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FEB 18 2016

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*Date*: FEB 18 2016
*Refer To*: ADESH-16-018
*LAUR*: 16-20780
*Locates Action No.*: n/a

John Kieling, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

**Subject: Submittal of the Completion Report for Combined Regional Aquifer Well R-67 and Chromium Corehole 6**

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Completion Report for Combined Regional Aquifer Well R-67 and Chromium Corehole 6 in accordance with Section IV.A.3.e.iv, Well Completion, of the Compliance Order on Consent.

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for combined regional aquifer groundwater well R-67 and Chromium Corehole 6 (CrCH-6), located within Technical Area 61 at Los Alamos National Laboratory in Los Alamos County, New Mexico.

If you have any questions, please contact Stephani Swickley at (505) 606-1628 (sfuller@lanl.gov) or Cheryl Rodriguez at (505) 665-5330 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Bruce Robinson, Program Director
Environmental Remediation Program
Los Alamos National Laboratory

Sincerely,

David S. Rhodes, Supervisor
Environmental Management
Los Alamos Field Office

BR/DR/SS:sm

Enclosures: Two hard copies with electronic files – Completion Report for Combined Regional Aquifer Well R-67 and Chromium Corehole 6 (EP2016-0005)

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LA-UR-16-20780
February 2016
EP2016-0005

# Completion Report for Combined Regional Aquifer Well R-67 and Chromium Corehole 6

Prepared by the Associate Directorate for Environmental Management

EP2016-0005

# Completion Report for Combined Regional Aquifer Well R-67 and Chromium Corehole 6

February 2016

Responsible project manager:

| Printed Name | Signature | Title | Organization | Date |
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| Stephani Swickley for | Theodore J. Ball | Project Manager | Environmental Remediation Program | 2/10/16 |

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| for Randall Erickson | | Associate Director | Associate Directorate for Environmental Management | 2/11/16 |

Responsible DOE representative:

| Printed Name | Signature | Title | Organization | Date |
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| David S. Rhodes | | Supervisor | DOE-EM-LA | 2-17-2016 |

# EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for combined regional aquifer groundwater well R-67 and Chromium Corehole 6 (CrCH-6), located within Technical Area 61 (TA-61) at Los Alamos National Laboratory (LANL or the Laboratory) in Los Alamos County, New Mexico. The R-67 monitoring well is intended to augment the existing monitoring well network to better define chromium contamination flow paths above and within the regional aquifer as required by the New Mexico Environment Department's (NMED's) 2014 "Approval with Modifications of the Phase II Investigation Report for Sandia Canyon." The objectives of the well are to fully constrain the nature and extent of chromium contamination in the regional aquifer west and upgradient of well R-62.

In addition, this location optimizes the objectives for CrCH-6, as stated in the July 2014 Drilling Work Plan for Chromium Project Coreholes, specifically to characterize the upgradient portion of the primary chromium plume. Data derived from CrCH-6 will be evaluated to determine the western extent of anthropogenic chromium in vadose zone pore water and core and within the regional aquifer.

The combined R-67 and CrCH-6 monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was used only to a depth of 1115 ft below ground surface (bgs). Well R-67 was drilled to a total depth of 1324.6 ft bgs.

Coring was performed at specified target intervals relying on various coring tools to maximize sample recovery and quality. A Laboratory-supplied tracer was added to the drilling water used for advancing the borehole in subsequent coring runs to distinguish native water from introduced water. The tracer and drill water mix was suspended at 1205 ft bgs.

The following geologic formations were encountered at the combined R-67 and CrCH-6 borehole: Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, the Puye Formation, and Miocene Pumiceous Sediments.

Well R-67 was completed as a single-screen well, allowing evaluation of water quality and water levels within the regional aquifer. The screened interval is set between 1242.6 ft and 1263.0 ft bgs within Miocene Pumiceous Sediments. The static depth to water after well installation was measured at 1226.7 ft bgs.

The well was completed in accordance with an NMED-approved well design. The well was developed and the regional aquifer groundwater met target water-quality parameters. Aquifer testing indicates that regional aquifer monitoring well R-67 will perform effectively in meeting the planned objectives. A sampling system and transducer were placed above the screened interval, and groundwater sampling at R-67 will be performed as part of the annual Interim Facility-wide Groundwater Monitoring Plan.

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## Acronyms and Abbreviations

| | |
|---|---|
| amsl | above mean sea level |
| ASTM | American Society for Testing and Materials |
| bgs | below ground surface |
| Consent Order | Compliance Order on Consent’ |
| CrCH | Chromium Corehole |
| DO | dissolved oxygen |
| DTW | depth to water |
| EES | Earth and Environmental Sciences (Laboratory group) |
| Eh | oxidation-reduction potential |
| ENV-CP | Environmental Protection Division–Environmental Compliance Programs |
| EP | Environmental Programs |
| ESH | Environment, Safety, and Health (Laboratory directorate) |
| gpd | gallons per day |
| gpm | gallons per minute |
| hp | horsepower |

| | |
|---|---|
| I.D. | inside diameter |
| LANL | Los Alamos National Laboratory |
| NAD | North American Datum |
| NMED | New Mexico Environment Department |
| NTU | nephelometric turbidity unit |
| O.D. | outside diameter |
| ORP | oxidation-reduction potential |
| PVC | polyvinyl chloride |
| RCT | radiological control technician |
| SOP | standard operating procedure |
| SVOC | semivolatile organic compound |
| TA | technical area |
| TD | total depth |
| TOC | total organic carbon |
| VOC | volatile organic compound |
| WCSF | waste characterization strategy form |

## 1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for combined regional aquifer monitoring well R-67 and Chromium Corehole 6 (CrCH-6), hereafter referred to as R-67. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005 (revised 2012), Compliance Order on Consent (the Consent Order). The combined R-67 and CrCH-6 monitoring well borehole was drilled between July 17 and August 16, 2015, and completed between August 27 and September 21, 2015, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate. Combined well R-67 and CrCH-6 is located within Technical Area 61 (TA-61) of the Laboratory's in Los Alamos County, New Mexico (Figure 1.0-1).

The R-67 monitoring well is intended to augment the existing monitoring well network to better define chromium contamination flow paths above and within the regional aquifer as required by the New Mexico Environment Department's (NMED's) 2014 "Approval with Modifications of the Phase II Investigation Report for Sandia Canyon" (LANL 2012, 228624; NMED 2014, 524467). The objectives of the well are to define the nature and extent of chromium contamination in the regional aquifer west and upgradient of well R-62. Secondary objectives were to identify and establish water levels in perched-intermediate aquifers, if present, and to collect drill-cuttings and core samples for lithologic description and pore water analysis.

The combined R-67 and CrCh-6 borehole was drilled in accordance with the NMED-approved "Drilling Work Plan for Combined Groundwater Monitoring Well R-67 and CrCH-6" (LANL 2015, 600265; NMED 2015, 600341). It was drilled to a total depth (TD) of 1324.6 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals from ground surface to TD. Coring was performed at specified target intervals using various coring tools to maximize sample recovery and quality. A monitoring well was installed with a screened interval between 1242.6 and 1263.0 ft bgs within Miocene Pumiceous Sediments. The depth to water (DTW) of 1226.7 ft bgs was recorded on October 7, 2015, after well installation.

Post-installation activities included well development, aquifer testing, surface completion, conducting a geodetic survey, and sampling system installation. Future activities will include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the EP Records Processing Facility. This report contains brief descriptions of activities and supporting figures, tables, and appendixes associated with the R-67/CrCH-6 project.

## 2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide activities associated with the drilling, installation, and development of combined regional aquifer well R-67 and CrCH-6:

- "Drilling Work Plan for Combined Groundwater Monitoring Well R-67 and CrCH-6" (LANL 2015, 600265);
- "Field Implementation Plan for Combined Regional Aquifer Well R-67 and Corehole 6 (CrCH-6)" (TerranearPMC 2015, 601188);

- "IWD [Integrated Work Document] for Drilling and Installation of LANL Well R-67" (TerranearPMC 2015, 601190);
- "Storm Water Pollution Prevention Plan R-67/CrCH-6 Well Drilling Project" (LANL 2015, 601185); and
- "Waste Characterization Strategy Form: R-67/CrCH-6 Well Drilling" (LANL 2015, 601189).

## 3.0 DRILLING ACTIVITIES

This section describes the drilling approach and provides a chronological summary of field activities conducted at combined monitoring well R-67 and CrCH-6.

### 3.1 Drilling Approach

The drilling method, equipment, and drill-casing sizes for the combined monitoring well R-67 and CrCH-6 were selected to retain the ability to investigate and case/seal off any perched groundwater encountered above the regional aquifer and to evaluate pore water and core within the vadose zone and regional aquifer. Further, the drilling approach ensured that a sufficiently sized drill casing was used to meet the required 2-in.-minimum annular thickness of the filter pack around a 5.88-in. outside-diameter (O.D.) well screen.

Dual-rotary drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-67 borehole. The drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, deck-mounted air compressor, and general drilling equipment. Auxiliary equipment included two Ingersoll Rand skid-mounted air compressors. Three sizes of A53 grade-B flush-welded mild-carbon-steel casing (16-in.-O.D., and 12-in.-and 10-in.–inside-diameter [I.D.]) were used for the R-67 project.

The dual-rotary drilling technique at R-67 used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all within the vadose zone) included potable water and a mixture of potable water with Baroid Quik Foam foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of the foaming agent was terminated at 1115 ft bgs, approximately 100 ft above the expected top of the regional aquifer. No additives other than potable water and Laboratory-supplied tracer were used for drilling below 1115 ft bgs. Total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

The Foremost DR-24HD drill rig was also used to collect core within the R-67 borehole to fulfill the requirements specified in the "Drilling Work Plan for Combined Groundwater Monitoring Well R-67 and CrCH-6" and was equipped with coring tools to maximize sample recovery and quality. Coring tools utilized included a 3.5-in.-I.D. by 5-ft-long hollow-stem split core barrel attached to a hammer-driven barrel and a 4.25-in-I.D. by 12-ft-long hollow-stem auger. The drilling approach for the coring intervals was to core ahead of the drill casing, retrieve the core, and then advance the casing to the bottom of the core run. The next core run was then made ahead of the casing. This process was repeated until the target interval was completed.

A Laboratory-supplied tracer (sodium 1, 5-naphthalene disulfonate) was added to the drilling water used for advancing the borehole in subsequent coring runs to distinguish native water from introduced water. The tracer was added to two 305-gal. polyethylene (poly) tanks while the tanks were filled with potable water (from a municipal source) to assist with mixing and dissolving the tracer. The tracer and drill water mix were used starting approximately 40 ft above a coring interval and while the borehole was advanced during core runs. The tracer and drill water mix as well as drilling foam above 1115 ft bgs were minimized to the extent possible starting 40 ft above and through the coring intervals. Use of tracer and drill water mix was suspended at 1205 ft bgs.

## 3.2 Chronology of Drilling Activities for the Combined Well R-67 and CrCH-6

The DR-24HD drill rig, drilling equipment, and supplies were mobilized to the R-67 drill site from July 15 to 16, 2015. The equipment and tooling were decontaminated before mobilization to the site. On July 17, following on-site equipment inspections, drilling of the monitoring well borehole began at 1435 h using dual-rotary methods with a 15-in. tricone bit and 16-in. drill casing.

The 16-in. surface casing was advanced through the Tshirege Member of the Bandelier Tuff and Cerro Toledo interval to 241.0 ft bgs on July 19. From July 20 to 21, core was collected through the Cerro Toledo interval and Otowi Member of the Bandelier Tuff with the hollow-stem split core barrel from 241.0 to 261.3 ft bgs. The 16-in. surface casing was then advanced through the Otowi Member of the Bandelier Tuff to 415.0 ft bgs. On July 23, open-hole drilling commenced using a 15-in. tricone bit. Drilling proceeded through the Otowi Member of the Bandelier Tuff to 555.0 ft bgs on July 24. The 16-in. casing shoe was cut on July 24 at 410.0 ft bgs.

Between July 25 and July 26, a 12-in. casing string was installed in the open borehole to a depth of 543.6 ft bgs. Beginning July 26, a 12-in. underreaming hammer bit was used to advance the 12-in. casing through the Otowi Member of the Bandelier Tuff and the Guaje Pumice Bed of the Otowi Member to 610.9 ft bgs. From July 27 to 28, core was collected through the Puye Formation with the hollow-stem split core barrel from 610.9 ft to 620.1 ft bgs. Drilling was temporarily suspended and the 12-in. casing was pulled back 78.4 ft from 617.0 ft to 538.6 ft bgs. A Laboratory video borehole log, natural gamma ray log, and induction log were recorded on July 29 in the open portion of the borehole. From July 29 to August 2, the 12-in. casing was advanced through the Puye Formation to 999 ft bgs. The 12-in. casing shoe was successfully cut on August 2 at 991.7 ft bgs.

Between August 3 and August 4, a 10-in. casing string was installed to a depth of 996.0 ft bgs. The 10-in. casing string and an underreaming hammer bit were advanced through the Puye Formation and Miocene Pumiceous Sediments. From August 7 to 9, while the 10-in. casing string was advanced, core was collected through the Miocene Pumiceous Sediments with the hollow-stem split core barrel from 1145.4 ft to 1150.4 ft bgs, 1165.8 ft to 1170.4 ft bgs, 1184.7 ft to 1188.9 ft bgs, and 1205.4 ft to 1209.2 ft bgs. On August 12 and 15, core was collected through the Miocene Pumiceous Sediments with the hollow-stem auger from 1251.2 ft to 1253.7 ft bgs and 1255.6 ft to 1260.7 ft bgs. After reaching a TD of 1324.6 ft bgs on August 16 at 0413 h, water levels in the borehole were measured and recorded. A Laboratory natural gamma log was recorded the same day. The casing shoe was cut on August 17 at 1319.3 ft bgs.

Operationally, drilling proceeded 24 h/d, 7 d/wk from July 17 to August 16.

## 4.0 SAMPLING ACTIVITIES

This section describes the cuttings, coring, pore water, and groundwater sampling activities for combined monitoring well R-67 and CrCH-6. All sampling activities were conducted in accordance with applicable quality procedures.

## 4.1 Cuttings and Core Sampling

Cuttings samples were collected from the R-67 monitoring well borehole at 5-ft intervals from ground surface to the TD of 1324.6 ft bgs. At each interval, approximately 500 mL of bulk cuttings was collected by the site geologist from the drilling discharge cyclone, placed in resealable plastic bags, labeled, and archived in core boxes. Whole rock, +35 and +10 sieve-size fractions were also processed, placed in chip trays, and archived for each 5-ft interval. Radiological control technicians (RCTs) screened the cuttings before removal from the site. All screening measurements were within the range of background values. The cuttings samples were delivered to the Laboratory's archive at the conclusion of drilling activities.

R-67 stratigraphy is summarized in section 5.1 and a detailed lithologic log is presented in Appendix A.

Core barrel liners (Lexan) were used during coring. The Lexan liners were capped, taped shut to preserve moisture, and marked with orientation stripes upon retrieval by the site geologist. The Lexan liners were archived in core boxes with corehole number, run number, and footage interval. RCTs screened the core before removal from the site. All screening measurements were within the range of background values. Samples on site were picked up by Laboratory personnel and delivered to a refrigerated truck storage unit located in Mortandad Canyon.

Core recovery from CrCH-6 averaged 75% overall. Attempted depths of coring and actual core collected are summarized in Table 4.1-1.

## 4.2 Pore Water and Groundwater Sampling

Attempts to collect pore water, if present, were made from each core run. The site geologist drained any free moisture from the core tube/barrel into a large plastic bottle and labeled each bottle with corehole name, depth, and date and time of collection. Seventeen groundwater-screening samples were collected during coring. The Laboratory's Earth and Environmental Sciences Group 14 (EES-14) analyzed 12 of the coring samples for anions and metals and 5 samples for alkalinity and pH.

Ten groundwater-screening samples were collected during development from the pump's discharge line for total organic carbon (TOC) analysis. The TOC results are presented in Appendix B. Three samples were collected during aquifer testing. Two of the samples were analyzed for, anions, metals, alkalinity, and pH. The holding time expired for one TOC sample because of EES-14 instrument failure and was not analyzed.

Table 4.2-1 presents a summary of screening samples collected during the R-67 monitoring well installation. The TOC results and field water-quality parameters are presented in Appendix B.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for a full suite of constituents in accordance with the requirements of the Interim Facility-Wide Groundwater Monitoring Plan. The analytical results will be included in periodic monitoring report for the Chromium Investigation monitoring group. After the first year, the analytical suite and sample frequency at R-67 will be evaluated and reported in the annual Interim Facility-Wide Groundwater Monitoring Plan.

# 5.0 GEOLOGY AND HYDROGEOLOGY

The geologic and hydrogeologic features encountered at R-67 are summarized below. The Laboratory's geology task leader and project site geologist examined cuttings and the natural gamma log to determine geologic contacts and hydrogeologic conditions. Drilling observations and water-level measurements were used to identify groundwater encountered at R-67.

## 5.1 Stratigraphy

Rock units for the R-67 borehole are presented below in order of youngest to oldest in stratigraphic occurrence. Lithologic descriptions are based on binocular microscope analysis of drill. Figure 5.1-1 illustrates the stratigraphy at R-67. A detailed lithologic log for R-67 is presented in Appendix A.

### Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (0–15 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff was encountered from 0 to 15 ft bgs. Unit 3 is a poorly to moderately welded devitrified ash-flow tuff (i.e., ignimbrite) that is crystal-rich, slightly pumiceous, and lithic-poor and exhibits a matrix of fine ash.

### Unit 2, Tshirege Member of the Bandelier Tuff, Qbt 2 (15–80 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff was encountered from 15 ft to 80 ft bgs. Unit 2 represents a moderately to strongly welded devitrified rhyolitic ash-flow tuff (i.e., ignimbrite) that is composed of abundant quartz and sanidine crystals. Cuttings typically contain abundant fragments of indurated tuff and numerous free quartz and sanidine crystals.

### Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (80–137 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff was encountered from 80 ft to 137 ft bgs. Unit 1v is a poorly to moderately welded, devitrified rhyolitic ash-flow tuff that is pumiceous, generally lithic-poor, and crystal-bearing to locally crystal-rich. Abundant ash matrix is rarely preserved in cuttings. Cuttings commonly contain numerous fragments of indurated crystal-rich tuff with devitrified pumice. Abundant free quartz and sanidine crystals dominate cuttings in many intervals and minor small (generally less than 10 mm in diameter) volcanic lithic inclusions also occur in cuttings.

### Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (137–235 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 137 ft to 235 ft bgs. Unit 1g is a poorly welded vitric rhyolitic ash-flow tuff that is poorly to moderately indurated, strongly pumiceous, and crystal-bearing. White to pale orange, lustrous, glassy pumice lapilli are characteristic of Unit 1g. Cuttings contain abundant free quartz and sanidine crystals and glassy pumices.

### Cerro Toledo Interval, Qct (235–260 ft bgs)

The Cerro Toledo interval was encountered from 235 ft to 260 ft bgs. The Cerro Toledo interval is a sequence of poorly consolidated tuffaceous and volcaniclastic sediments that occurs intermediately between the Tshirege and Otowi Members of the Bandelier Tuff. Sediments are largely stained with orange oxidation on grain surfaces.

### Otowi Member of the Bandelier Tuff, Qbo (260–580 ft bgs)

The Otowi Member of the Bandelier Tuff was encountered from 260 ft to 580 ft bgs. The Otowi Member is composed of poorly welded vitric rhyolitic ash-flow tuffs that are pumiceous and crystal- and lithic-bearing. Drill cuttings contain pale orange to white pumices, volcanic lithic clasts, and quartz and sanidine crystals. Lithic fragments are commonly subangular to subrounded and are generally of intermediate volcanic composition, including porphyritic dacites.

### Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (580–608 ft bgs)

The Guaje Pumice Bed represents an air-fall tephra deposit of rhyolitic pumice that forms the base of the Otowi Member. The Guaje deposit was encountered from 580 ft to 608 ft bgs. Drill cuttings in this interval contain abundant lustrous vitric pumice lapilli (up to 15 mm in diameter) with trace occurrences of small volcanic lithic fragments. The deposit is poorly consolidated.

### Puye Formation, Tpf (608–1145 ft bgs)

Puye Formation volcaniclastic sediments were encountered from 608 ft to 1145 ft bgs. The Puye Formation consists of alluvial fan deposits eroded from volcanic rocks in the nearby Jemez Mountains. Cuttings from this interval consist of grey, red, and purple dacitic and rhyolitic gravels, volcaniclastic sands, and minor devitrified pumice clasts. Cuttings are generally angular to subangular.

### Miocene Pumiceous Sediments, Tjfp (1145–1324.6 ft bgs)

A pumice-rich volcaniclastic section, referred to as Miocene Pumiceous Sediments, was intersected from 1145 ft bgs to the bottom of the R-67 borehole at 1324.6 ft bgs. This unassigned unit is locally interfingered with Puye Formation sediments. These sediments consist of fine to medium gravels with fine to coarse sands and are moderately to poorly sorted, are weakly cemented, and contain detrital pumices and perlite clasts.

