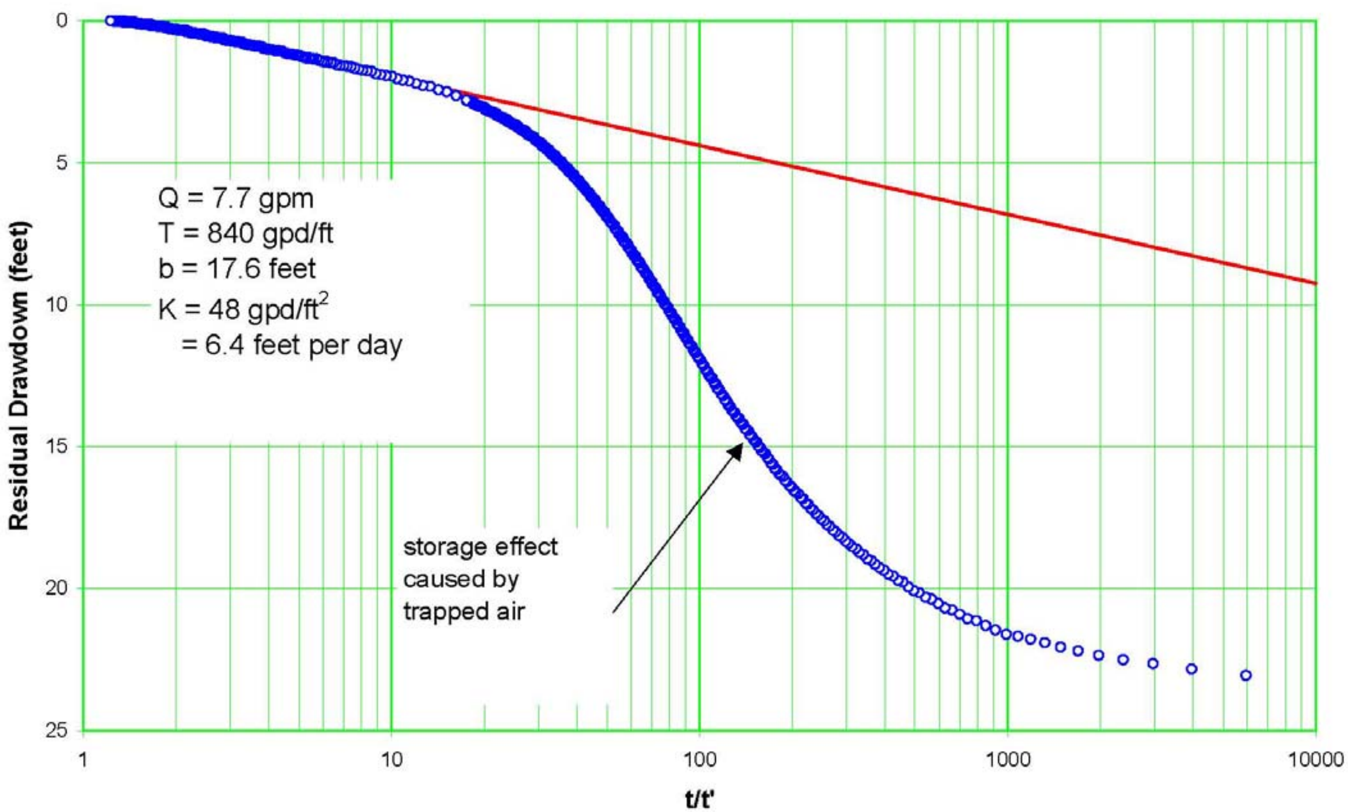


Figure 18. Well R-16r Test 2 Recovery - Expanded Scale

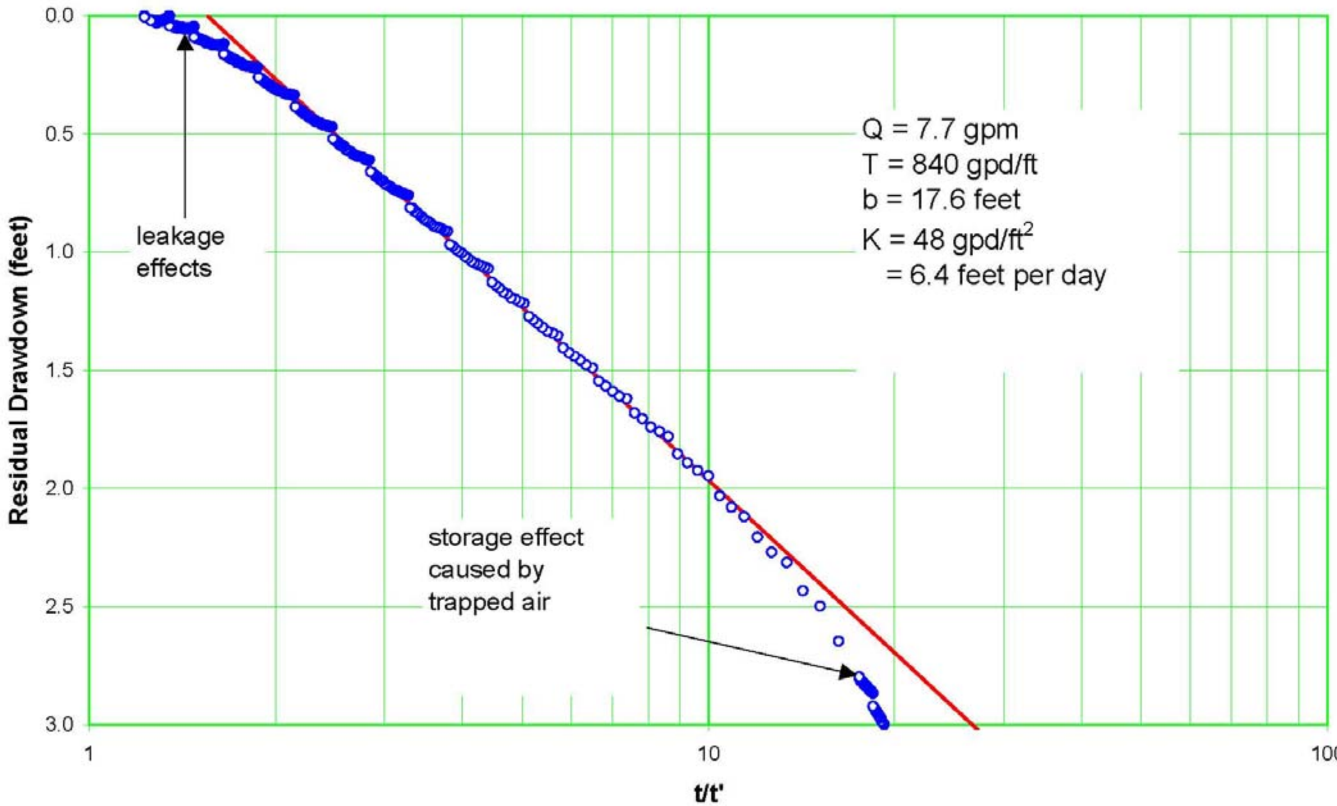


Figure 19. Head Buildup Following Test 2 Packer Deflation