## 5.2 Groundwater

Drilling at R-67 proceeded without any groundwater indications until 1240 ft bgs as noted by the drilling crew. The borehole was then advanced to the TD of 1324.6 ft bgs. The water level was 1226.4 ft bgs on August 18, before well installation. The DTW in the completed well was 1226.7 ft bgs on October 7.

During development, the average pumping rate was approximately 6.1 gallons per minute (gpm) with varying pump placement throughout the screened interval.

# 6.0 BOREHOLE LOGGING

On July 29, 2015, a video survey, natural gamma ray log and induction log were recorded. A natural gamma ray log was recorded on August 16, 2015, inside the 10-in. casing from 1324.6 ft to 400 ft bgs after the borehole was advanced to TD. On October 14, video and gamma ray logs were recorded in the completed well to confirm screen placement depth and filter pack location. Logging was conducted with Laboratory logging equipment and staff (Appendixes C and D). A summary of video and geophysical logging runs is presented in Table 6.0-1.

# 7.0 WELL INSTALLATION R-67 MONITORING WELL

The R-67 well was installed between August 27 and September 21, 2015.

## 7.1 Well Design

The R-67 well was designed in accordance with requirements in the Consent Order and NMED approved the final well design before the well was installed (Appendix E). The well was designed with a 20-ft-long screened interval between 1243 ft and 1263 ft bgs to monitor the groundwater quality near the top of the regional aquifer within the Miocene Pumiceous Sediments.

## 7.2 Well Construction

From August 19 to August 26, 2015, the stainless-steel well casing, screens, and tremie pipe were decontaminated, and the workover rig and initial well construction materials were mobilized to the site.

The R-67 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-O.D. type A304 passivated stainless-steel beveled casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The screened section utilized two 10-ft lengths of 5.0-in.-I.D. rod-based 0.040-in. slot wire-wrapped screens to make up the 20-ft-long screen interval. All individual casing and screen sections were welded together using compatible stainless-steel welding rods. A 2-in. steel tremie pipe was used to deliver backfill and annular fill materials down-hole during well construction. A short length of 16-in. (5.0-ft casing and shoe, from 410 ft to 415 ft bgs); 12-in. (7.3-ft casing and shoe, from 991.7 ft to 999 ft bgs); and 10-in. drill casing (5.0-ft casing and shoe, from 1319.3 ft to 1324.3 ft bgs) remain in the borehole. The 16-in. and 12-in. casing stubs were entombed in the upper bentonite seal, and the 10-in. casing stub was encased in slough and bentonite backfill at the bottom of the borehole.

A 10.3-ft-long stainless-steel sump was placed below the bottom of the well screen. The well casing was started into the borehole on August 27 at 0850 h. The well casing was hung by wireline with the bottom at 1273.7 ft bgs. However, during well construction, the casing was raised 0.4 ft, setting the bottom of the casing at 1273.3 ft bgs. Stainless-steel centralizers were welded to the well casing approximately 2.0 ft above and below the screened interval. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

The installation of annular materials began on September 4 after the bottom of the borehole was measured at 1321.7 ft bgs (approximately 2.9 ft of slough had accumulated in the borehole). The bentonite backfill was installed between September 4 and 5 from 1268.7 ft to 1321.7 ft bgs using 37.8 $ft^3$ of 3/8-in. bentonite chips.

The filter pack was installed between September 6 and 8 from 1238.4 ft to 1268.7 ft bgs using 22.5 $ft^3$ of 10/20 silica sand. The actual volume of filter pack sand was 62% greater than the calculated volume and is likely from an oversized borehole caused by sloughing in the unconsolidated Puye Formation. The filter pack was surged to promote compaction. The fine-sand collar was installed above the filter pack from 1235.9 ft to 1238.4 ft bgs using 1.0 $ft^3$ of 20/40 silica sand.

From September 8 to 9, the bentonite seal was installed from 1198.6 ft to 1235.9 ft bgs. On September 9, the well casing was accidentally raised while the 10-in. drill casing was being raised. The well casing was pushed back down to 0.4 ft from its original set depth. From September 9 to 11, the well was bailed and water was added to the well screen to run the subcontractor's video camera and record well screen and casing condition. The well screen and casing were observed to be in good condition and well construction continued. From September 11 to 21, the bentonite seal was installed to 60.2 ft bgs. Total 3/8-in. bentonite chips used for the seal from 60.2 ft to 1235.9 ft bgs was 1131.9 $ft^3$. On September 21, a cement seal was installed from 3.0 ft to 60.2 ft bgs. The cement seal used 101.6 $ft^3$ of Portland Type I/II/V cement. This volume exceeded the calculated volume of 70.4 $ft^3$ by 44% and is likely from cement loss to the near surface formations and a larger borehole diameter than used in the calculations because of some washout.

Operationally, well construction proceeded 12 h/d, 7 d/wk from August 27 to September 8, and 24 h/d, 7 d/wk, from September 9 to 21.

## 8.0 POST-INSTALLATION ACTIVITIES

Following well installation at R-67, the well was developed and aquifer pumping tests were conducted. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system was installed. Site restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved decision trees for land application of drill cuttings and groundwater.

### 8.1 Well Development

The well was developed between September 23 and October 6, 2015. Initially, the screened interval was swabbed and bailed to remove formation fines in the filter pack and well sump. Bailing continued until water clarity visibly improved. Final development was then performed with a submersible pump.

The swabbing tool employed was a 4.5-in.-O.D., 1-in.-thick nylon disc attached to a weighted steel rod. The wireline-conveyed tool was drawn repeatedly across the screened interval causing a surging action across the screen and filter pack. The bailing tool was a 4.0-in.-O.D. by 21.0-ft-long carbon-steel bailer with a total capacity of 12 gal. The tool was repeatedly lowered by wireline, filled, withdrawn from the well, and emptied into the cuttings pit. Approximately 390 gal. of groundwater was removed during bailing activities.

After bailing, a 5-horsepower (hp), 4-in. Grundfos submersible pump was installed in the well for the final stage of well development. The screened interval was pumped from top to bottom and from bottom to top in 2-ft increments from September 27 to 30. Purging continued from October 1 to 6 with the pump intake set below the bottom of the well screen. Approximately 33,903 gal. of groundwater was purged with the submersible pump during well development.

**Total Volumes of Introduced and Purged Water**

During drilling, approximately 5875 gal. of potable water was added below the top of the regional aquifer at approximately 1226 ft bgs. Approximately 10,577 gal. was added during installation of the annular seals. In total, approximately 16,452 gal. of potable water was introduced to the borehole below 1226 ft bgs during project activities.

Approximately 34,293 gal. of groundwater was purged at R-67 during well development activities. Another 6768 gal. was purged during aquifer testing. The total amount of groundwater purged during post-installation activities was 41,061 gal.

### 8.1.1 Well Development Field Parameters

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance in microSiemens per centimeter were measured. The required TOC and turbidity values for adequate well development are less than 2.0 mgC/L and less than 5 nephelometric turbidity units (NTU), respectively.

Field parameters were measured by collecting aliquots of groundwater from the discharge pipe with the use of a flow-through cell. The final parameters at the end of well development were pH of 7.38, temperature of 9.65ºC, specific conductance of 231 µS/cm, and turbidity of 3.7 NTU. TOC values ranged from 3.1 mgC/L to the final value of 1.6 mgC/L measured for a sample collected on October 5, 2015. Table B-2.2-1 in Appendix B shows field parameters and purge volumes measured during well development.

During the 24-h aquifer test, the turbidity values ranged from 1 to 82.6 NTU, with the final recorded value of 1.5 NTU.

## 8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-67 between October 7 and 12, 2015. Several short-duration tests with short-duration recovery periods were performed on the first 3 d of testing. A 24-h pump test with the pump intake at 1250.3 ft bgs, followed by a 24-h recovery period completed the testing of the screened interval. The average pumping rate for the 24-h test was approximately 3.7 gpm.

A 5-hp pump was used for the aquifer tests. A total of approximately 6768 gal. of groundwater was purged during aquifer testing. Turbidity, temperature, pH, DO, ORP, and specific conductance were measured during the aquifer tests. Measured parameters are presented in Appendix B. The R-67 aquifer test results and analysis are presented in Appendix F.

## 8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-67 was installed on December 1 and 2, 2015. The pumping system utilizes an environmentally retrofitted 4-in. 5-hp Grundfos submersible pump set in a shroud near the top of the screened interval. The pump column is constructed of 1-in. threaded/coupled passivated stainless-steel pipe. One 1-in. stainless-steel check valve was installed above the pump shroud to provide redundancy to the built-in check valve in the top of the pump body. A weep valve was installed at the bottom of the uppermost pipe joint to protect the pump column from freezing. To measure water levels in the well, two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) pipes were installed to sufficient depth to set a dedicated transducer and to provide access for manual water-level measurements. The PVC transducer tubes are equipped with 9-in. sections of 0.010-in. slot screen with a threaded end cap on the bottom of each tube. An In-Situ Level Troll 500 30-psig transducer was installed in one of the PVC tubes to monitor the water level in the well’s screened interval.

Sampling system details for R-67 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for the well. Figure 8.3-1c presents a performance curve for the submersible pump installed.

## 8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 10 in. thick, was installed at the R-67 wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 16-in.-O.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. Four bollards, painted yellow for visibility, were set at the outside edges of the pad to protect the well from traffic. All the bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

## 8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on November 12, 2015 (Table 8.5-1). The survey data conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground surface elevation near the concrete pad, the top of the brass survey marker in the concrete pad, the top of the well casing, and the top of the protective casing for the R-67 monitoring well.

### 8.6 Waste Management and Site Restoration

Waste generated from the R-67/CrCh-6 project included drilling fluids, purged groundwater, drill cuttings, decontamination water, and contact waste. A summary of the waste characterization samples collected during drilling, well construction and development of the R-67 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with “Waste Characterization Strategy Form for Installation of Regional Well R-67/CrCH-6” (LANL 2015, 601189).

Fluids produced during drilling, well development, and aquifer testing are expected to be land-applied after a review of associated analytical results per the waste characterization strategy form (WCSF) and the ENV-RCRA-QP-010.2, Land Application of Groundwater. If it is determined the drilling fluids are nonhazardous but cannot meet the criteria for land application, they will be evaluated for treatment and disposal at one of the Laboratory’s wastewater treatment facilities. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA-QP-011.2, Land Application of Drill Cuttings. If the drill cuttings do not meet the criteria for land application, they will be disposed of at an authorized facility.

Decontamination fluid used for cleaning equipment is containerized. The fluid waste was sampled and will be disposed of at an authorized facility. Characterization of contact waste will be based upon acceptable knowledge pending analyses of the waste samples collected from the drill cuttings, purge water, and decontamination fluid.

Site restoration activities will include removing drilling fluids and cuttings from the pit and managing the fluids and cuttings as described above, removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area, as appropriate.

## 9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Collection of core in 5-ft runs was planned at the approximate depths:

- 210 ft to 230 ft bgs, Cerro Toledo interval
- 565 ft to 595 ft bgs, Guaje Pumice Bed–Puye Formation contact
- 1150 ft to1200 ft bgs, base of the Puye Formation
- 1235 ft to 1255 ft bgs, top of the regional aquifer within the Miocene pumiceous unit

The actual collection depth of core was modified in the field based on the driller’s and project site geologist’s observations during drilling and examination of drill cuttings. The Laboratory subcontractor representative and geology task leader were consulted before deviations from planned collection depths were made.

On September 9, 2015, the well casing was accidentally raised while the 10-in. drill casing was being raised. The well casing was pushed back down to 0.4 ft from its original set depth. From September 9 to 11, the well was bailed and water was added to the well screen to run the subcontractor's video camera and record well screen and casing condition. The well screen and casing were observed to be in good condition and well construction continued.

Drilling, sampling, and well construction at R-67 were performed as specified in "Drilling Work Plan for Combined Groundwater Monitoring Well R-67 and CrCH-6" (LANL 2015, 600265).

## 10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the combined monitoring well R-67 and CrCH-6.

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

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

## 11.0 REFERENCES AND MAP DATA SOURCES

### 11.1 References

*The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID or ESH ID. This information is also included in text citations. ER IDs were assigned by the EP Directorate's Records Processing Facility (IDs through 599999), and ESH IDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.*

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

LANL (Los Alamos National Laboratory), September 2012. "Phase II Investigation Report for Sandia Canyon," Los Alamos National Laboratory document LA-UR-12-24593, Los Alamos, New Mexico. (LANL 2012, 228624)

LANL (Los Alamos National Laboratory), March 2015. "Drilling Work Plan for Combined Groundwater Monitoring Well R-67 and CrCH-6," Los Alamos National Laboratory document LA-UR-15-21004, Los Alamos, New Mexico. (LANL 2015, 600265)

LANL (Los Alamos National Laboratory), March 2, 2015. "Waste Characterization Strategy Form for Installation of Regional Well R-67/CrCH-6," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2015, 601189)

LANL (Los Alamos National Laboratory), June 18, 2015. "Storm Water Pollution Prevention Plan, R-67/CrCH-6 Well Drilling Project, Los Alamos National Laboratory," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2015, 601185)

NMED (New Mexico Environment Department), February 19, 2014. "Approval with Modifications, Phase II Investigation Report for Sandia Canyon," New Mexico Environment Department letter to P. Maggiore (DOE-LASO) and J.D. Mousseau (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2014, 524467)

NMED (New Mexico Environment Department), April 2, 2015. "Approval with Modifications, Drilling Work Plan for Combined Groundwater Monitoring Well R-67 and CrCH-6," New Mexico Environment Department letter to P. Maggiore (DOE-NA-LA) and M. Brandt (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2015, 600341)

TerranearPMC, July 2015. "Field Implementation Plan for Combined Regional Aquifer Well R-67 and Corehole 6 (CrCH-6)," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2015, 601188)

TerranearPMC, July 9, 2015. "IWD [Integrated Work Document] for Drilling and Installation of LANL Well R-67," Los Alamos, New Mexico. (TerranearPMC 2015, 601190)

### 11.2 Map Data Sources

Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2008-0109; 12 April 2010.

Hypsography, 100 and 20 Foot Contour Interval; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1991.

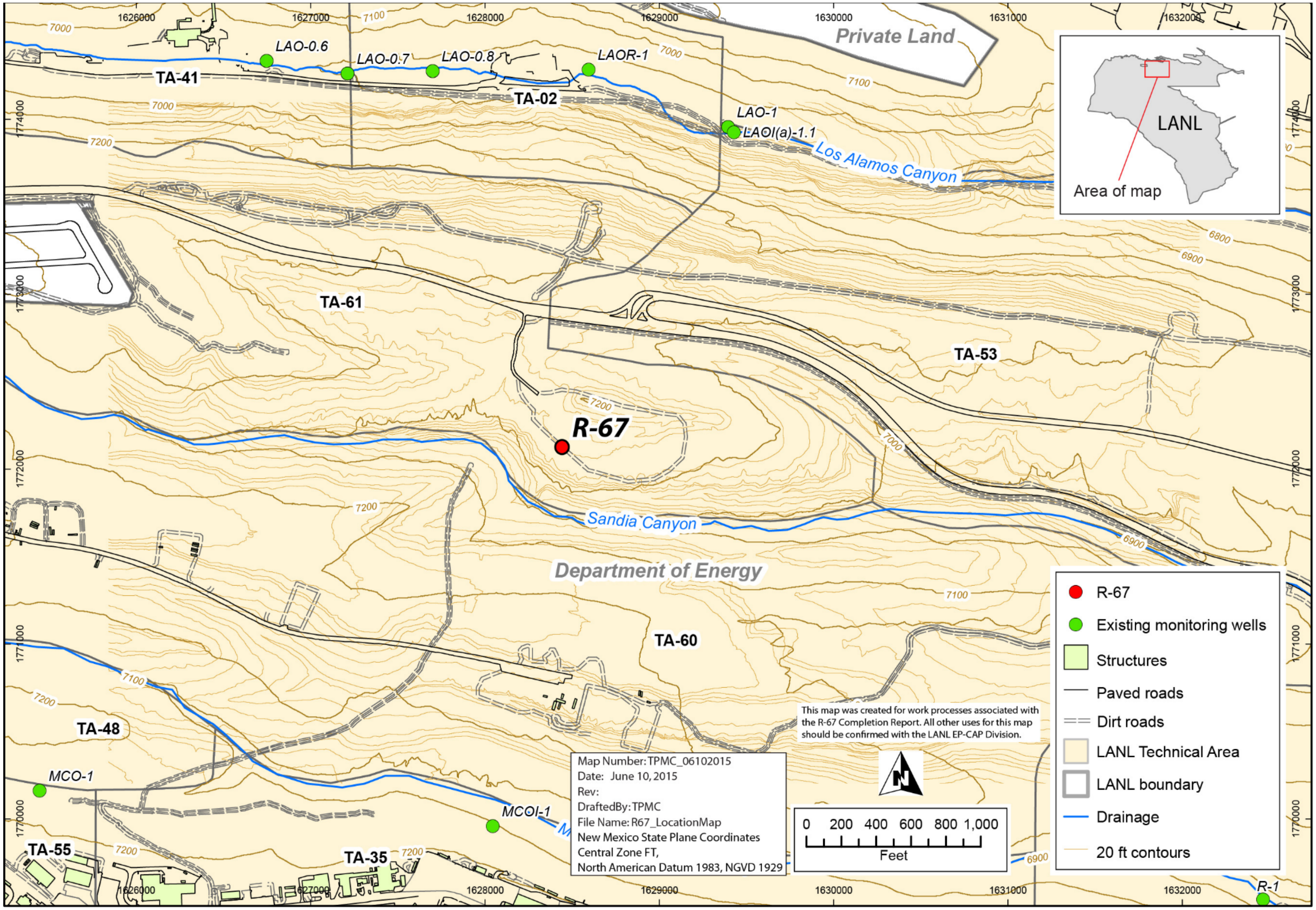
Surface Drainages, 1991; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program, ER2002-0591; 1:24,000 Scale Data; Unknown publication date.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

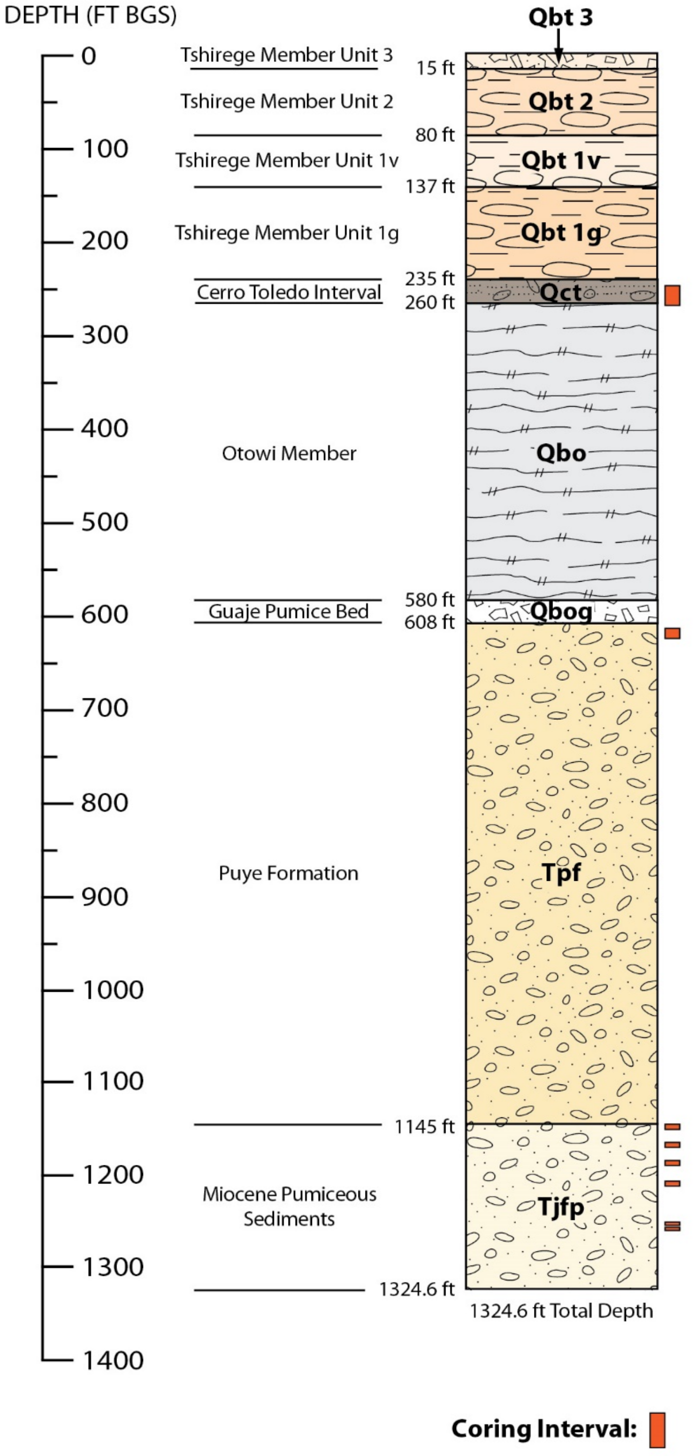
Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Division; 4 December 2009.



This map was created for work processes associated with the R-67 Completion Report. All other uses for this map should be confirmed with the LANL EP-CAP Division.

Map Number: TPMC_06102015
Date: June 10, 2015
Rev:
DraftedBy: TPMC
File Name: R67_LocationMap
New Mexico State Plane Coordinates
Central Zone FT,
North American Datum 1983, NGVD 1929

Figure 1.0-1 Location of monitoring well R-67



## DRILLING INFORMATION

**DRILLING COMPANY/PERSONNEL:**
Boart Longyear
D. Sandy, D. Tucker, R. Ostler

**DRILL RIG:** Foremost DR-24HD

**DRILLING METHOD:**
☒ DUAL ROTARY ☒ AIR ROTARY

**DRILLING FLUID TYPE:**

| 0–1115 ft bgs | 1115–1324.6 ft bgs |
|---|---|
| ☒ WATER | ☒ WATER |
| ☒ AIR | ☒ AIR |
| ☒ QUIK FOAM FOAMING AGENT | |

**DRILLING START/FINISH:**
DATE: 07/17/2015 TIME: 1435
DATE: 08/16/2015 TIME: 0413

**CORING INTERVALS:**
241.0 - 261.3 FT BGS
610.9 - 620.1 FT BGS
1145.4 - 1150.4 FT BGS
1165.8 - 1170.4 FT BGS
1184.7 - 1188.9 FT BGS
1205.4 - 1209.2 FT BGS
1251.2 - 1253.7 FT BGS
1255.6 - 1260.7 FT BGS

▼ 1226.4 ft bgs (08/18/15)
(pre well installation)

TerranearPMC

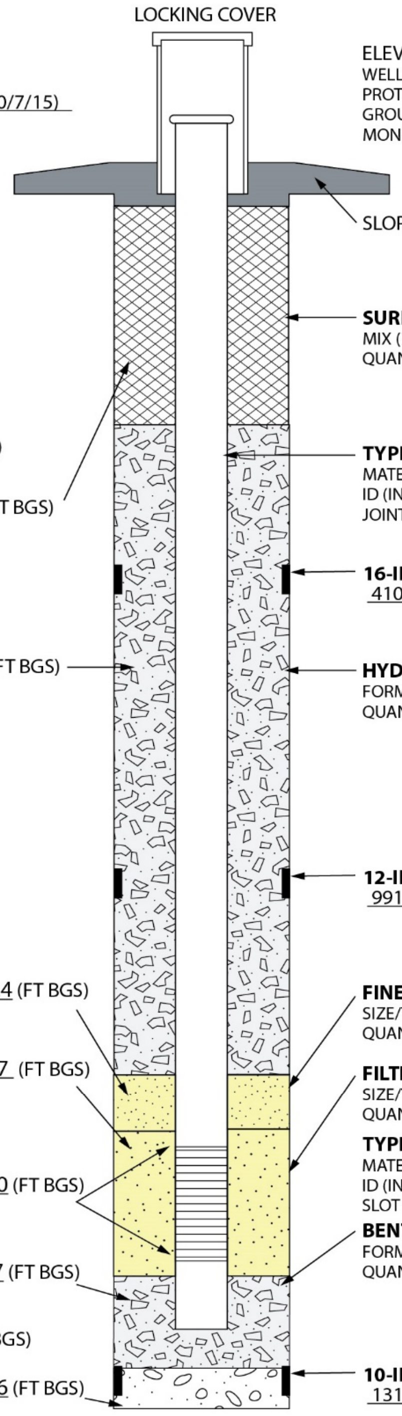
Drafted By: TPMC
Project Number: 86318

Date: October 8, 2015
Filename: R67_Lithology_FactSheet

**Borehole Stratigraphy for Combined Groundwater Monitoring Well R-67 and Corehole CrCH-6**
Technical Area 61 (TA-61)
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure
**5.1-1**
**NOT TO SCALE**

**Figure 5.1-1 Monitoring well R-67 borehole stratigraphy**



TOTAL LENGTH
OF CASING AND SCREEN (FT) 1275.7

DEPTH TO WATER
FOLLOWING INSTALLATION (FT BGS) 1226.7 (10/7/15)

DIAMETER OF BOREHOLE
16.00 (IN) FROM 0 TO 415 (FT BGS)
15.00 (IN) FROM 415 TO 555 (FT BGS)
12.75 (IN) FROM 555 TO 999 (FT BGS)
10.75 (IN) FROM 999 TO 1324.6 (FT BGS)

**SURFACE COMPLETION**
PROTECTIVE CASING
TYPE STEEL SIZE (IN) 16
PROTECTIVE POSTS INSTALLED __
SURFACE SEAL AND PAD
CHECK FOR SETTLEMENT __
PAD MATERIAL __
REINFORCED __
PAD DIMENSIONS (FT) 10 (L) 10 (W) 0.8 (H)

**SURFACE SEAL** 3.0 TO 60.2 (FT BGS)

**HYDRATED BENTONITE CHIP SEAL** 60.2 TO 1235.9(FT BGS)

**FINE SAND COLLAR** 1235.9 TO 1238.4 (FT BGS)

**FILTER PACK** 1238.4 TO 1268.7 (FT BGS)

***SCREENED INTERVAL*** 1242.6 TO 1263.0 (FT BGS)

**BENTONITE SEAL** 1268.7 TO 1321.7 (FT BGS)

**BOTTOM OF CASING** 1273.3 (FT BGS)

**SLOUGH** 1321.7 TO 1324.6 (FT BGS)

**BOTTOM OF BORING** 1324.6

ELEVATIONS (FT AMSL)
WELL CAP 7125.69
PROTECTIVE CASING 7126.73
GROUND SURFACE 7122.71
MONUMENT MARKER 7123.25

**SURFACE SEAL**
MIX (WT%) CEMENT 100 BENTONITE 0
QUANTITY USED 101.6 CALCULATED 70.4

**TYPE OF CASING**
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.56 ($5\frac{9}{16}$)
JOINT TYPE BEVELED/WELDED

**16-IN CASING/SHOE**
410.0 TO 415.0 (FT BGS)

**HYDRATED BENTONITE SEAL**
FORM CHIP
QUANTITY USED (FT$^3$) 1131.9 CALCULATED (FT$^3$) 1012.1

**12-IN CASING/SHOE**
991.7 TO 999.0 (FT BGS)

**FINE SAND COLLAR**
SIZE/TYPE 20/40 SILICA
QUANTITY USED (FT$^3$) 1.0 CALCULATED (FT$^3$) 1.2

**FILTER PACK SAND**
SIZE/TYPE 10/20 SILICA
QUANTITY USED (FT$^3$) 22.5 CALCULATED (FT$^3$) 13.9

**TYPE OF SCREEN**
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.88 ($5\frac{7}{8}$)
SLOT SIZE (IN) 0.040 JOINT TYPE BEVELED/WELDED

**BENTONITE SEAL**
FORM CHIP
QUANTITY USED(FT$^3$) 37.8 CALCULATED(FT$^3$) 32.4

**10-IN CASING/SHOE**
1319.3 TO 1324.3 (FT BGS)

**STAINLESS-STEEL CENTRALIZERS**
USED 4 AT 2.0 ft ABOVE AND
BELOW WELL SCREENS

**WELL COMPLETION BEGAN**
DATE 8/27/15 TIME 0850
**WELL COMPLETION FINISHED**
DATE 9/21/15 TIME 1745

TerranearPMC

Drafted By: TPMC
Project Number: 86318
Date: December 17, 2015
File Name: R-67_WellAsBuiltFactSheet

**As-Built Well Construction for Combined Groundwater Monitoring Well R-67 and Corehole CrCH-6**
Technical Area 61 (TA-61)
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure
**7.2-1**
**NOT TO SCALE**

**Figure 7.2-1 Monitoring well R-67 as-built well construction diagram**

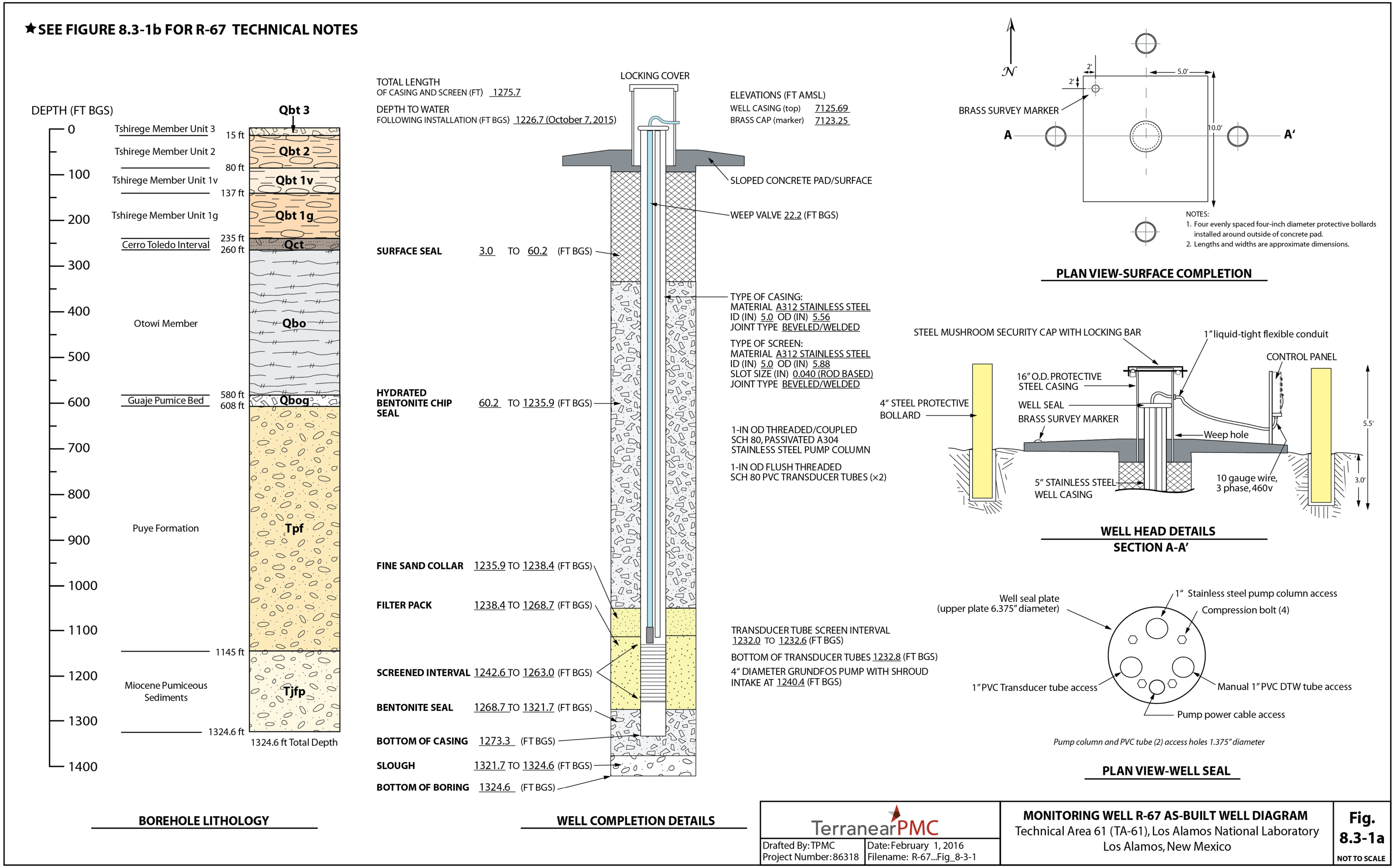


**Figure 8.3-1a Monitoring well R-67 as-built diagram with borehole lithology and technical well completion details**

# R-67 TECHNICAL NOTES:

## SURVEY INFORMATION*

**Brass Marker**

| | |
|---|---|
| Northing: | 1772073.07 ft |
| Easting: | 1628530.72 ft |
| Elevation: | 7123.25 ft AMSL |

**Well Casing** (top of stainless steel)

| | |
|---|---|
| Northing: | 1772069.22 ft |
| Easting: | 1628533.56 ft |
| Elevation: | 7125.69 ft AMSL |

## BOREHOLE GEOPHYSICAL LOGS

LANL video and natural gamma logs

## DRILLING INFORMATION

**Drilling Company**

Boart Longyear

**Drill Rig**

Foremost DR-24HD

**Drilling Methods**

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

**Drilling Fluids**

Air, potable water, AQF-2 Foam (to 1115 ft bgs)

## MILESTONE DATES

**Drilling**

| | |
|---|---|
| Start: | 07/17/2015 |
| Finished: | 08/16/2015 |

**Well Completion**

| | |
|---|---|
| Start: | 08/27/2015 |
| Finished: | 09/21/2015 |

**Well Development**

| | |
|---|---|
| Start: | 09/23/2015 |
| Finished: | 10/06/2015 |

## WELL DEVELOPMENT

**Development Methods**

Performed swabbing, bailing, and pumping
Total Volume Purged: 34,293 gal.

**Parameter Measurements (Final)**

| | |
|---|---|
| pH: | 7.38 |
| Temperature: | 9.65°C |
| Specific Conductance: | 231 µS/cm |
| Turbidity: | 3.7 NTU |

## AQUIFER TESTING

Constant Rate Pumping Test

| | |
|---|---|
| Water Produced: | 6768 gal. |
| Average Flow Rate: | 3.7 gpm |
| Performed on: | 10/07–12/2015 |

## DEDICATED SAMPLING SYSTEM

**Pump (Shrouded)**

Make: Grundfos
Model: 10S50-930CBM
S/N: P11432247
Environmental retrofit
Top of pump intake 1238.0 ft bgs
Base of shroud 1240.4 ft bgs

**Motor**

Make: Franklin Electric
Model: 2343278602
5 hp, 3-phase, 460V

**Pump Shroud**

Pumps of Oklahoma custom 4.6-in. O.D. schd. 5
A304 stainless steel with schd. 40 pipe connections

**Pump Column**

1-in. threaded/coupled schd. 80, pickled and
passivated A304 stainless steel tubing
Weep valve installed at 22.2 ft bgs
Check valve installed at 1232.8 ft bgs

**Transducer Tubes**

2 × 1-in. flush threaded schd. 80 PVC tubing,
0.010-in. slot screens at 1232.0-1232.6 ft bgs

**Transducer**

Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/N: 430572

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

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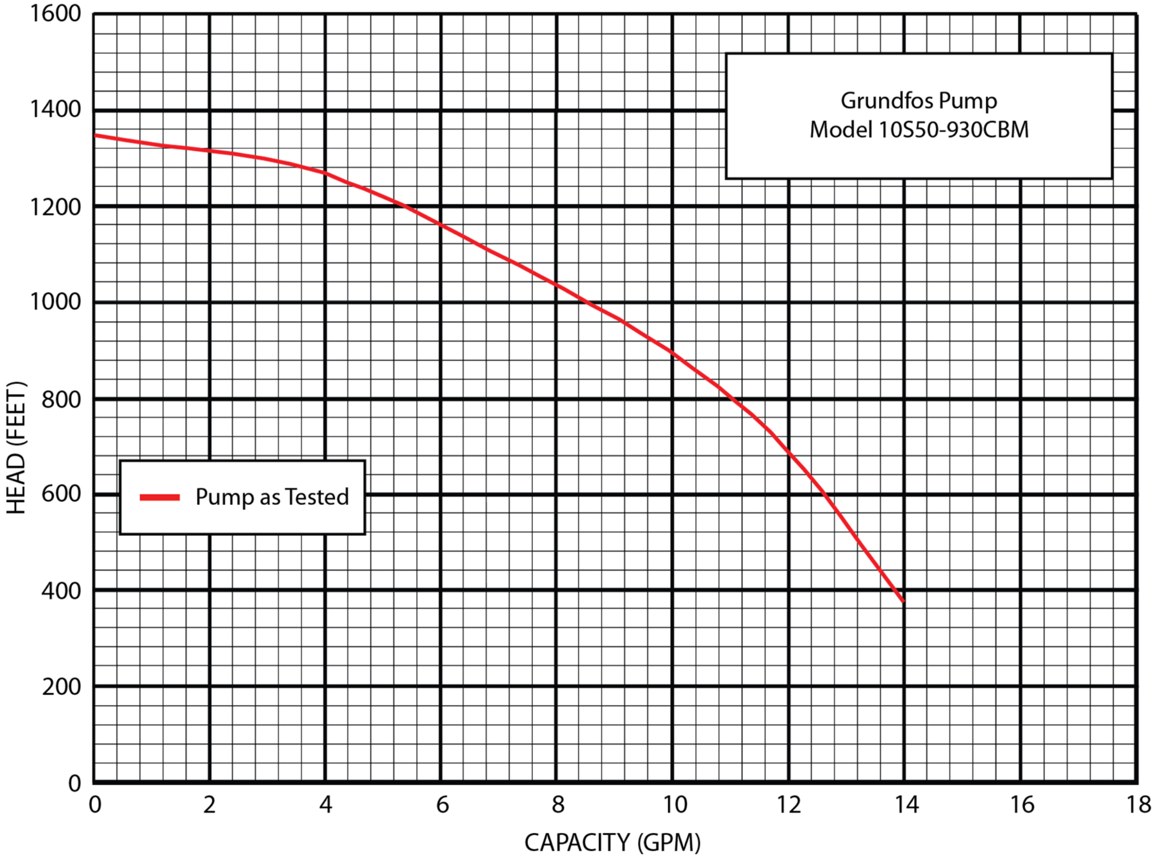
| | | | |
|---|---|---|---|
| Drafted By: TPMC<br>Project Number: 86318 | Date: February 1, 2016<br>Filename: R-67_TechnicalNotes_Fig8.3-1b | **R-67 TECHNICAL NOTES**<br>Technical Area 61 (TA-61)<br>Los Alamos National Laboratory<br>Los Alamos, New Mexico | **Fig. 8.3-1b**<br>**NOT TO SCALE** |

**Figure 8.3-1b As-built technical notes for monitoring well R-67**

**R-67 PUMP CURVE:**



TerranearPMC

| | |
|---|---|
| Drafted By: TPMC<br>Project Number: 86318 | Date: December 4, 2015<br>Filename: R-67_PumpCurves_Fig8-3-1c |

**R-67 DEDICATED PUMP PERFORMANCE CURVE**
Technical Area 61 (TA-61), Los Alamos National Laboratory
Los Alamos, New Mexico

**Fig.
8.3-1c**
**NOT TO SCALE**

**Figure 8.3-1c Pump curve for monitoring well R-67**

### Table 3.1-1
### Fluid Quantities Used during R-67 Drilling and Well Construction

| Date | Depth Interval (ft bgs) | Water (gal.) | Cumulative Water (gal.) | Quick Foam (gal.) | Cumulative Quick Foam (gal.) |
|---|---|---|---|---|---|
| **Drilling** | | | | | |
| 7/17/15 | 0–115 | 2150 | 2150 | 1.75 | 1.75 |
| 7/18/15 | 115–155 | 1000 | 3150 | 1 | 2.75 |
| 7/19/15 | 155–244 | 2125 | 5275 | 2.75 | 5.5 |
| 7/21/15 | 244–280 | 1050 | 6325 | 3.75 | 9.25 |
| 7/22/15 | 280–420 | 2075 | 8400 | 7 | 16.25 |
| 7/23/15 | 420–455 | 1225 | 9625 | 4 | 20.25 |
| 7/24/15 | 455–555 | 2025 | 11,650 | 7 | 27.25 |
| 7/26/15 | 555–600 | 1365 | 13,015 | 5.5 | 32.75 |
| 7/27/15 | 600–614 | 1125 | 14,140 | 5.75 | 38.5 |
| 7/28/15 | 614–617 | 375 | 14,515 | 1 | 39.5 |
| 7/29/15 | 617–700 | 1525 | 16,040 | 6.5 | 46 |
| 7/30/15 | Circulate borehole | 300 | 16,340 | 0.25 | 46.25 |
| 7/31/15 | 700–820 | 2750 | 19,090 | 9.5 | 55.75 |
| 8/1/15 | 820–999 | 5975 | 25,065 | 20 | 75.75 |
| 8/5/15 | 999–1095 | 2950 | 28,015 | 13 | 88.75 |
| 8/6/15 | 1095–1145 | 1400 | 29,415 | 1.75 | 90.5 |
| 8/7/15 | 1145–1170 | 300 | 29,715 | n/a* | 90.5 |
| 8/8/15 | 1170–1189 | 300 | 30,015 | n/a | 90.5 |
| 8/9/15 | 1189–1215 | 675 | 30,690 | n/a | 90.5 |
| 8/10/15 | 1215–1245 | 1400 | 32,090 | n/a | 90.5 |
| 8/11/15 | 1245–1251 | 400 | 32,490 | n/a | 90.5 |
| 8/12/15 | 1251–1256 | 300 | 32,790 | n/a | 90.5 |
| 8/14/15 | LANL Video lost tool (not recorded) | 2000 | 34,790 | n/a | 90.5 |
| 8/15/15 | 1256–1324.6 | 2175 | 36,965 | n/a | 90.5 |
| **Well Construction** | | | | | |
| 9/4/15 | 1321.7–1300 | 2939 | 2939 | n/a | n/a |
| 9/5/15 | 1300–1265 | 3118 | 6057 | n/a | n/a |
| 9/6/15 | 1265–1238 | 1756 | 7813 | n/a | n/a |
| 9/8/15 | 1238–1213 | 2212 | 10,025 | n/a | n/a |
| 9/9/15 | 1213–1174 | 2508 | 12,533 | n/a | n/a |
| 9/10/15 | Subcontractor Video well casing (not recorded) | 553 | 13,086 | n/a | n/a |
| 9/11/15 | 1174–1125 | 1941 | 15,027 | n/a | n/a |
| 9/12/15 | 1125–1019 | 7522 | 22,549 | n/a | n/a |

### Table 3.1-1 (continued)

| Date | Depth Interval (ft bgs) | Water (gal.) | Cumulative Water (gal.) | Quick Foam (gal.) | Cumulative Quick Foam (gal.) |
|---|---|---|---|---|---|
| 9/13/15 | 1019–1008 | 745 | 23,294 | n/a | n/a |
| 9/15/15 | 1008–990 | 35 | 23,329 | n/a | n/a |
| 9/16/15 | 990–924 | 4620 | 27,949 | n/a | n/a |
| 9/17/15 | 924–780 | 546 | 28,495 | n/a | n/a |
| 9/18/15 | 780–484 | 760 | 29,255 | n/a | n/a |
| 9/19/15 | 484–422 | 260 | 29,515 | n/a | n/a |
| 9/20/15 | 422–120 | 1422 | 30,937 | n/a | n/a |
| 9/21/15 | 120–3 | 656 | 31,593 | n/a | n/a |
| **Total Water Volume (gal.)** | | | | | |
| R-67 | 68,558 | | | | |

*n/a = Not applicable.