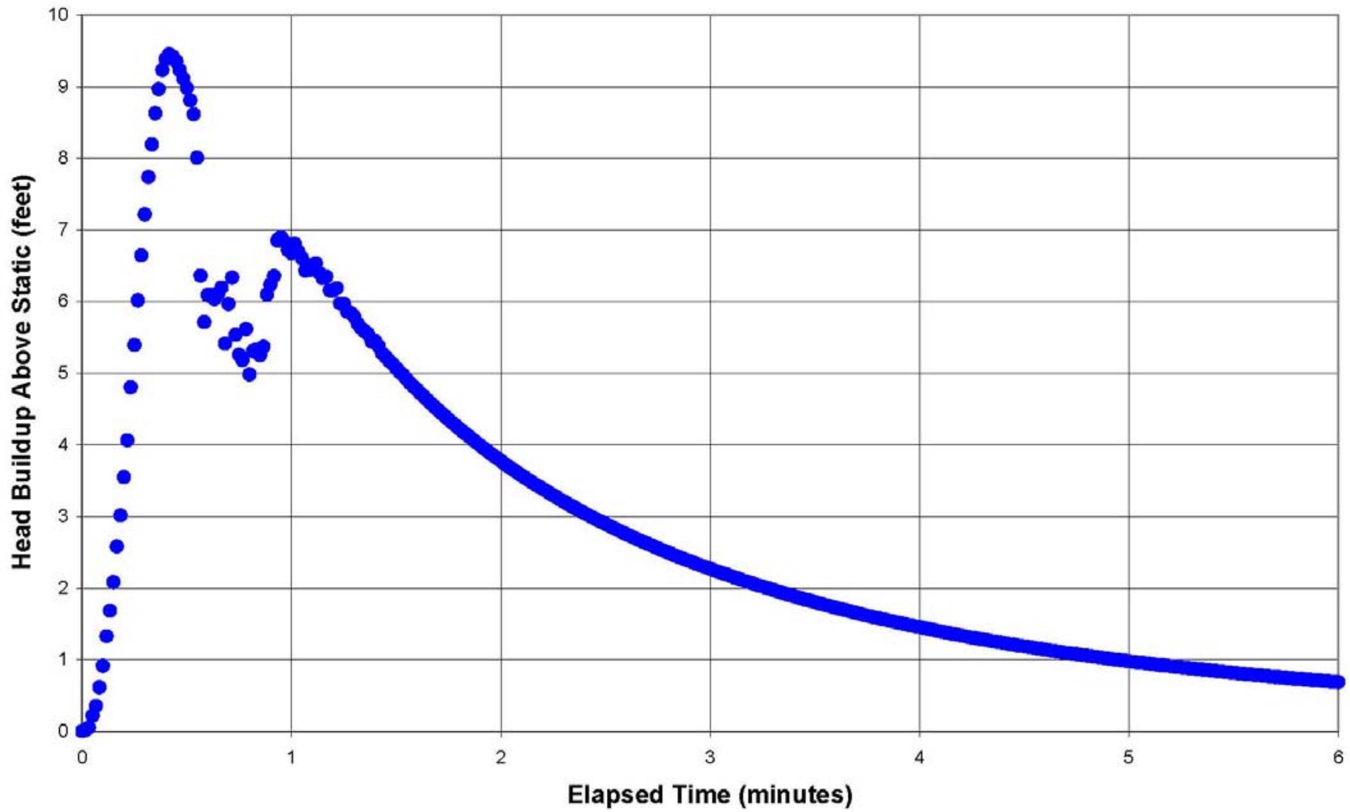
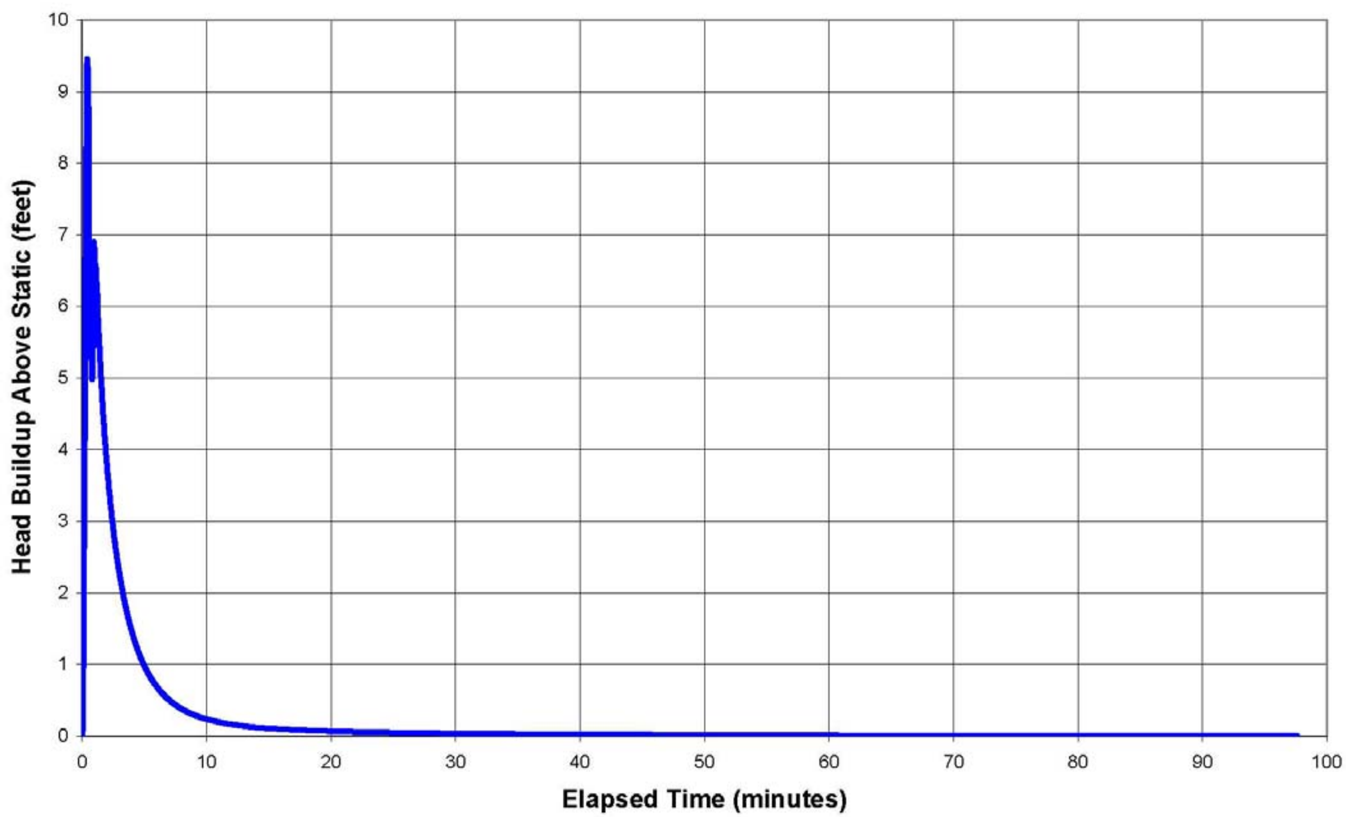