### Table 4.1-1
### Summary of Coring Depth Intervals

| Depth Interval Attempted (ft bgs) | Depth Interval Retrieved (ft bgs) |
|---|---|
| 241–246 | 241–244 |
| 244–249 | 244–248 |
| 248–253 | 248–252 |
| 252–257 | 252–256.3 |
| 256.3–261.3 | 256.3–261.3 |
| 610.6–615.6 | 610.9–614.6 |
| 614.6–619.6 | 613.6–617.0 |
| 617.0–620.9 | 616.6–620.1 |
| 1145–1150 | 1145.4–1150.4 |
| 1165–1170 | 1165.8–1170.4 |
| 1185–1190 | 1184.7–1188.9 |
| 1205–1210 | 1205.4–1209.2 |
| 1245–1250 | No recovery |
| 1245.8–1250.8 | No recovery |
| 1251.2–1256.2 | 1251.2–1253.7 |
| 1255.6–1260.6 | 1255.6–1260.7 |

### Table 4.2-1
### Summary of Groundwater Screening Samples Collected during Coring, Well Development, and Aquifer Testing at Combined Monitoring Well R-67 and CrCH-6

| Location ID | Sample ID | Date Collected | Collection Depth (ft bgs) | Sample Type | Analysis |
|---|---|---|---|---|---|
| **Coring** | | | | | |
| Corehole 6 | CrCH6-15-103070 | 7/20/15 | 241–244 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-103066 | 7/21/15 | 244–248 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-103067 | 7/21/15 | 248–252 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-103068 | 7/21/15 | 252–256.3 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-103069 | 7/21/15 | 256.3–261.3 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-102741 | 7/27/15 | 610–611 | Groundwater, Air-lift | Alkalinity, pH |
| Corehole 6 | CrCH6-15-102746 | 7/27/15 | 610–611 | Groundwater, Air-lift | Anions, Metals |
| Corehole 6 | CrCH6-15-102788 | 7/27/15 | 610.9–614.6 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-102789 | 7/28/15 | 616.6–620.1 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-102742 | 7/30/15 | 700 | Groundwater, Air-lift | Alkalinity, pH |
| Corehole 6 | CrCH6-15-102747 | 7/30/15 | 700 | Groundwater, Air-lift | Anions, Metals |
| Corehole 6 | CrCH6-15-103136 | 8/7/15 | 1145.4–1150.4 | Core water, Core barrel | Alkalinity, pH |
| Corehole 6 | CrCH6-15-103166 | 8/7/15 | 1145.4–1150.4 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-103137 | 8/8/15 | 1165.8–1170.4 | Core water, Core barrel | Alkalinity, pH |
| Corehole 6 | CrCH6-15-103167 | 8/8/15 | 1165.8–1170.4 | Core water, Core barrel | Anions, Metals |
| Corehole 6 | CrCH6-15-103138 | 8/9/15 | 1205.4–1209.2 | Core water, Core barrel | Alkalinity, pH |
| Corehole 6 | CrCH6-15-103168 | 8/9/15 | 1205.4–1209.2 | Core water, Core barrel | Anions, Metals |
| **Well Development** | | | | | |
| R-67 | GWR67-15-102751 | 9/27/15 | 1244.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102752 | 9/28/15 | 1244.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102753 | 9/29/15 | 1251.6 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102754 | 9/30/15 | 1267.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102755 | 10/1/15 | 1267.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102756 | 10/2/15 | 1267.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102757 | 10/3/15 | 1267.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102758 | 10/4/15 | 1267.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102759 | 10/5/15 | 1267.7 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102760 | 10/6/15 | 1267.7 | Groundwater, Pumped | TOC |
| **Aquifer Testing** | | | | | |
| R-67 | GWR67-15-102766 | 10/10/15 | 1250.3 | Groundwater, Pumped | Anions, Metals, Alkalinity, pH |
| R-67 | GWR67-15-102767 | 10/11/15 | 1250.3 | Groundwater, Pumped | Anions, Metals, Alkalinity, pH |
| R-67 | GWR67-15-102761 | 10/11/15 | 1250.3 | Groundwater, Pumped | TOC |

## Table 6.0-1
## R-67 Video and Geophysical Logging Runs

| Date | Logging Interval | Description |
|---|---|---|
| 7/29/15 | 0–617.0 ft bgs | Laboratory video 0–616 ft bgs. Laboratory natural gamma ray log 618.9–0 ft bgs. Laboratory induction log 619–535 ft bgs. |
| 8/14/15 | 0–1256 ft bgs | Laboratory video 0–1256 ft bgs to locate top of lost tooling (not recorded). |
| 8/16/15 | 0–1324.6 ft bgs | Laboratory natural gamma ray log run through 10-in. casing 1324–400 ft bgs. |
| 10/14/15 | 0–1273.3 ft bgs | Laboratory video 0–1270.5 ft bgs. Laboratory natural gamma ray log run in the completed well casing 1273–473 ft bgs. |

## Table 7.2-1
## R-67 Monitoring Well Annular Fill Materials

| Material | Volume |
|---|---|
| Upper surface seal: cement slurry | 101.6 $ft^3$ |
| Upper bentonite seal: bentonite chips | 1131.9 $ft^3$ |
| Fine sand collar: 20/40 silica sand | 1.0 $ft^3$ |
| Filter pack: 10/20 silica sand | 22.5 $ft^3$ |
| Backfill: bentonite chips | 37.8 $ft^3$ |

## Table 8.5-1
## R-67 Survey Coordinates

| Identification | Northing | Easting | Elevation |
|---|---|---|---|
| R-67 brass survey marker embedded in pad | 1772073.07 | 1628530.72 | 7123.25 |
| R-67 ground surface near pad | 1772079.07 | 1628528.33 | 7122.71 |
| R-67 top of stainless-steel well casing | 1772069.22 | 1628533.56 | 7125.69 |
| R-67 top of 16-in. protective casing | 1772069.14 | 1628532.70 | 7126.73 |

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

## Table 8.6-1
## Summary of Waste Samples Collected during Drilling, Development, and Sample System Installation at R-67

| Location ID | Sample ID | Date Collected | Description | Sample Type |
|---|---|---|---|---|
| R-67 | WST61-15-102547 | 7/20/15 | Drill fluids VOC[a]/SVOC[b] initial sample – UF[c] | Liquid |
| R-67 | WST61-15-102550 | 7/20/15 | Drill fluids VOC/SVOC initial sample – UF FD[d] | Liquid |
| R-67 | WST61-15-102553 | 7/20/15 | Drill fluids VOC/SVOC initial sample – UF FTB[e] | Liquid |
| R-67 | WST61-15-102548 | 7/30/15 | Drill fluids VOC/SVOC midpoint sample – UF | Liquid |
| R-67 | WST61-15-102551 | 7/30/15 | Drill fluids VOC/SVOC midpoint sample – UF FD | Liquid |
| R-67 | WST61-15-102554 | 7/30/15 | Drill fluids VOC/SVOC midpoint sample – UF FTB | Liquid |
| R-67 | WST61-15-102549 | 8/16/15 | Drill fluids VOC/SVOC final sample – UF | Liquid |
| R-67 | WST61-15-102552 | 8/16/15 | Drill fluids VOC/SVOC final sample – UF FD | Liquid |
| R-67 | WST61-15-102555 | 8/16/15 | Drill fluids VOC/SVOC final sample – UF FTB | Liquid |
| R-67 | WST61-15-105182 | 9/30/15 | Drill fluids non-VOC sample – UF | Liquid |
| R-67 | WST61-15-105181 | 9/30/15 | Drill fluids non-VOC sample – F[f] | Liquid |
| R-67 | WST61-15-102541 | 7/20/15 | Drill cuttings VOC initial sample | Solid |
| R-67 | WST61-15-102544 | 7/20/15 | Drill cuttings VOC initial sample – FTB | Solid |
| R-67 | WST61-15-102542 | 7/30/15 | Drill cuttings VOC midpoint sample | Solid |
| R-67 | WST61-15-102545 | 7/30/15 | Drill cuttings VOC midpoint sample – FTB | Solid |
| R-67 | WST61-15-102543 | 7/30/15 | Drill cuttings VOC final sample | Solid |
| R-67 | WST61-15-102546 | 7/30/15 | Drill cuttings VOC final sample – FTB | Solid |
| R-67 | WST61-15-105180 | 9/30/15 | Drill cuttings non-VOC sample | Solid |
| R-67 | WST61-15-105525 | 12/9/15 | Decontamination fluids sample – F | Liquid |
| R-67 | WST61-15-105526 | 12/9/15 | Decontamination fluids sample – UF | Liquid |
| R-67 | WST61-15-105527 | 12/9/15 | Decontamination fluids sample – FD | Liquid |
| R-67 | WST61-15-105528 | 12/9/15 | Decontamination fluids sample – FTB | Liquid |
| R-67 | WST61-15-105529 | 12/9/15 | Development fluids sample – F | Liquid |
| R-67 | WST61-15-105530 | 12/9/15 | Development fluids sample – UF | Liquid |
| R-67 | WST61-15-105531 | 12/9/15 | Development fluids sample – FD | Liquid |
| R-67 | WST61-15-105532 | 12/9/15 | Development fluids sample – FTB | Liquid |

[a] VOC = Volatile organic compound.

[b] SVOC = Semivolatile organic compound.

[c] UF = Unfiltered sample.

[d] FD = Field duplicate.

[e] FTB = Field trip blank.

[f] F = Filtered sample.

# Appendix A

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## *Borehole R-67/CrCH-6 Lithologic Log*

| | | |
|---|---|---|
| **BOREHOLE IDENTIFICATION (ID):**<br>R-67/CrCH-6 | **TECHNICAL AREA (TA):** 61 | |
| **DRILLING COMPANY:** Boart Longyear Company | **START DATE/TIME:** 07/17/2015; 1435 | **END DATE/TIME:** 08/16/2015; 0413 |
| **DRILLING METHOD:** Dual Rotary | **MACHINE**: Foremost DR-24 HD | **SAMPLING METHOD:** Grab/core |
| **GROUND ELEVATION:** 7122.71 ft amsl | | **TOTAL DEPTH:** 1324.6 ft |
| **DRILLERS:** D. Sandy, D. Tucker, R. Ostler | **SITE GEOLOGISTS:** T. Naibert, T. Sower, J. Jordan, L. Anderson | |

| DEPTH (ft bgs) | LITHOLOGY | LITHOLOGIC SYMBOL | NOTES |
|---|---|---|---|
| 0–5 | **UNIT 3 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:**<br>Rhyolitic Tuff—Light gray (N8) moderately welded, crystal-bearing tuff with minor lithic fragments<br>0–5 ft WR/+10F: 60%–70% welded ash flow tuff fragments; 25%–35% quartz and sanidine crystals; 20% fragments of asphalt-covered fill material from drill pad construction; <5% rhyolitic and dacitic lithic clasts.<br>+35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 3 | Note: Drill cuttings for descriptive analysis were collected at 5-ft intervals from ground surface to borehole total depth (TD) at 1324.6 ft below ground surface (bgs). |
| 5–15 | Rhyolitic Tuff—Light gray (N8) moderately welded, crystal-bearing tuff with minor lithic fragments<br>5–15 ft WR/+10F: 60%–70% welded ash flow tuff fragments; 25%–35% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts.<br>+35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 3 | The Qbt3/Qbt2 contact, estimated at 15 ft bgs, is based on natural gamma logging. |
| 15–30 | **UNIT 2 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:**<br>Rhyolitic Tuff—gray (N6) to pale purple (5P 6/2), strongly welded, crystal-rich tuff.<br>15–30 ft WR/+10F: 80%–90% welded ash flow tuff fragments; 10%–20% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts.<br>+35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 2 | Unit 2 of the Tshirege Member of the Bandelier Tuff (Qbt 2), encountered from 15 ft to 80 ft bgs, is approximately 65 ft thick. |
| 30–35 | Rhyolitic Tuff—gray (N6) to pale purple (5P 6/2), strongly welded, crystal-rich tuff.<br>30–35 ft WR/+10F: 90% welded ash flow tuff fragments; 5% rhyolitic and dacitic lithic clasts; <5% quartz and sanidine crystals.<br>+35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 2 | Note: Larger, rounded lithic and tuff fragments in this zone. |

| DEPTH (ft bgs) | LITHOLOGY | LITHOLOGIC SYMBOL | NOTES |
|---|---|---|---|
| 35–60 | Rhyolitic Tuff—gray (N6) to pale purple (5P 6/2), strongly welded, crystal-rich tuff.<br>35–60 ft WR/+10F: 80%–90% welded ash flow tuff fragments; 10%–20% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts.<br>+35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 2 | Note: More purple than above. |
| 60–80 | Rhyolitic Tuff—gray (N6) to pale purple (5P 6/2), strongly welded, crystal-rich tuff.<br>60–80 ft WR/+10F: 40%–60% welded ash flow tuff fragments; 40%–60% quartz and sanidine crystals; trace rhyolitic and dacitic lithic clasts.<br>+35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 2 | The Qbt2/Qbt1v contact, estimated at 80 ft bgs, is based on change in penetration rate during drilling. |
| 80–85 | **UNIT 1v OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:**<br>Rhyolitic Tuff—gray (N6), moderately welded, crystal-rich tuff.<br>80–85 ft WR/+10F/+35F: 80%–95% quartz and sanidine crystals; 5%–20% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 1v | Unit 1v of the Tshirege Member of the Bandelier Tuff (Qbt 1v), encountered from 80 to 140 ft bgs, is approximately 60 ft thick. |
| 85–90 | Rhyolitic Tuff—gray (N6), moderately welded, crystal-rich tuff.<br>85–90 ft WR/+35F: 80%–95% quartz and sanidine crystals; 5%–20% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts.<br>+10F: 50% rounded, welded ash flow tuff fragments; 50% dacitic lithic fragments. | Qbt 1v | |
| 90–120 | Rhyolitic Tuff—gray (N6), moderately welded, crystal-rich tuff.<br>90–120 ft WR/+10F/+35F: 80%–95% quartz and sanidine crystals; 5%–20% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts. | Qbt 1v | |
| 120–135 | Rhyolitic Tuff—gray to light gray (N6 to N7), moderately welded, crystal-rich tuff.<br>120–135 ft WR/+35F: 80%–95% quartz and sanidine crystals; 5%–20% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts.<br>+10F: 40%–90% welded ash flow tuff fragments; 10%–60% quartz and sanidine crystals; trace lithics. | Qbt 1v | |
| 135–140 | Rhyolitic Tuff—orange (5YR 8/4), weathered, moderately welded tuff.<br>135–140 ft WR/+10F/ +35F: 70%–95% welded ash flow tuff fragments; 5%–30% quartz and sanidine crystals; trace rhyolitic and dacitic lithic clasts. | Qbt 1v | The Qbt1v/Qbt1g contact, estimated at 140 ft bgs, is based on natural gamma logs and presence of devitrified pumice in cuttings. |

| DEPTH (ft bgs) | LITHOLOGY | LITHOLOGIC SYMBOL | NOTES |
|---|---|---|---|
| 140–205 | **UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:**<br>Rhyolitic Tuff—gray to light gray (N6 to N7), poorly welded, pumice-rich tuff.<br>140–205 ft WR/+10F: 80%–95% glassy, often rounded, rhyolitic pumice fragments; 5%–15% quartz and sanidine crystals; 5% rhyolitic and dacitic lithic clasts.<br>+35F: 40%–70% glassy pumice fragments; 30%–60% quartz and sanidine crystals; <5% lithics; trace ash flow tuff fragments. | Qbt 1g | Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 140 ft to 236 ft bgs, is approximately 96 ft thick. |
| 205–210 | Rhyolitic Tuff—gray to light gray (N6 to N7), poorly welded, pumice-rich tuff.<br>205–210 ft WR/+10F: 80%–95% glassy, often rounded, rhyolitic pumice fragments; 5%–15% quartz and sanidine crystals; 5% rhyolitic and dacitic lithic clasts.<br>+35F: 90% quartz and sanidine crystals; 10% glassy pumice fragments; <5% lithics; trace ash flow tuff fragments. | Qbt 1g | |
| 210–236 | Rhyolitic Tuff—gray to light gray (N6 to N7), poorly welded, pumice-rich tuff.<br>210–236 ft WR/+10F: 90%–95% glassy, often rounded, rhyolitic pumice fragments; 5% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts.<br>+35F: 40%–70% glassy pumice fragments; 30%–60% quartz and sanidine crystals; <5% lithics; trace ash flow tuff fragments. | Qbt 1g | The Qbt1g/Qct contact, estimated at 236 ft bgs, is based on drill cuttings and observations while drilling. |
| 236–270 | **CERRO TOLEDO INTERVAL**:<br>Volcaniclastic Sediments—silt to gravel size, rounded to subangular orange pumice clasts, white to orange ash flow tuff fragments, dacite clasts, and rhyolite clasts.<br>236–270 ft WR/+10F: 60%–85% pumice and ash flow tuff fragments; 15%–40% dacite and rhyolite clasts; trace angular quartz grains;<br>+35F: 60%–80% pumice clasts; 15%–30% volcanic clasts; 5%–15% angular quartz grains. | Qct | The Cerro Toledo Interval (Qct), encountered from 236 ft to 270 ft bgs, is 34 ft thick.<br>The Qct/Qbo contact, estimated at 270 ft bgs, is based on drill cuttings and natural gamma logging. |
| 270–315 | **OTOWI MEMBER OF THE BANDELIER TUFF:**<br>Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff.<br>270–315 ft WR: 70%–85% ash flow tuff and orange pumice fragments; 15%–30% gray to red volcanic lithics; <5% quartz crystals.<br>+10F: 60%–90% ash flow tuff and orange pumice fragments; 10%–40% gray volcanic lithics.<br>+35F: 70%–85% ash flow tuff and orange pumice fragments; 10%–25% gray to red volcanic lithics; 5%–15% quartz crystals. | Qbo | The Otowi Member of the Bandelier Tuff (Qbo), encountered from 270 ft to 580 ft bgs, is approximately 310 ft thick. |

| DEPTH (ft bgs) | LITHOLOGY | LITHOLOGIC SYMBOL | NOTES |
|---|---|---|---|
| 315–320 | Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff.<br>315–320 ft WR: 60% ash flow tuff and orange pumice fragments; 35%–40% gray volcanic lithics; <5% quartz crystals.<br>+10F: 50% ash flow tuff and orange pumice fragments; 50% gray to dark gray volcanic lithics.<br>+35F: 60%–85% ash flow tuff and orange pumice fragments; 10%–35% gray to red volcanic lithics; 5%–15% quartz crystals. | Qbo | |
| 320–340 | No Sample Returns. | Qbo | |
| 340–430 | Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff.<br>340–430 ft WR/+10F: 50%–75% light gray to dark gray volcanic lithics; 25%–50% ash flow tuff and white to orange pumice fragments; <5% quartz crystals.<br>+35F: 40%–70% gray volcanic lithics; 20%–40% ash flow tuff and orange pumice fragments; 10%–20% quartz crystals. | Qbo | Note: increase in volcanic lithics in cuttings indicates poor welding in tuffs in this interval. |
| 430–580 | Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff.<br>430–580 ft WR/+10F: 60%–80% white pumice with minor ash flow tuff fragments; 20%–40% gray volcanic lithics; trace quartz crystals.<br>+35F: 60%–85% white pumice fragments; 10%–35% gray volcanic lithics; 5% quartz crystals. | Qbo | The Qbo/Qbog contact, estimated at 580 ft bgs, is based on pumice size in cuttings. |
| 580–609 | **GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:**<br>Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff.<br>580–609 ft WR/+10F: 70%–100% white pumice with minor ash flow tuff fragments; 0–30% gray volcanic lithics; trace quartz crystals.<br>+35F: 60%–85% white pumice fragments; 10%–35% gray volcanic lithics; 5% quartz crystals. | Qbog | The Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog), encountered from 580 ft to 609 ft bgs, is approximately 29 ft thick.<br>The Qbog/Tpf contact, estimated at 609 ft bgs, is based on change in penetration rate while drilling and on drill cuttings. |
| 609–780 | **PUYE FORMATION:**<br>Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>609–780 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; trace quartz grains. | Tpf | The Puye Formation (Tpf), encountered from 609 ft to 1145 ft bgs, is approximately 536 ft thick. |
| 780–800 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite in a tan clay matrix.<br>780–800 ft WR/+10F/+35F: 40%–70% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; 30%–60% nodules of tan clay; trace quartz grains. | Tpf | |

| DEPTH (ft bgs) | LITHOLOGY | LITHOLOGIC SYMBOL | NOTES |
|---|---|---|---|
| 800–1000 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>800–1000 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; trace quartz grains. | Tpf | |
| 1000–1010 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>1000–1010 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm. | Tpf | Note: This interval contains very little fines, mostly gravel. |
| 1010–1090 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>1010–1090 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; trace quartz grains. | Tpf | |
| 1090–1100 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>1090–1100 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 30 mm. | Tpf | Note: This interval contains very little fines, mostly gravel. |
| 1100–1115 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>1100–1115 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; trace quartz grains. | Tpf | |
| 1115–1135 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>1100–1115 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; trace quartz grains. | Tpf | Note: Cuttings from this interval are coated in tan silt/clay. |
| 1135–1145 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite.<br>1135–1145 ft WR/+10F/+35F: 100% subangular to subrounded clasts of dacite and rhyolite up to 20 mm; trace quartz grains. | Tpf | The Tpf/Tjfp contact, estimated at 1145 ft bgs, is based on presence of pumice in sediments below 1145 ft bgs. |
| 1145–1230 | **MIOCENE PUMICEOUS SEDIMENTS:**<br>Volcaniclastic Sediments—varicolored grains of dacite and rhyolite with rounded white pumice.<br>1135–1145 ft WR/+10F/+35F: 60%–90% subangular to subrounded clasts of dacite and rhyolite up to 15 mm; 10%–40% subrounded to rounded white pumices; trace quartz grains. | Tjfp | Miocene Pumiceous Sediments (Tjfp), encountered from 1145 ft to 1324.6 ft bgs, is at least 179.6 ft thick. |
| 1230–1235 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite with rounded white pumice.<br>1135–1145 ft WR/+10F/+35F: 60%–90% subangular to subrounded clasts of dacite and rhyolite up to 3 mm; 10%–40% subrounded to rounded white pumices; trace quartz grains. | Tjfp | Note: This interval has an increase in fine sand and smaller gravel |

| DEPTH (ft bgs) | LITHOLOGY | LITHOLOGIC SYMBOL | NOTES |
|---|---|---|---|
| 1235–1324.6 | Volcaniclastic Sediments—varicolored grains of dacite and rhyolite with rounded white pumice.<br>1135–1145 ft WR/+10F/+35F: 60%–90% subangular to subrounded clasts of dacite and rhyolite up to 15 mm; 10%–40% subrounded to rounded white pumices; trace quartz grains. | Tjfp | TD = 1324.6 ft |

ABBREVIATIONS

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

% = estimated percent by volume of a given sample constituent

amsl = above mean sea level

bgs = below ground surface

Qbt 3 = Unit 3 of the Tshirege Member of the Bandelier Tuff

Qbt 2 = Unit 2 of the Tshirege Member of the Bandelier Tuff

Qbt 1v = Unit 1v (devitrified) of the Tshirege Member of the Bandelier Tuff

Qbt 1g = Unit 1g (glassy) of the Tshirege Member of the Bandelier Tuff

Qct = Cerro Toledo interval

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed

Tpf = Puye Formation

Tjfp = Miocene Pumiceous Sediments

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in

1 in = 25.4 mm

# Appendix B

*Screening Groundwater Analytical Results for Well R-67*

## B-1.0 SCREENING GROUNDWATER ANALYSES AT R-67

Well R-67 is a regional aquifer monitoring well with one well screen from 1242.6 ft to 1263.0 ft below ground surface (bgs) in Miocene Pumiceous Sediments. This appendix presents screening analytical results for samples collected during coring, well development and aquifer testing at R-67, located at Technical Area 61 (TA-61) at Los Alamos National Laboratory (LANL or the Laboratory).

### Laboratory Analyses

Seventeen groundwater-screening samples were collected during coring. The Laboratory's Earth and Environmental Sciences Group 14 (EES-14) analyzed 12 of the coring samples for anions and metals and 5 samples for alkalinity and pH.

Ten groundwater-screening samples were collected during well screen development, and three groundwater samples were collected during aquifer testing. The Laboratory's EES-14 analyzed the well development samples for total organic carbon (TOC) and two of the aquifer test samples for anions, metals, alkalinity, and pH. Because of an instrument failure at the EES-14 Laboratory, the holding time for one TOC sample collected at the end of the aquifer test expired and was not analyzed. Table B-1.0-1 lists the samples submitted for analyses from R-67.

### Field Analyses

Additionally, groundwater samples were collected from a flow-through cell at regular intervals during well development and aquifer testing and measured for pH, conductivity, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity.

## B-2.0 SCREENING ANALYTICAL RESULTS

This section presents the TOC concentrations and field parameters measured during well development and aquifer testing.

### B-2.1 Total Organic Carbon

TOC concentrations were between 1.5 and 3.1 mgC/L in 10 groundwater samples collected during well development at well R-67 (Table B-2.1-1). TOC concentrations were below the target concentration of 2.0 mgC/L at the end of well development. Table B-2.1-1 also presents the U.S. Environmental Protection Agency (EPA) method by which the samples were analyzed.

### B-2.2 Field Parameters

Field parameters measured during well development and aquifer testing are summarized in Table B-2.2-1. Development of the well screen was initially conducted for 13 d. Aquifer testing was then conducted for 6 d. Well development and aquifer test field parameters are summarized below.

During well development and aquifer testing, pH varied from 6.20 to 7.72 and temperature ranged from −2.57°C to 11.55°C. Concentrations of DO varied from 0.43 mg/L to 14.35 mg/L. Specific conductance ranged from 212 μS/cm to 243 μS/cm, and turbidity values varied from 0.0 to 1311.10 nephelometric turbidity units (NTU). Corrected oxidation-reduction potential (Eh) values, determined from field ORP measurements, varied from 82.1 mV to 370.5 mV. One temperature-dependent correction factor was used to calculate Eh values from field ORP measurements: 208.9 mV at 15°C. Figure B-2.2-1 shows the field parameters measured over the course of well development and aquifer testing.

The final parameters measured at the end of the aquifer testing period were pH of 7.47, temperature of 8.78°C, DO of 7.95 mg/L, specific conductance of 233 µS/cm, Eh of 250.0 mV, and turbidity of 1.5 NTU.

## B-3.0 SUMMARY OF SCREENING ANALYTICAL RESULTS

TOC concentrations were below the target level of 2.0 mgC/L at the end of well development and turbidity was 1.5 NTU at the end of aquifer testing. R-67 will be sampled quarterly for 1 yr and data collected will be assessed and incorporated into the annual Interim Facility-Wide Groundwater Monitoring Plan. Data from ongoing sampling at R-67 will be analyzed and presented in appropriate Laboratory periodic monitoring reports.

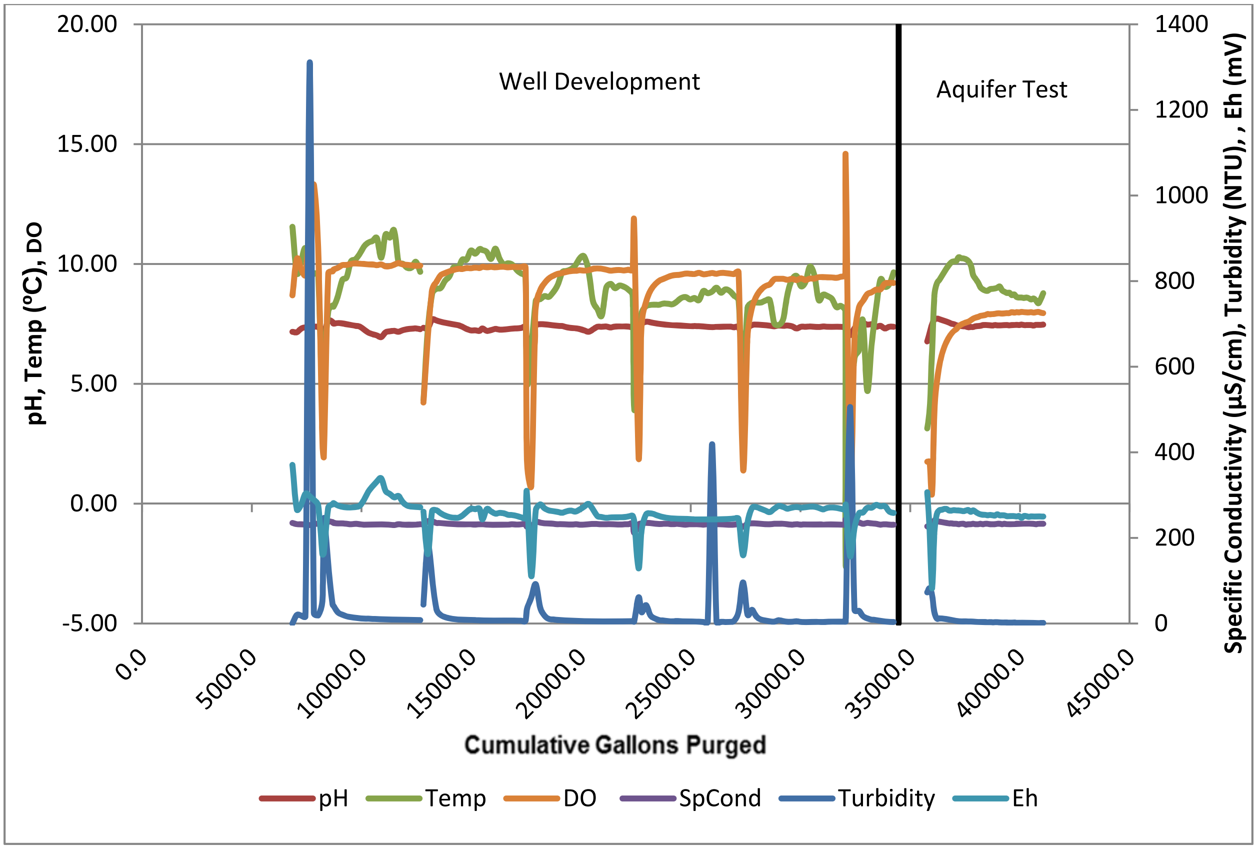

**Figure B-2.2-1** Field parameters versus volume purged during R-67 well development and aquifer testing

### Table B-1.0-1
### Summary of Groundwater Screening Samples Collected during Drilling/Coring, Well Development, and Aquifer Testing at Well R-67

| Location ID | Sample ID | Date Collected | Collection Depth (ft bgs) | Sample Type | Analysis |
|---|---|---|---|---|---|
| **Drilling/Coring** | | | | | |
| R-67 | CrCH6-15-103070 | 7/20/15 | 241–244 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-103066 | 7/21/15 | 244–248 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-103067 | 7/21/15 | 248–252 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-103068 | 7/21/15 | 252–256.30 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-103069 | 7/21/15 | 256.30–261.30 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-102741 | 7/27/15 | 610–611 | Groundwater, Air-lift | Alkalinity, pH |
| R-67 | CrCH6-15-102746 | 7/27/15 | 610–611 | Groundwater, Air-lift | Anions, Metals |
| R-67 | CrCH6-15-102788 | 7/27/15 | 610.88–614.63 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-102789 | 7/28/15 | 616.64–620.08 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-102742 | 7/30/15 | 700 | Groundwater, Air-lift | Alkalinity, pH |
| R-67 | CrCH6-15-102747 | 7/30/15 | 700 | Groundwater, Air-lift | Anions, Metals |
| R-67 | CrCH6-15-103136 | 8/7/15 | 1145.40–1150.40 | Groundwater, Cored | Alkalinity, pH |
| R-67 | CrCH6-15-103166 | 8/7/15 | 1145.40–1150.40 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-103137 | 8/8/15 | 1165.80–1170.35 | Groundwater, Cored | Alkalinity, pH |
| R-67 | CrCH6-15-103167 | 8/8/15 | 1165.80–1170.35 | Groundwater, Cored | Anions, Metals |
| R-67 | CrCH6-15-103138 | 8/9/15 | 1205.35–1209.16 | Groundwater, Cored | Alkalinity, pH |
| R-67 | CrCH6-15-103168 | 8/9/15 | 1205.35–1209.16 | Groundwater, Cored | Anions, Metals |
| **Well Development** | | | | | |
| R-67 | GWR67-15-102751 | 9/27/15 | 1244.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102752 | 9/28/15 | 1244.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102753 | 9/29/15 | 1251.64 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102754 | 9/30/15 | 1267.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102755 | 10/1/15 | 1267.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102756 | 10/2/15 | 1267.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102757 | 10/3/15 | 1267.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102758 | 10/4/15 | 1267.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102759 | 10/5/15 | 1267.73 | Groundwater, Pumped | TOC |
| R-67 | GWR67-15-102760 | 10/6/15 | 1267.73 | Groundwater, Pumped | TOC |
| **Aquifer Test** | | | | | |
| R-67 | GWR67-15-102766 | 10/10/15 | 1250.27 | Groundwater, Pumped | Anions, Metals, Alkalinity, pH |
| R-67 | GWR67-15-102767 | 10/11/15 | 1250.27 | Groundwater, Pumped | Anions, Metals, Alkalinity, pH |
| R-67 | GWR67-15-102761 | 10/11/15 | 1250.27 | Groundwater, Pumped | TOC |

## Table B-2.1-1
## TOC Results

| Sample ID | EPA Method | TOC Concentration (mgC/L) |
|---|---|---|
| GWR67-15-102751 | SW-846:9060 | 3.1 |
| GWR67-15-102752 | SW-846:9060 | 1.7 |
| GWR67-15-102753 | SW-846:9060 | 1.6 |
| GWR67-15-102754 | SW-846:9060 | 1.5 |
| GWR67-15-102755 | SW-846:9060 | 1.5 |
| GWR67-15-102756 | SW-846:9060 | 1.6 |
| GWR67-15-102757 | SW-846:9060 | 1.6 |
| GWR67-15-102758 | SW-846:9060 | 1.6 |
| GWR67-15-102759 | SW-846:9060 | 1.7 |
| GWR67-15-102760 | SW-846:9060 | 1.6 |
| GWR67-15-102761 | n/a* | Not analyzed because of instrument failure. |

*n/a = Not applicable.

## Table B-2.2-1
## Purge Volumes and Field Parameters during Well Development and Aquifer Testing at R-67

| Date | pH | Temp (°C) | DO (mg/L) | ORP (mV) | Eh (mV) | Specific Conductivity (µS/cm) | Turbidity (NTU) | Purge Volume between Samples (gal.) | Cumulative Purge Volume (gal.) |
|---|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | | |
| 9/23/15 | n/r*; bailing | | | | | | | 40 | 40.0 |
| 9/24/15 | n/r; bailing | | | | | | | 181 | 221.0 |
| 9/25/15 | n/r; bailing | | | | | | | 169 | 390.0 |
| 9/27/15 | n/r; pumping through screen | | | | | | | 670.0 | 1060.0 |
| 9/28/15 | n/r; pumping through screen | | | | | | | 1184.0 | 2244.0 |
| 9/29/15 | n/r; pumping through screen | | | | | | | 2164.6 | 4408.6 |
| 9/30/15 | n/r; pumping through screen | | | | | | | 2185.3 | 6593.9 |
| | 7.17 | 11.55 | 8.69 | 162 | 370.5 | 235 | 0 | 257.4 | 6851.3 |
| | 7.15 | 9.64 | 10.20 | 58 | 266.8 | 232 | 19.8 | 198.0 | 7049.3 |
| | 7.30 | 10.10 | 9.79 | 69 | 277.5 | 232 | 18.8 | 198.0 | 7247.3 |
| | 7.35 | 10.65 | 9.55 | 95 | 303.4 | 231 | 16.9 | 198.0 | 7445.3 |
| | 7.26 | 9.48 | 11.68 | 88 | 296.9 | 230 | 1311.1 | 198.0 | 7643.3 |
| | 7.38 | 9.61 | 13.31 | 80 | 288.8 | 232 | 24.3 | 184.8 | 7828.1 |
| | 7.36 | 9.54 | 10.67 | 67 | 275.5 | 233 | 19.0 | 198.0 | 8026.1 |
| 10/1/15 | 7.18 | 4.09 | 2.47 | −47 | 161.5 | 228 | 54.0 | 195.2 | 8221.3 |
| | 7.11 | 5.74 | 1.98 | −44 | 165.3 | 229 | 245.4 | 65.0 | 8286.3 |
| | 7.63 | 8.02 | 9.61 | 62 | 270.8 | 238 | 136.3 | 197.4 | 8483.7 |
| | 7.58 | 8.27 | 9.69 | 69 | 278.2 | 237 | 44.8 | 197.4 | 8681.1 |
| | 7.51 | 8.22 | 9.77 | 72 | 281.2 | 235 | 41.1 | 46.1 | 8727.2 |
| | 7.54 | 8.66 | 9.84 | 66 | 275.3 | 234 | 26.0 | 197.4 | 8924.6 |
| | 7.52 | 9.33 | 9.95 | 64 | 273.0 | 234 | 20.8 | 197.4 | 9122.0 |
| | 7.48 | 9.44 | 9.96 | 63 | 271.4 | 233 | 16.9 | 197.4 | 9319.4 |
| | 7.46 | 10.10 | 10.00 | 62 | 270.8 | 232 | 14.7 | 197.4 | 9516.8 |
| | 7.42 | 10.19 | 10.03 | 64 | 272.5 | 233 | 13.7 | 197.4 | 9714.2 |
| | 7.39 | 10.41 | 10.01 | 66 | 274.8 | 232 | 12.5 | 197.4 | 9911.6 |
| | 7.27 | 10.72 | 10.00 | 80 | 288.6 | 231 | 11.3 | 197.4 | 10109.0 |
| | 7.14 | 10.89 | 9.98 | 99 | 307.7 | 231 | 11.5 | 197.4 | 10306.4 |
| | 7.07 | 10.96 | 9.98 | 112 | 320.6 | 231 | 10.8 | 197.4 | 10503.8 |
| | 7.02 | 11.08 | 9.95 | 123 | 331.7 | 232 | 10.4 | 197.4 | 10701.2 |
| | 6.95 | 10.26 | 9.98 | 130 | 339.2 | 232 | 9.8 | 197.4 | 10898.6 |
| | 7.15 | 11.23 | 9.90 | 101 | 310.1 | 231 | 10.0 | 197.4 | 11096.0 |
| | 7.19 | 11.10 | 9.91 | 94 | 302.6 | 231 | 9.0 | 197.4 | 11293.4 |
| | 7.21 | 11.39 | 9.97 | 86 | 294.9 | 230 | 9.0 | 197.4 | 11490.8 |