Figure 20. Head Buildup Following Test 2 Packer Deflation - Extended Scale



Appendix E

Deviations from Planned Activities

Activity	Drilling Work Plan for R-16r (Kleinfelder 2005a)	R-16r Actual Work
Planned Depth	Target total depth was 700 feet (ft) below ground surface (bgs).	R-16r was drilled to 655 ft bgs.
Drilling Method	Air rotary with foam-assist.	Air rotary, air rotary with foam-assist, and air rotary casing hammer techniques were used.
Screening Water Samples for Contaminant Analysis	If perched water was encountered in the unsaturated zone, groundwater samples were to be collected from each perched zone for screening analysis.	Perched water was not encountered during drilling. One screening groundwater sample was collected from the regional aquifer.
Cuttings Samples Collected for Contaminant Analysis	Bulk cutting samples were to be collected every 10 ft to 450 ft bgs, and thereafter at 5-ft intervals. Sieved samples were to be collected at 5-ft intervals below 450 ft bgs.	At the direction of LANL scientists, cuttings samples were collected at 10-ft intervals to 550 ft bgs, and thereafter at 5-ft intervals to total depth. Sieved samples were collected at 5-ft intervals from 550 ft bgs to total depth.
Logging	Natural gamma, array induction and video logging to be conducted.	Gamma logging was conducted at R-16r. Video and induction logging could not be conducted because 9⅝-in. drill casing was left in place to 635 ft bgs prior to well construction due to borehole instability.
Casing	11¾-inch (in.) casing planned to 147 ft bgs.	13⅜-in. casing was installed to 119 ft bgs and could not be advanced further. 12¼-in. casing was installed to 199 ft bgs. 9⅝ in. casing was installed to 635 ft bgs.
Borehole Diameter	Planned to be 12¼-in. to total depth.	9⅝-in. casing had to be installed to 635 ft bgs using air rotary casing hammer and an 8½-in. bit.
Annular Fill Materials used in Well Construction	The Drill Plan called for bentonite/sand mix below the sump and a 20/40 sand transition filter pack at 10 ft above the primary filter pack.	At DOE's direction, bentonite/sand was replaced by 10/20 sand. Because of difficulties tagging the primary filter pack, it was installed to 33 ft above the well screen, so no transition filter pack was installed.
Well Construction	The well design called for an overall 23-ft screened interval with a 10-ft sump.	The two pipe-based screens were only 7.5-ft long, making the screened interval 17.6-ft long. A 14-ft sump was installed beneath the well screen.