## Table B-2.2-1 (continued)

| Date | pH | Temp (°C) | DO (mg/L) | ORP (mV) | Eh (mV) | Specific Conductivity (µS/cm) | Turbidity (NTU) | Purge Volume between Samples (gal.) | Cumulative Purge Volume (gal.) |
|---|---|---|---|---|---|---|---|---|---|
| | 7.17 | 10.07 | 10.04 | 89 | 297.9 | 232 | 9.4 | 197.4 | 11688.2 |
| | 7.24 | 10.01 | 9.98 | 74 | 283.2 | 231 | 9.4 | 197.4 | 11885.6 |
| | 7.28 | 9.84 | 9.96 | 67 | 275.6 | 231 | 8.7 | 197.4 | 12083.0 |
| | 7.30 | 9.85 | 9.94 | 64 | 273.2 | 231 | 8.0 | 197.4 | 12280.4 |
| | 7.31 | 10.09 | 9.92 | 64 | 272.6 | 231 | 8.1 | 197.4 | 12477.8 |
| | 7.28 | 9.67 | 9.93 | 63 | 271.6 | 232 | 8.0 | 197.4 | 12675.2 |
| | n/r; purged prior to shutting off pump | | | | | | | 85.5 | 12760.7 |
| 10/2/15 | 7.34 | 4.32 | 4.22 | 52 | 261.3 | 230 | 44.2 | 62.0 | 12822.7 |
| | 7.32 | 7.24 | 6.92 | -47 | 162.0 | 239 | 186.5 | 196.5 | 13019.2 |
| | 7.68 | 8.76 | 8.91 | 54 | 262.6 | 239 | 106.7 | 196.5 | 13215.7 |
| | 7.64 | 8.96 | 9.25 | 56 | 264.6 | 235 | 33.9 | 196.5 | 13412.2 |
| | 7.59 | 9.00 | 9.53 | 49 | 257.4 | 235 | 19.9 | 196.5 | 13608.7 |
| | 7.55 | 9.30 | 9.62 | 44 | 252.6 | 234 | 15.1 | 196.5 | 13805.2 |
| | 7.51 | 9.48 | 9.70 | 40 | 248.6 | 233 | 12.2 | 196.5 | 14001.7 |
| | 7.48 | 9.86 | 9.75 | 39 | 247.5 | 232 | 10.5 | 196.5 | 14198.2 |
| | 7.45 | 9.80 | 9.80 | 38 | 247.1 | 232 | 9.6 | 196.5 | 14394.7 |
| | 7.38 | 10.18 | 9.79 | 43 | 252.0 | 232 | 8.9 | 196.5 | 14591.2 |
| | 7.29 | 10.18 | 9.83 | 52 | 260.8 | 232 | 8.4 | 196.5 | 14787.7 |
| | 7.23 | 10.56 | 9.82 | 59 | 268.3 | 232 | 8.3 | 196.5 | 14984.2 |
| | 7.23 | 10.43 | 9.85 | 58 | 267.2 | 231 | 8.0 | 196.5 | 15180.7 |
| | 7.21 | 10.62 | 9.83 | 59 | 268.0 | 232 | 7.5 | 196.5 | 15377.2 |
| | 7.31 | 10.58 | 9.88 | 35 | 243.4 | 232 | 7.3 | 131.0 | 15508.2 |
| | 7.21 | 10.50 | 9.86 | 58 | 267.3 | 231 | 7.0 | 196.5 | 15704.7 |
| | 7.24 | 10.21 | 9.88 | 53 | 262.0 | 231 | 7.2 | 196.5 | 15901.2 |
| | 7.29 | 10.64 | 9.86 | 48 | 256.8 | 231 | 6.8 | 196.5 | 16097.7 |
| | 7.26 | 10.21 | 9.88 | 50 | 258.5 | 231 | 7.1 | 196.5 | 16294.2 |
| | 7.26 | 9.98 | 9.88 | 49 | 257.4 | 231 | 7.1 | 196.5 | 16490.7 |
| | 7.29 | 10.03 | 9.86 | 45 | 253.9 | 231 | 7.1 | 196.5 | 16687.2 |
| | 7.30 | 9.96 | 9.88 | 44 | 253.3 | 232 | 6.7 | 196.5 | 16883.7 |
| | 7.31 | 9.74 | 9.87 | 42 | 251.2 | 231 | 6.9 | 196.5 | 17080.2 |
| | 7.33 | 9.60 | 9.87 | 39 | 248.1 | 232 | 6.6 | 196.5 | 17276.7 |
| | 7.35 | 9.45 | 9.86 | 39 | 247.6 | 232 | 6.5 | 196.5 | 17473.2 |

### Table B-2.2-1 (continued)

| Date | pH | Temp (°C) | DO (mg/L) | ORP (mV) | Eh (mV) | Specific Conductivity (µS/cm) | Turbidity (NTU) | Purge Volume between Samples (gal.) | Cumulative Purge Volume (gal.) |
|---|---|---|---|---|---|---|---|---|---|
| 10/3/15 | 6.20 | 5.07 | 1.80 | 97 | 305.6 | 226 | 33.5 | 63.5 | 17536.7 |
| | 6.87 | 6.44 | 0.77 | −98 | 110.6 | 226 | 60.9 | 200.7 | 17737.4 |
| | 7.42 | 8.46 | 8.19 | 56 | 264.4 | 237 | 92.0 | 200.7 | 17938.1 |
| | 7.49 | 8.53 | 8.90 | 69 | 278.3 | 236 | 37.5 | 200.7 | 18138.8 |
| | 7.48 | 8.66 | 9.20 | 60 | 269.1 | 234 | 18.4 | 200.7 | 18339.5 |
| | 7.46 | 8.63 | 9.40 | 55 | 264.2 | 234 | 10.7 | 200.7 | 18540.2 |
| | 7.44 | 8.83 | 9.51 | 54 | 262.5 | 233 | 9.5 | 200.7 | 18740.9 |
| | 7.42 | 9.13 | 9.59 | 52 | 260.7 | 232 | 8.1 | 200.7 | 18941.6 |
| | 7.41 | 9.65 | 9.62 | 50 | 258.8 | 232 | 7.2 | 200.7 | 19142.3 |
| | 7.36 | 9.71 | 9.67 | 53 | 262.2 | 232 | 6.7 | 200.7 | 19343.0 |
| | 7.33 | 9.78 | 9.71 | 55 | 263.8 | 231 | 6.6 | 200.7 | 19543.7 |
| | 7.32 | 9.94 | 9.71 | 53 | 261.6 | 232 | 6.0 | 200.7 | 19744.4 |
| | 7.28 | 10.24 | 9.74 | 58 | 266.5 | 231 | 6.1 | 200.7 | 19945.1 |
| | 7.23 | 10.31 | 9.72 | 64 | 273.2 | 231 | 5.7 | 200.7 | 20145.8 |
| | 7.17 | 9.70 | 9.74 | 71 | 279.5 | 232 | 5.4 | 200.7 | 20346.5 |
| | 7.27 | 8.44 | 9.80 | 58 | 266.6 | 233 | 5.5 | 200.7 | 20547.2 |
| | 7.38 | 8.12 | 9.81 | 42 | 251.1 | 232 | 5.4 | 200.7 | 20747.9 |
| | 7.38 | 7.85 | 9.80 | 40 | 248.8 | 232 | 4.9 | 200.7 | 20948.6 |
| | 7.39 | 9.01 | 9.76 | 38 | 246.8 | 232 | 5.0 | 200.7 | 21149.3 |
| | 7.35 | 9.17 | 9.72 | 39 | 248.1 | 232 | 5.2 | 200.7 | 21350.0 |
| | 7.39 | 8.99 | 9.74 | 39 | 247.9 | 232 | 4.9 | 200.7 | 21550.7 |
| | 7.39 | 9.10 | 9.75 | 40 | 248.4 | 231 | 4.8 | 200.7 | 21751.4 |
| | 7.39 | 9.05 | 9.73 | 40 | 248.6 | 232 | 5.1 | 200.7 | 21952.1 |
| | 7.39 | 8.93 | 9.76 | 41 | 250.1 | 232 | 4.7 | 200.7 | 22152.8 |
| | 7.38 | 8.67 | 9.77 | 43 | 251.6 | 233 | 5.7 | 200.7 | 22353.5 |
| 10/4/15 | 7.61 | 3.94 | 11.69 | 31 | 239.7 | 212 | 4.8 | 70.3 | 22423.8 |
| | 7.17 | 6.42 | 1.92 | −80 | 128.9 | 231 | 61.3 | 201.0 | 22624.8 |
| | 7.48 | 7.94 | 7.48 | 8 | 217.1 | 234 | 26.3 | 134.0 | 22758.8 |
| | 7.59 | 8.23 | 8.40 | 46 | 254.5 | 235 | 43.0 | 201.0 | 22959.8 |
| | 7.57 | 8.29 | 8.88 | 48 | 257.3 | 235 | 19.4 | 201.0 | 23160.8 |
| | 7.53 | 8.30 | 9.13 | 46 | 255.0 | 233 | 12.0 | 201.0 | 23361.8 |
| | 7.50 | 8.30 | 9.30 | 42 | 251.0 | 233 | 8.0 | 201.0 | 23562.8 |
| | 7.48 | 8.35 | 9.38 | 39 | 248.1 | 233 | 7.0 | 201.0 | 23763.8 |
| | 7.46 | 8.34 | 9.46 | 38 | 246.6 | 233 | 5.5 | 201.0 | 23964.8 |
| | 7.44 | 8.32 | 9.52 | 37 | 245.5 | 232 | 5.1 | 201.0 | 24165.8 |
| | 7.44 | 8.43 | 9.54 | 36 | 245.0 | 233 | 6.0 | 201.0 | 24366.8 |

## Table B-2.2-1 (continued)

| Date | pH | Temp (°C) | DO (mg/L) | ORP (mV) | Eh (mV) | Specific Conductivity (µS/cm) | Turbidity (NTU) | Purge Volume between Samples (gal.) | Cumulative Purge Volume (gal.) |
|---|---|---|---|---|---|---|---|---|---|
| | 7.43 | 8.58 | 9.56 | 36 | 244.7 | 232 | 5.3 | 201.0 | 24567.8 |
| | 7.42 | 8.62 | 9.60 | 36 | 244.5 | 231 | 5.0 | 201.0 | 24768.8 |
| | 7.40 | 8.52 | 9.59 | 35 | 244.3 | 232 | 4.6 | 201.0 | 24969.8 |
| | 7.41 | 8.58 | 9.58 | 34 | 243.3 | 232 | 4.8 | 201.0 | 25170.8 |
| | 7.40 | 8.49 | 9.63 | 34 | 243.2 | 232 | 4.2 | 201.0 | 25371.8 |
| | 7.39 | 8.87 | 9.57 | 35 | 243.5 | 231 | 3.7 | 201.0 | 25572.8 |
| | 7.38 | 8.78 | 9.59 | 35 | 243.5 | 232 | 3.7 | 201.0 | 25773.8 |
| | 7.36 | 8.85 | 9.62 | 34 | 242.8 | 231 | 418.9 | 201.0 | 25974.8 |
| | 7.38 | 9.01 | 9.59 | 35 | 243.6 | 232 | 3.8 | 201.0 | 26175.8 |
| | 7.38 | 8.80 | 9.63 | 35 | 244.1 | 232 | 4.1 | 201.0 | 26376.8 |
| | 7.38 | 8.94 | 9.62 | 35 | 244.0 | 231 | 3.7 | 201.0 | 26577.8 |
| | 7.39 | 8.87 | 9.60 | 35 | 244.2 | 231 | 3.8 | 201.0 | 26778.8 |
| | 7.36 | 8.67 | 9.58 | 36 | 245.3 | 231 | 6.5 | 201.0 | 26979.8 |
| | 7.36 | 8.47 | 9.66 | 35 | 244.1 | 232 | 27.4 | 201.0 | 27180.8 |
| 10/5/15 | 6.86 | 5.03 | 1.41 | −49 | 159.5 | 226 | 96.1 | 205.3 | 27386.1 |
| | 7.30 | 8.17 | 6.99 | 27 | 236.2 | 233 | 20.9 | 202.5 | 27588.6 |
| | 7.45 | 8.38 | 8.17 | 61 | 269.9 | 234 | 32.1 | 202.5 | 27791.1 |
| | 7.47 | 8.39 | 8.65 | 63 | 271.9 | 234 | 16.2 | 202.5 | 27993.6 |
| | 7.46 | 8.39 | 8.92 | 59 | 267.9 | 233 | 9.5 | 202.5 | 28196.1 |
| | 7.44 | 8.47 | 9.08 | 55 | 264.0 | 232 | 7.0 | 202.5 | 28398.6 |
| | 7.43 | 8.49 | 9.15 | 51 | 260.3 | 232 | 5.1 | 202.5 | 28601.1 |
| | 7.40 | 7.53 | 9.36 | 59 | 268.0 | 233 | 4.5 | 202.5 | 28803.6 |
| | 7.43 | 7.45 | 9.38 | 66 | 274.5 | 233 | 7.7 | 202.5 | 29006.1 |
| | 7.42 | 7.68 | 9.38 | 64 | 272.4 | 233 | 5.7 | 202.5 | 29208.6 |
| | 7.43 | 8.75 | 9.34 | 59 | 268.3 | 232 | 4.1 | 202.5 | 29411.1 |
| | 7.40 | 9.35 | 9.38 | 62 | 271.0 | 231 | 4.2 | 202.5 | 29613.6 |
| | 7.31 | 9.50 | 9.33 | 63 | 272.2 | 232 | 5.3 | 209.3 | 29822.9 |
| | 7.38 | 9.07 | 9.40 | 62 | 270.6 | 231 | 3.4 | 202.5 | 30025.4 |
| | 7.38 | 9.25 | 9.33 | 63 | 271.8 | 232 | 3.7 | 202.5 | 30227.9 |
| | 7.39 | 9.89 | 9.39 | 64 | 272.9 | 231 | 3.9 | 202.5 | 30430.4 |
| | 7.38 | 9.54 | 9.39 | 64 | 273.0 | 231 | 3.6 | 202.5 | 30632.9 |
| | 7.37 | 8.50 | 9.45 | 61 | 270.3 | 232 | 3.5 | 195.8 | 30828.6 |
| | 7.39 | 8.72 | 9.45 | 58 | 266.7 | 231 | 3.7 | 202.5 | 31031.1 |
| | 7.38 | 8.66 | 9.44 | 61 | 270.3 | 231 | 3.9 | 202.5 | 31233.6 |
| | 7.38 | 8.54 | 9.44 | 62 | 270.9 | 232 | 4.6 | 202.5 | 31436.1 |
| | 7.38 | 8.20 | 9.42 | 61 | 270.3 | 231 | 4.3 | 202.5 | 31638.6 |

## Table B-2.2-1 (continued)

| Date | pH | Temp (°C) | DO (mg/L) | ORP (mV) | Eh (mV) | Specific Conductivity (µS/cm) | Turbidity (NTU) | Purge Volume between Samples (gal.) | Cumulative Purge Volume (gal.) |
|---|---|---|---|---|---|---|---|---|---|
| | 7.38 | 8.25 | 9.47 | 59 | 268.0 | 231 | 4.2 | 202.5 | 31841.1 |
| | 7.35 | 8.03 | 9.56 | 58 | 266.8 | 232 | 4.3 | 202.5 | 32043.6 |
| 10/6/15 | 7.30 | -2.57 | 14.35 | 69 | 277.4 | 243 | 4.5 | 18.58 | 32062.2 |
| | 7.03 | 3.74 | 0.80 | -51 | 157.7 | 222 | 505.7 | 200.4 | 32262.6 |
| | 7.32 | 6.08 | 6.90 | 15 | 223.7 | 233 | 31.8 | 200.4 | 32463.0 |
| | 7.48 | 6.40 | 8.18 | 48 | 257.3 | 236 | 29.9 | 200.4 | 32663.4 |
| | 7.54 | 7.65 | 8.45 | 50 | 259.3 | 233 | 17.6 | 180.4 | 32843.7 |
| | 7.47 | 4.71 | 8.74 | 62 | 270.4 | 235 | 12.1 | 200.4 | 33044.1 |
| | 7.48 | 6.65 | 8.82 | 62 | 270.7 | 234 | 9.0 | 200.4 | 33244.5 |
| | 7.38 | 8.15 | 8.93 | 68 | 277.2 | 233 | 8.4 | 200.4 | 33444.9 |
| | 7.42 | 9.35 | 8.94 | 65 | 273.7 | 231 | 5.9 | 200.4 | 33645.3 |
| | 7.31 | 9.05 | 9.18 | 65 | 274.3 | 232 | 4.6 | 200.4 | 33845.7 |
| | 7.38 | 9.15 | 9.21 | 53 | 261.7 | 231 | 4.0 | 200.4 | 34046.1 |
| | 7.38 | 9.65 | 9.21 | 49 | 258.3 | 231 | 3.7 | 200.4 | 34246.5 |
| | n/r; purged prior to shutting off pump | | | | | | | 46.8 | 34293.3 |
| **Aquifer Test** | | | | | | | | | |
| 10/7/15 | n/r, pumping, mini-tests | | | | | | | 291 | 34584.3 |
| 10/8/15 | n/r, pumping, mini-tests | | | | | | | 950 | 35534.3 |
| 10/9/15 | n/r, pumping, mini-tests | | | | | | | 194 | 35728.3 |
| 10/10/15 to 10/11/15 | 6.77 | 3.14 | 1.75 | 98 | 306.8 | 227 | 72.8 | 47.7 | 35776.0 |
| | 7.12 | 3.92 | 1.74 | 8 | 216.9 | 224 | 82.6 | 110.1 | 35886.1 |
| | 7.49 | 6.34 | 0.43 | −127 | 82.1 | 225 | 67.0 | 110.1 | 35996.2 |
| | 7.69 | 8.73 | 3.90 | 7 | 215.6 | 241 | 24.9 | 110.1 | 36106.3 |
| | 7.72 | 9.19 | 5.08 | 47 | 256.2 | 239 | 11.6 | 110.1 | 36216.4 |
| | 7.70 | 9.33 | 5.75 | 56 | 264.5 | 238 | 12.1 | 110.1 | 36326.5 |
| | 7.66 | 9.50 | 6.21 | 57 | 265.7 | 237 | 11.7 | 110.1 | 36436.6 |
| | 7.63 | 9.65 | 6.53 | 59 | 267.6 | 236 | 11.1 | 110.1 | 36546.7 |
| | 7.59 | 9.82 | 6.76 | 59 | 267.6 | 235 | 10.3 | 110.1 | 36656.8 |
| | 7.56 | 9.96 | 6.95 | 55 | 264.1 | 234 | 9.4 | 110.1 | 36766.9 |
| | 7.51 | 10.07 | 7.10 | 55 | 263.9 | 234 | 8.3 | 110.1 | 36877.0 |
| | 7.49 | 10.11 | 7.21 | 56 | 265.0 | 233 | 7.2 | 110.1 | 36987.1 |
| | 7.45 | 10.12 | 7.28 | 55 | 264.3 | 233 | 6.1 | 110.1 | 37097.2 |
| | 7.42 | 10.28 | 7.40 | 55 | 264.3 | 232 | 5.7 | 110.1 | 37207.3 |
| | 7.41 | 10.24 | 7.47 | 55 | 263.4 | 233 | 4.8 | 110.1 | 37317.4 |
| | 7.40 | 10.23 | 7.52 | 54 | 262.5 | 233 | 5.1 | 110.1 | 37427.5 |
| | 7.39 | 10.20 | 7.56 | 55 | 264.0 | 231 | 5.1 | 110.1 | 37537.6 |

## Table B-2.2-1 (continued)

| Date | pH | Temp (°C) | DO (mg/L) | ORP (mV) | Eh (mV) | Specific Conductivity (µS/cm) | Turbidity (NTU) | Purge Volume between Samples (gal.) | Cumulative Purge Volume (gal.) |
|---|---|---|---|---|---|---|---|---|---|
| | 7.36 | 10.12 | 7.59 | 56 | 265.2 | 232 | 4.9 | 110.1 | 37647.7 |
| | 7.37 | 9.96 | 7.65 | 52 | 261.0 | 232 | 4.7 | 110.1 | 37757.8 |
| | 7.37 | 9.54 | 7.72 | 56 | 264.4 | 233 | 4.5 | 110.1 | 37867.9 |
| | 7.40 | 9.38 | 7.76 | 52 | 261.1 | 232 | 4.0 | 110.1 | 37978.0 |
| | 7.41 | 9.23 | 7.79 | 49 | 257.4 | 232 | 3.8 | 110.1 | 38088.1 |
| | 7.42 | 9.03 | 7.83 | 46 | 255.3 | 233 | 3.7 | 110.1 | 38198.2 |
| | 7.45 | 8.94 | 7.85 | 45 | 254.1 | 232 | 3.7 | 110.1 | 38308.3 |
| | 7.45 | 8.89 | 7.87 | 45 | 254.1 | 233 | 3.6 | 110.1 | 38418.4 |
| | 7.45 | 8.88 | 7.91 | 44 | 252.9 | 233 | 3.0 | 110.1 | 38528.5 |
| | 7.44 | 8.95 | 7.90 | 45 | 253.8 | 232 | 3.3 | 110.1 | 38638.6 |
| | 7.43 | 8.96 | 7.91 | 44 | 253.0 | 232 | 2.9 | 110.1 | 38748.7 |
| | 7.45 | 8.98 | 7.92 | 43 | 252.3 | 232 | 3.1 | 110.1 | 38858.8 |
| | 7.44 | 9.01 | 7.94 | 46 | 255.2 | 233 | 3.1 | 110.1 | 38968.9 |
| | 7.44 | 9.06 | 7.94 | 44 | 252.8 | 233 | 2.7 | 110.1 | 39079.0 |
| | 7.44 | 8.90 | 7.93 | 44 | 253.1 | 232 | 2.6 | 110.1 | 39189.1 |
| | 7.45 | 8.84 | 7.94 | 44 | 252.6 | 233 | 2.5 | 110.1 | 39299.2 |
| | 7.45 | 8.79 | 7.95 | 42 | 250.8 | 232 | 2.4 | 110.1 | 39409.3 |
| | 7.44 | 8.80 | 7.95 | 42 | 250.9 | 232 | 2.0 | 110.1 | 39519.4 |
| | 7.45 | 8.70 | 7.99 | 42 | 251.1 | 232 | 2.0 | 110.1 | 39629.5 |
| | 7.45 | 8.73 | 7.97 | 42 | 251.0 | 232 | 2.5 | 110.1 | 39739.6 |
| | 7.46 | 8.62 | 7.99 | 41 | 250.1 | 233 | 1.8 | 110.1 | 39849.7 |
| | 7.45 | 8.60 | 7.98 | 42 | 251.2 | 233 | 1.8 | 110.1 | 39959.8 |
| | 7.47 | 8.60 | 8.00 | 38 | 246.9 | 233 | 2.0 | 110.1 | 40069.9 |
| | 7.45 | 8.58 | 7.99 | 42 | 251.3 | 233 | 1.9 | 110.1 | 40180.0 |
| | 7.45 | 8.60 | 7.98 | 42 | 250.8 | 233 | 1.8 | 110.1 | 40290.1 |
| | 7.45 | 8.57 | 7.98 | 40 | 249.3 | 233 | 1.6 | 110.1 | 40400.2 |
| | 7.45 | 8.52 | 7.99 | 41 | 250.3 | 233 | 1.3 | 110.1 | 40510.3 |
| | 7.43 | 8.56 | 7.97 | 41 | 249.8 | 233 | 1.6 | 110.1 | 40620.4 |
| | 7.46 | 8.48 | 7.99 | 42 | 250.4 | 232 | 1.5 | 110.1 | 40730.5 |
| | 7.46 | 8.36 | 8.00 | 41 | 250.2 | 233 | 1.0 | 110.1 | 40840.6 |
| | 7.46 | 8.54 | 7.97 | 41 | 249.9 | 233 | 1.4 | 110.1 | 40950.7 |
| | 7.47 | 8.78 | 7.95 | 41 | 250.0 | 233 | 1.5 | 110.1 | 41060.8 |

Note: One temperature-dependent correction factor was used to calculate Eh values from field ORP measurements: 208.9 mV at 15°C.

*n/r = Not recorded.

# Appendix C

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*Geophysical Logs*
*(on CD included with this document)*

# Appendix D

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*Borehole Video Logging*
*(on DVD included with this document)*

# Appendix E

*Final Well Design and*
*New Mexico Environment Department Approval*

**From:** Everett, Mark Capen
**Sent:** Tuesday, August 18, 2015 11:17 AM
**To:** Dale, Michael Ray
**Cc:** Rodriguez, Cheryl L; Shen, Hai; Ball, Ted; Swickley, Stephani Fuller; Katzman, Danny
**Subject:** R-67 proposed well design
**Attachments:** R-67 Well Design Justification_final.doc

Michael,

Attached, please find our proposed well design for R-67. The depth to water of 1226 ft has been confirmed with multiple measurements over two days, both with the drill casing on the bottom of the borehole and pulled back 20 ft. Please let me know if wish to discuss the design or if you are ok with it as is, respond with your concurrence.

Thanks,

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

# Proposed Well Design for Regional Aquifer Well R-67

## R-67 Well Objectives

Regional aquifer well R-67 is being installed in Sandia Canyon as required by the New Mexico Environment Department's (NMED's) approval with modifications of the Phase II Investigation Report for Sandia Canyon, dated February 19, 2014. Los Alamos National Laboratory (LANL) and NMED collaboratively selected the location of the well which is shown in Figure 1. The approval with modifications from NMED states the objective of the well is to "fully constrain the nature and extent of chromium contamination in the regional aquifer west and upgradient of R-62." Data from this well may also provide important information regarding the upgradient extent of the infiltration pathway(s) for chromium and related contaminants. Coring was also conducted during drilling to meet the objectives for Corehole 6 as described in the March 2015 R-67/Corehole 6 drilling workplan. Coring will be discussed in the R-67/corehole 6 well completion report.

## R-67 Recommended Well Design

It is recommended that R-67 be installed as a single-screen well with a 20-ft stainless steel, 40-slot, wire-wrapped well screen. The top of the well screen would be set 17 ft below the regional water table. The primary filter pack will consist of 10/20 sand extending 5 ft above and 5 ft below the screen openings. A 2-ft secondary filter pack (transition sand) consisting of 20/40 sand will be placed above the primary filter pack. The 17 ft of submergence to the top of the well screen allows for a 5-ft filter pack and 2-ft transition sand resulting in 10 ft of additional submergence beneath the water table allowing for potential drawdown during development. The proposed well design is shown in Figure 2. This well design is based on the objectives stated above and on the information summarized below.

## R-67 Well Design Considerations

At a total depth (TD) of 1324 ft, the R-67 borehole contained 16-in drill casing from 0 to 415 ft, 12.75-in drill casing from 0–999 ft, and 10-in drill casing from 0-1324.6 ft. Preliminary lithological logs indicate that the geologic contacts are, in descending stratigraphic order: Qbt 3 (0-15 ft), Qbt 2 (15-85 ft), Qbt 1v (85-140 ft), Qbt 1g (140-235 ft), Qct (235-270 ft?), Qbof (270 ft?- 568? ft), Qbog (568?-610 ft), Tpf (610-1145 ft), and Miocene pumiceous unit (1145-1324.6 ft). The proposed well screen will be in the Miocene pumiceous unit. Well cuttings and cores from R-67 indicate that the Miocene pumiceous unit consists of poorly sorted and subangular to subrounded pumice-rich sands and gravels with minor dacite fragments and significant amounts of quartz, feldspar, biotite, and other mafic minerals.

Characterization activities within the regional aquifer included the collection of cuttings at 5-ft intervals and collection of core within the zone selected for the well screen. In addition, a cased-hole gamma log was collected on 08/16/15 from 0-1324.6 ft. Based on drillers' observations of water production and multiple water-level measurements, the regional piezometric surface occurs at a depth of approximately 1226 ft, consistent with the expected range.

The proposed well screen targets the 1243 to 1263 ft interval with the goal of monitoring near the water table for nearby infiltration pathways as well as representing slightly deeper flow paths that may originate further upcanyon including within the Sandia wetland. Sediments making up Miocene pumiceous unit in this interval are primarily sands and gravels with a silty matrix of glass, crystals, and lithic fragments. The grain-size distribution appears to have good porosity and permeability characteristics. A 10-ft well screen was evaluated as a means to monitor a more discrete zone of groundwater near the top of the regional aquifer. However, the longer 20-ft screen was chosen because the longer screen provides greater assurance that preferential pathways in the stratigraphically complex aquifer will be adequately captured by water entering the well screen.

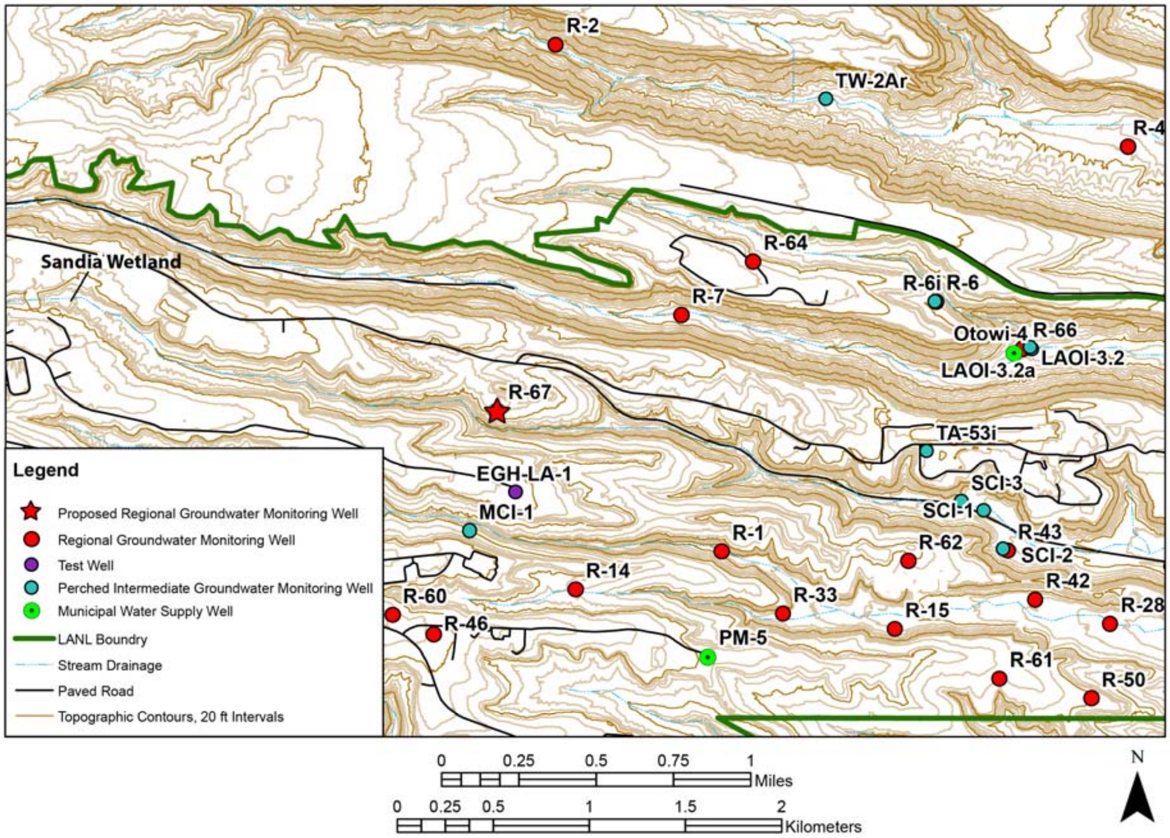

Figure 1. Map of well R-67 location

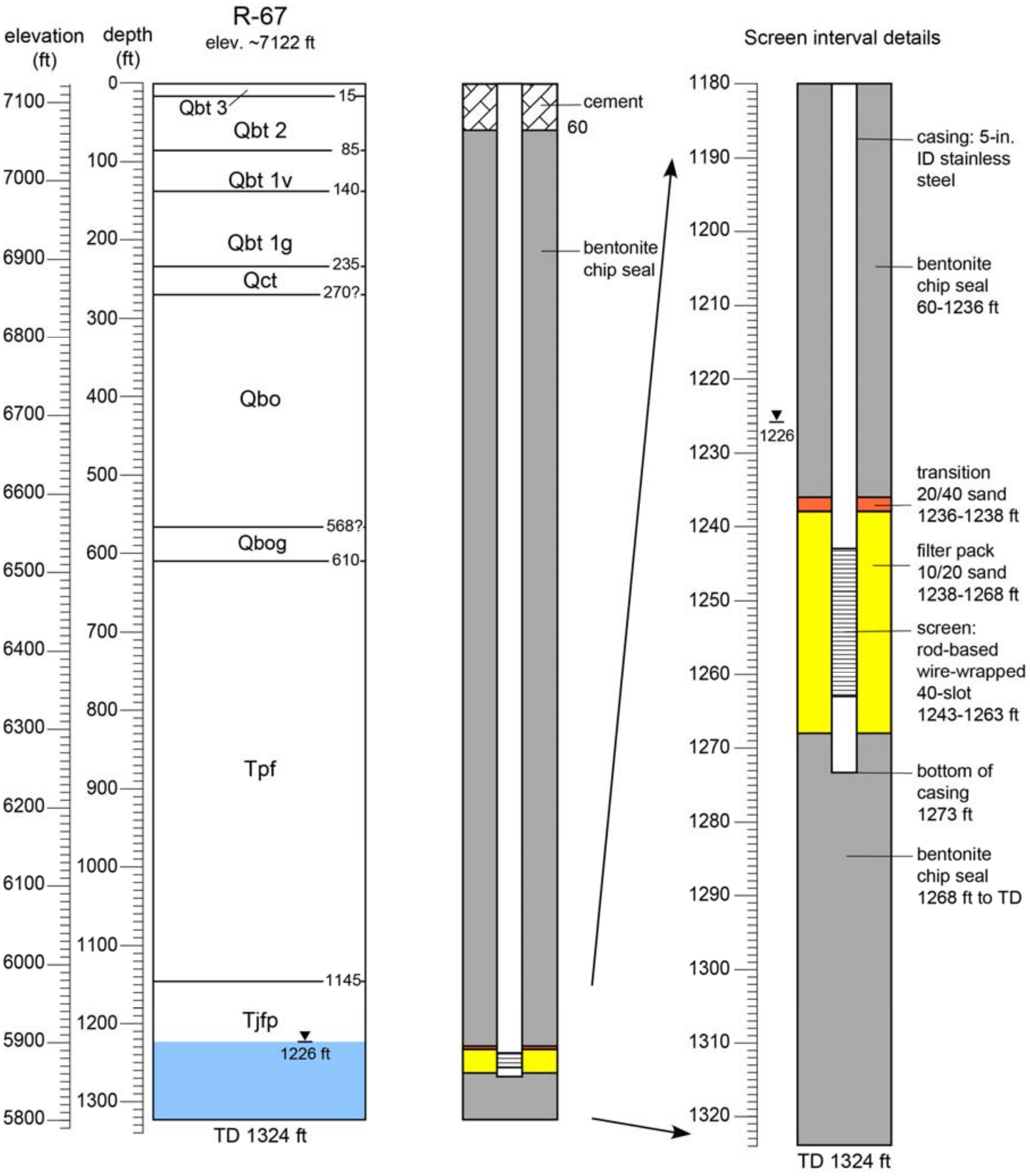

Figure 2. Proposed well design for R-67

From: Dale, Michael, NMENV [mailto:Michael.Dale@state.nm.us]
Sent: Tuesday, August 18, 2015 4:51 PM
To: Everett, Mark Capen <meverett@lanl.gov>
Cc: Cobrain, Dave, NMENV <dave.cobrain@state.nm.us>; Wear, Benjamin, NMENV <Benjamin.Wear@state.nm.us>; Kulis, Jerzy, NMENV <jerzy.kulis@state.nm.us>; Rodriguez, Cheryl L <cheryl.rodriguez@em.doe.gov>; Shen, Hai <hai.shen@em.doe.gov>; Ball, Ted <tedball@lanl.gov>; Fellenz, David, NMENV <David.Fellenz@state.nm.us>; Swickley, Stephani Fuller <sfuller@lanl.gov>; Katzman, Danny <katzman@lanl.gov>; Longmire, Patrick <plongmire@lanl.gov>; Longmire, Patrick, NMENV <Patrick.Longmire@state.nm.us>; Granzow, Kim, NMENV <Kim.Granzow@state.nm.us>; Yanicak, Stephen M <syanicak@lanl.gov>; Green, Megan, NMENV <Megan.Green@state.nm.us>; Ball, Ted <tedball@lanl.gov>
Subject: RE: R-67 proposed well design

Mark,

New Mexico Environment Department (NMED) hereby approves the installation of the regional-aquifer well R-67 as proposed in your e-mail, with attachments, that was received today, August 18, 2015 at 3:45 PM. This approval is based on information available to NMED at the time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. To end, please note that NMED recommends that an additional 2 - 4 feet of transition filter-pack sand be installed above the depth of 1236 ft bgs with the intent to insure that bentonite sealant positioned above does not migrate downward into the screened interval during well development, aquifer testing or during normal purge pumping for groundwater sampling. Please call if you have any questions concerning this approval.

Thank you,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

---

From: Everett, Mark Capen [meverett@lanl.gov]
Sent: Tuesday, August 18, 2015 3:45 PM
To: Dale, Michael, NMENV
Subject: FW: R-67 proposed well design

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

From: Everett, Mark Capen
Sent: Tuesday, August 18, 2015 11:17 AM
To: Dale, Michael Ray
Cc: Rodriguez, Cheryl L; Hai Shen (hai.shen@em.doe.gov); Ball, Ted; Swickley, Stephani F (sfuller@lanl.gov); Katzman, Danny
Subject: R-67 proposed well design

Michael,

Attached, please find our proposed well design for R-67. The depth to water of 1226 ft has been confirmed with multiple measurements over two days, both with the drill casing on the bottom of the borehole and pulled back 20 ft. Please let me know if wish to discuss the design or if you are ok with it as is, respond with your concurrence.

Thanks,

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

From: Dale, Michael, NMENV [mailto:Michael.Dale@state.nm.us]
Sent: Thursday, August 27, 2015 7:49 AM
To: Everett, Mark Capen <meverett@lanl.gov>
Cc: Wear, Benjamin, NMENV <Benjamin.Wear@state.nm.us>; Kulis, Jerzy, NMENV <jerzy.kulis@state.nm.us>
Subject: RE: R-67 proposed well design

Mark,

No problem on not going with the longer transition pack. Please let us know when you're going to begin development.

Take care and thanks,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

---

From: Everett, Mark Capen [meverett@lanl.gov]
Sent: Wednesday, August 26, 2015 10:29 AM
To: Dale, Michael, NMENV
Cc: Cobrain, Dave, NMENV; Wear, Benjamin, NMENV; Kulis, Jerzy, NMENV; Rodriguez, Cheryl L; Shen, Hai; Ball, Ted; Fellenz, David, NMENV; Swickley, Stephani Fuller; Katzman, Danny; Longmire, Patrick; Longmire, Patrick, NMENV; Granzow, Kim, NMENV; Yanicak, Steve; Green, Megan, NMENV; Ball, Ted
Subject: RE: R-67 proposed well design

Michael,

Thank you for the well design approval. After careful technical review, we have decided to stick with the two feet of transition sand above the primary filter pack. Construction should begin tomorrow, please let us know if you have additional concerns.

Thanks,

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

-----Original Message-----
From: Dale, Michael, NMENV [mailto:Michael.Dale@state.nm.us]
Sent: Tuesday, August 18, 2015 4:51 PM
To: Everett, Mark Capen
Cc: Cobrain, Dave, NMENV; Wear, Benjamin, NMENV; Kulis, Jerzy, NMENV; Rodriguez, Cheryl L; Shen, Hai; Ball, Ted; Fellenz, David, NMENV; Swickley, Stephani Fuller; Katzman, Danny; Longmire, Patrick; Longmire, Patrick, NMENV; Granzow, Kim, NMENV; Yanicak, Stephen M; Green, Megan, NMENV; Ball, Ted
Subject: RE: R-67 proposed well design

Mark,

New Mexico Environment Department (NMED) hereby approves the installation of the regional-aquifer well R-67 as proposed in your e-mail, with attachments, that was received today, August 18, 2015 at 3:45 PM. This approval is based on information available to NMED at the time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. To end, please note that NMED recommends that an additional 2 - 4 feet of transition filter-pack sand be installed above the depth of 1236 ft bgs with the intent to insure that bentonite sealant positioned above does not migrate downward into the screened interval during well development, aquifer testing or during normal purge pumping for groundwater sampling. Please call if you have any questions concerning this approval.

Thank you,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

---

From: Everett, Mark Capen [meverett@lanl.gov]
Sent: Tuesday, August 18, 2015 3:45 PM
To: Dale, Michael, NMENV
Subject: FW: R-67 proposed well design

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

From: Everett, Mark Capen
Sent: Tuesday, August 18, 2015 11:17 AM
To: Dale, Michael Ray
Cc: Rodriguez, Cheryl L; Hai Shen (hai.shen@em.doe.gov); Ball, Ted; Swickley, Stephani F (sfuller@lanl.gov); Katzman, Danny
Subject: R-67 proposed well design

Michael,

Attached, please find our proposed well design for R-67. The depth to water of 1226 ft has been confirmed with multiple measurements over two days, both with the drill casing on the bottom of the borehole and pulled back 20 ft. Please let me know if wish to discuss the design or if you are ok with it as is, respond with your concurrence.

Thanks,

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

# Appendix F

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*Aquifer Testing Report*

## F-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted during October 2015 at well R-67, a regional aquifer well located at Technical Area 61 (TA-61) between Jemez Road and Sandia Canyon at Los Alamos National Laboratory (LANL or the Laboratory). The tests on R-67 were conducted to characterize the saturated materials and quantify the hydraulic properties of the screened interval. Testing consisted of a step-drawdown test, brief trial pumping, background water-level data collection, and a 24-h constant-rate pumping test.

Typically, the R-wells are evaluated using just the trial tests and 24-h test. However, during development at R-67, while running the pump throughout the screened interval at the pump's maximum discharge rate of approximately 6.5 gallons per minute (gpm), the development crew noted that the pump broke suction (cavitated) as soon as it was raised above the bottom of the well screen. This indicated the pumping water level had been pulled far down into the screen, dewatering the screen and filter pack at this pumping rate. This observation made it essential to conduct a step-drawdown test to obtain drawdown data at a range of pumping rates so that an evaluation could be made of acceptable sampling rates—ones that would not dewater the well screen.

As in most of the R-well pumping tests conducted on the Pajarito Plateau, an inflatable packer system was installed in R-67 to try to eliminate casing storage effects on the test data. This setup was not effective at eliminating storage effects because of the antecedent dewatering that occurred during well development. It is possible that when the filter pack was dewatered originally, air became trapped in the filter pack outside the blank casing just above the well screen when water levels recovered. Subsequent expansion and contraction of this air space during pumping and recovery induced a storage-like effect on the early pumping and recovery data. Implementation of the inflatable packer was effective, however, in reducing the duration of the storage-dominated response compared with what would have occurred without a packer.

### Conceptual Hydrogeology

R-67 is completed within Miocene pumiceous deposits. The well screen is 20.4 ft long, extending from 1242.6 ft to 1263.0 ft below ground surface (bgs). The static water level measured on October 7, 2015, before testing was 1229.51 ft below the top of the 5-in. stainless-steel casing (1226.53 ft bgs). The casing elevation was 7125.69 ft above mean sea level (amsl), making the groundwater elevation 5896.18 ft amsl. The brass cap elevation at the well was surveyed at 7123.25 ft amsl, placing the water level 1227.07 ft below the brass cap.

Miocene sediments extended from above the static water level to a depth of at least 1324.6 ft bgs where the pilot hole was terminated during drilling. The presence of the water table within the permeable Miocene sediments implied locally unconfined conditions.

### R-67 Testing

R-67 was tested from October 7 to 12, 2015. On October 7, the pump was installed and operated long enough to fill the drop pipe to prepare for the step-drawdown test the following morning.

Step-drawdown testing began at 7:30 a.m. on October 8 and continued for 3 h until 10:30 a.m. Testing consisted of six half-hour steps starting at 6.70 gpm (the maximum rate of the test pump) and stepping down to a low rate of 3.56 gpm. Following step-drawdown testing, background data were recorded until 8:00 a.m. the next morning.

Trial testing of R-67 (trial 1) began at 8:00 a.m. on October 9 at a discharge rate of 3.7 gpm and continued for 30 min. Following 30 min of recovery, a second trial test (trial 2) was performed at 9:00 a.m. for 60 min at a discharge rate of 3.7 gpm. Following shutdown, recovery/background data were recorded for 1320 min until the start of the 24-h pumping test.

The 24-h pumping test began at 8:00 a.m. on October 10 and continued until 8:00 a.m. on October 11. Recovery data were recorded for 1455 min until 8:15 a.m. on October 12 when the pump was pulled from the well.

## F-2.0 BACKGROUND DATA

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

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

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

Subsequent pumping tests, including R-67, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When the well is monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, when a nonvented transducer is used, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from TA-54 tower site from the Environmental Protection Division–Environmental Compliance Programs (ENV-CP). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead brass cap elevation is at 7123.25 ft amsl. The static water level in R-67 was 1227.07 ft below the brass cap, making the water-table elevation 5896.18 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-67.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R-67} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-67}}{T_{WELL}}\right)\right] \quad \textbf{Equation F-1}$$

Where, $P_{WT}$ = barometric pressure at the water table inside R-67

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

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

$R$ = gas constant, in J/Kg/degree Kelvin (287.04 J/Kg/degree Kelvin)

$E_{R\text{-}67}$ = brass cap elevation at R-67 site, in feet (7123.25 ft)

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

$E_{WT}$ = elevation of the water level in R-67, in feet (5896.18 ft)

$T_{TA54}$ = air temperature near TA-54, in degrees Kelvin (assigned a value of 56.2 degrees Fahrenheit, or 286.6 degrees Kelvin)

$T_{WELL}$ = air column temperature inside R-67, in degrees Kelvin (assigned a value of 63.8 degrees Fahrenheit, or 290.8 degrees Kelvin)

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

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

## F-3.0 IMPORTANCE OF EARLY DATA

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

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

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

**Equation F-2**

Where, $t_c$ = duration of casing storage effect, in minutes

$D$ = inside diameter of well casing, in inches

$d$ = outside diameter of drop pipe, in inches

$Q$ = discharge rate, in gallons per minute

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

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

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

$$t_c = \frac{0.6\left[\left(D^2 - d^2\right) + S_y\left(D_B^2 - D_C^2\right)\right]}{\frac{Q}{s}}$$ **Equation F-3**

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

$D_B$ = diameter of borehole, in inches

$D_C$ = outside diameter of well casing, in inches

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

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. As discussed in Section F-1.0, this effort was not entirely successful in the testing performed on R-67 because of antecedent dewatering of the screen and filter pack that occurred during well development. Nevertheless, use of the inflatable packer dramatically reduced the duration of storage effects and proved useful in that regard.

## F-4.0 TIME-DRAWDOWN METHODS

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

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

where,

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

and

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

and where, $s$ = drawdown, in feet

$Q$ = discharge rate, in gallons per minute

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

$S$ = storage coefficient (dimensionless)

$t$ = pumping time, in days

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

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

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

**Equation F-7**

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

**Equation F-8**

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

$S$ = storage coefficient

$Q$ = discharge rate, in gallons per minute

$W(u)$ = match-point value

$s$ = match-point value, in feet

$u$ = match-point value

$t$ = match-point value, in minutes

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

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

**Equation F-9**

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

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

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

**Equation F-10**

Where, $T$ = transmissivity, in gallons per day per foot

$Q$ = discharge rate, in gallons per minute

$\Delta s$ = change in head over one log cycle of the graph, in feet

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

**Equation F-11**

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

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

$b$ = aquifer thickness

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

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

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

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

$K_z$ = vertical hydraulic conductivity

$K_r$ = horizontal hydraulic conductivity

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

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

**Equation F-12**

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

## F-5.0 RECOVERY METHODS

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

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

$$T = \frac{264Q}{\Delta s} \qquad \textbf{Equation F-13}$$

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

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

## F-6.0 SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas that are based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is not known, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

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

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

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

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

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

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

To apply this procedure, a storage coefficient value must be assigned. Storage coefficient values generally range from $10^{-5}$ to $10^{-3}$ for confined aquifers and 0.01 to 0.25 for unconfined aquifers (Driscoll 1986, 104226). Semiconfined conditions generally are associated with intermediate storage coefficient values between these ranges. For R-67, the test data and well log suggested unconfined conditions, so calculations were performed for an assigned storage coefficient range of 0.01 to 0.2. The lower-bound transmissivity calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, $b$. For R-67, $b$ was assigned a value of 100 ft, the approximate saturated thickness of Miocene sediments penetrated by the borehole before backfilling and well completion. The calculation is not particularly sensitive to the assigned value of saturated thickness. It is only necessary to use a value well in excess of the screen length. Ignoring deeper sediments has little effect on the calculation results because sediments far from the screened interval have minimal effect on yield.

## F-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-67 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure F-7.0-1 shows aquifer pressure data from R-67 during the test period along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-67 data are referred to in the figure as the “apparent hydrograph” because the measurements reflect the sum of water pressure and barometric pressure, having been recorded using a nonvented pressure transducer. The times of the pumping periods for the R-67 pumping tests are included on the figure for reference.

A comparison of the apparent hydrograph and barometric pressure curve showed little correlation between the two, suggesting a high barometric efficiency, likely close to 100%. Large changes in barometric pressure caused negligible change in the apparent hydrograph, meaning that the changes in water level were equal to and opposite of changes in barometric pressure.

Note that the recovery peaks following each of the first three pumping events were progressively higher. This was an indication that water levels were continuing to recovery from extensive purge pumping (more than 30,000 gal.) that was performed before test pumping. No other significant water level trends were observed in the data.

## F-8.0 WELL R-67 DATA ANALYSIS

This section presents the data obtained from the R-67 pumping tests and the results of the analytical interpretations. Data are presented for the step-drawdown test, trial 1, trial 2, and the 24-h constant-rate test.

### F-8.1 Well R-67 Step-Drawdown Test

Step-drawdown testing was conducted to determine what the safe sampling rate would be. This was done in response to observations during well development that the water level was pulled far down into the screen when pumping approximately 6.5 gpm.

Step-drawdown testing consisted of six steps, each 30 min long, starting at 6.70 gpm (the maximum rate of the test pump) and decreasing to a low rate of 3.56 gpm. Table F-8.1-1 summarizes the discharge rate and observed drawdown for each step. Figure F-8.1-1 provides a graphical depiction of the pumping rate and drawdown data and includes the location of the top of the well screen for reference.

As indicated in Figure F-8.1-1, surprisingly, the water level was never pulled into the well screen, even at the highest pumping rate. It was evident that had the initial discharge rate of 6.7 gpm been maintained for more than 30 min, the pumping water level would have been drawn a short distance into the screen, but probably not deep as had been observed during development.

This apparent deviation in pumping performance from that seen during development has two possible explanations: It was possible that (1) the extended purging procedures that removed more than 30,000 gal. of water may have further developed the well and improved the efficiency before test pumping; or (2) the majority of the yield to the well originated from near the top of the well screen. Under the second scenario, once the pumping water level was pulled into and beneath the producing zone, it would continue to decline rapidly until the pump broke suction. Unfortunately, the capacity of the test pump was not sufficient to stress the well sufficiently to test this second theory using brief pumping steps.

Note: Data extrapolated from the subsequent constant-rate tests presented below suggested that R-67 could sustain a discharge rate of 6.5 gpm for 2 h (typical duration of a sampling event) and a rate of 6.3 gpm for 24 hours without dewatering the well screen. However, if the second scenario in the previous paragraph is correct (most of the production located at the top of the well screen), dewatering could occur at these rates and it would be necessary to restrict the sampling rate to less than these levels.

Figure F-8.1-2 shows a plot of specific drawdown versus discharge rate for the six pumping steps. A flat plot implies laminar flow at all discharge rates, whereas increasing specific drawdown at greater pumping rates can result from increasing turbulent flow and/or dewatering of a portion of the well screen at the elevated rates. It is evident on the graph, however, that the specific drawdown *decreased* at increasing discharge rates—the opposite of what was expected. This was a result of the longer cumulative pumping times associated with the lower rates because pumping started at the maximum rate and was decreased over time. The absence of increasing specific drawdown at increasing pumping rates was an indication of largely laminar flow conditions at all pumping rates.

### F-8.2 Well R-67 Trial 1

Figure F-8.2-1 shows a semilog plot of the drawdown data collected from trial 1 on R-67 at a discharge rate of 3.7 gpm. The data appear chaotic and require some explanation.

When the pump was first started, no water was produced at the flow meter. Therefore, after half a minute, the pump was shut down to investigate. There were two reasons for the lack of immediate production of water. First, as was learned later, a portion of the drop pipe had drained overnight because of the worn, leaky threaded joints in the drop pipe string (which has been used for dozens of pump installations over the years). Second, although the discharge tubing at the surface had intentionally been left full of water at the conclusion of the step-drawdown test the previous day, apparently the pump crew rearranged the discharge tubing later that day and drained a portion of it in the process. Therefore, on pump startup, it took time to refill the drained drop pipe and surface discharge tubing before water reached the flow meter.

After a shutdown of approximately 2.5 min, the pump was restarted. The data recorded following the second pump start were plotted separately in Figure F-8.2-2.

It appeared that there may have been multiple locations within the drop pipe where drainage had occurred overnight. Whenever water leaks out of the pipe through a threaded joint, a void (vacuum) is formed just beneath the nearest overlying check valve. Thus, multiple voids can be created, depending on the locations of the leaky coupling joints. On startup, the pumping rate is elevated temporarily because the pump operates against just the water column between the pump and the lowest void. Once that void is filled, the head applied to the pump increases suddenly. As each successive void is filled, the pumping head rises in increments (and the pumping rate decreases) until the entire drop pipe string and flow control valve are filled with water.

As shown in Figure F-8.2-1, the water level decreased rapidly for 0.2 min and then began to rise. It was surmised that it took 0.2 min at the elevated pumping rate to fill the deepest void in the drop pipe string. Once that void was filled, the pumping rate declined because the pump operated against greater head. Therefore, the water level rose until pump shutoff at approximately 0.5 min.

The restart data shown in Figure F-8.2-2 showed two more indications of drop pipe drainage. After restart, water levels declined for 0.53 min and then rose, presumably in response to a head increase associated with filling an existing void in the drop pipe. The water level resumed declining until a time of 0.7 min when it began rising again, probably indicating that another small void had been filled. Water levels rose for another minute or so until they began to decline in response to the effects of ongoing pumping.

Usually, the drawdown deflections associated with sudden discharge rate reductions are “saw-tooth like,” that is, the water level spikes directly upward when the discharge rate declines and then recedes gradually. As shown in Figure F-8.2-2, however, when the last drop pipe void was filled it took nearly a minute for the water level to rise to a local maximum before declining again. This sluggish response was a likely indication of storage effects and suggested that air had been trapped in the filter pack and contributed to the observed sluggish pressure response.

A formula was derived to estimate the water volume contributed by the filter pack because of expansion of trapped air compared with that which would have been obtained from just the well casing had no packer been deployed. It was assumed that the durations of filter pack storage effects compared with casing storage effects would have essentially the same ratio. A simple application of Boyle’s Law to the R-67 well geometry resulted in the following estimate of the ratio of the filter pack storage volume caused by trapped air compared with the standard casing storage volume that would pertain if no inflatable packer had been deployed:

$$R = \frac{n\left(D_B^2 - D_C^2\right)}{\left(D^2 - d^2\right)} \frac{Ag}{\left(A + H\right)\left(A + H - s\right)}$$

**Equation F-16**

where, $R$ = ratio of filter pack water contribution to casing water contribution

$n$ = short-term drainable porosity of filter pack (estimated at 0.2)

$D_B$ = inside diameter of borehole, in inches (12.93 in. based on backfill volumes required)

$D_C$ = outside diameter of well casing, in inches (5.563 in.)

$D$ = inside diameter of well casing, in inches (5.111 in.)

$d$ = outside diameter of drop pipe, in inches (2.375 in.)

$A$ = atmospheric pressure, in feet of water (27.5 ft)

$H$ = height of water above top of screen, in feet (15.92 ft)

$g$ = height of filter pack and fine sand collar above top of screen, in feet (6.7 ft)

$s$ = drawdown, in feet (approximately 8 ft)

Based on the input parameter values shown, the calculated ratio was 0.16. The standard casing storage calculation produced an estimated storage duration of approximately 23 min. Multiplying this result by 0.16 yielded an estimated storage duration of 3.7 min for the filter pack water contribution. This value is at best approximate. The exact storage mechanism affecting the pumping test data was not known for certain. Also, because of construction difficulties associated with lifting the casing and pushing it back into position during backfilling procedures, it was possible that the filter pack height may have been affected and could be in error in the equation. Nevertheless, this estimate was useful in guiding the pumping test interpretation and appeared to be reasonably consistent with the observed pumping response.

The modified "$t_c$" value computed using this approach is identified in the plot shown in Figure F-8.2-2. Transmissivity was computed from the earliest data following "$t_c$" yielding 505 gallons per day per foot (gpd/ft). This value was considered only approximate because it was based on a graphical plot of the restart data that ignored the brief antecedent pumping and recovery.

By using the earliest possible data to compute transmissivity, before significant vertical expansion of the cone of depression, it was assumed that this represented the approximate transmissivity of just the screened interval or a zone modestly thicker than the screened interval. Dividing the obtained transmissivity value by the screen length of 20.4 ft yielded an estimated hydraulic conductivity of 24.8 gpd/ft$^2$, or 3.3 ft/d. This may be considered an upper limit for the hydraulic conductivity because the computed transmissivity value might correspond to a sediment thickness slightly greater than the screen length.

The late data in Figure F-8.2-2 showed the expected flattening of the slope corresponding to vertical growth of the cone of depression and possible delayed yield.

Figure F-8.2-3 shows recovery data recorded for 30 min following cessation of trial 1 pumping. The transmissivity determined from the slope of the graph immediately after "$t_c$" was 400 gpd/ft corresponding to a maximum hydraulic conductivity value of 19.6 gpd/ft$^2$, or 2.6 ft/d. The progressive flattening of the curve at late recovery time was consistent with vertical growth of the cone of impression and delayed yield.

### F-8.3 Well R-67 Trial 2

Figure F-8.3-1 shows a semilog plot of the drawdown data collected from trial 2 at a discharge rate of 3.7 gpm. The early data showed exaggerated drawdown, likely a response to a brief period (just a fraction of a second) of elevated discharge rate resulting from a tiny void in the drop pipe caused by leakage of water through a coupling joint during the recovery period between trials 1 and 2. The transmissivity value determined from the analysis was 390 gpd/ft, corresponding to a maximum hydraulic conductivity value of 19.1 gpd/ft$^2$, or 2.6 ft/d.

Figure F-8.3-2 shows recovery data recorded for 1320 min following cessation of pumping. The transmissivity determined from the line of fit on the graph was 405 gpd/ft corresponding to a maximum hydraulic conductivity value of 19.9 gpd/ft$^2$, or 2.7 ft/d.

Late data from both pumping and recovery showed the expected flattening effect associated with vertical growth of the cone of depression/impression and delayed yield.

### F-8.4 Well R-67 24-h Test

Figure F-8.4-1 shows a semilog plot of the drawdown data collected during the 24-h pumping test at a discharge rate of 3.7 gpm. The early data showed exaggerated drawdown caused by antecedent drainage of a portion of the drop pipe overnight. Note that the early data showed two abrupt rises in water level, suggesting at least two small voids in the drop pipe.

The transmissivity value determined from the time-drawdown analysis was 405 gpd/ft, corresponding to a maximum hydraulic conductivity value of 19.9 gpd/ft$^2$, or 2.7 ft/d.

The late drawdown data showed a small rise in water level associated with a slight reduction in discharge rate. The water produced during the 24-h pumping test was slightly aerated making it likely that the flow rate change was caused by gradual gas buildup in the pumped water that affected the pump bowl efficiency.

The data recorded before the reduction in discharge rate was plotted on an expanded scale as shown in Figure 8.4-2. The transmissivity computed from the line of fit on the graph was 2520 gpd/ft. It was assumed that this represented the transmissivity of the full thickness of hydraulically contiguous unconsolidated sediments beneath the site. This transmissivity is fairly low—between 1 and 2 orders of magnitude less than the transmissivity of the sediments within the Miocene trough some distance downgradient of the R-67 location.

Figure F-8.4-3 shows recovery data recorded following cessation of pumping. The transmissivity determined from the line shown on the graph was 415 gpd/ft corresponding to a maximum hydraulic conductivity value of 20.3 gpd/ft$^2$, or 2.7 ft/d.

The late recovery data are shown on the expanded-scale plot in Figure F-8.4-4. The transmissivity computed from the line of fit was 5140 gpd/ft. This value was not in good agreement with the transmissivity obtained from the late drawdown data (Figure F-8.4-2). The flatter slope on the recovery graph might be an indication of hysteretic effects. In unconfined aquifers, the early rate of recovery can be more rapid than that of drawdown because of a smaller effective storage coefficient during recovery. During pumping the capillary fringe above the water table increases in thickness, while during recover it gets thinner (Bevan et al. 2005, 105186). If the rate of thinning during recovery exceeds the rate of growth during pumping, the effective storage coefficient during recovery will be less than that during pumping, resulting in a more rapid initial recovery rate than drawdown rate, followed by a period of corresponding slowing of the recovery rate (flatter slope). Additionally, as the water table rebounds during recovery, it can trap air in the previously dewatered pore spaces, further decreasing the effective recovery storage coefficient.

At very late recovery time, it was noted that the recovery plot became steeper once the hysteresis effects subsided. These data were plotted in Figure F-8.4-5 as a rolling average to reduce the scatter. As shown on the plot, the transmissivity from the latest data was 2590 gpd/ft, in better agreement with the value obtained from the drawdown graph (Figure F-8.4-2).

### F-8.5 Combined Results

Table F-8.5-1 summarizes the results of the early-data analyses determining the hydraulic properties of the screened zone in R-67. The value obtained from the trial 1 drawdown was omitted from the calculated average because the results were considered only moderately reliable given the antecedent starting and stopping of the pump before the trial 1 restart data were collected. The other transmissivity values ranged from 390 to 415 gpd/ft, averaging 400 gpd/ft. The resulting upper-bound hydraulic conductivity values averaged 19.6 gpd/ft$^2$, or 2.6 ft/d.

### F-8.6 Well R-67 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by R-67. This was done to provide a frame of reference for evaluating the foregoing analyses.

The total saturated thickness of Miocene sediments was not known. In applying partial penetration analysis, however, it is only necessary to assign an aquifer thickness substantially greater than the well screen length because sediments far from the screened interval have negligible effect on yield. The aquifer thickness was arbitrarily assigned a value of 100 ft—the approximate thickness of saturated sediments penetrated during drilling of the borehole. The well screen length of 20.4 ft was used in the partial penetration calculations.

R-67 produced 3.7 gpm with 9.3 ft of drawdown for a specific capacity of 0.40 gpm/ft after 1440 min of pumping. In addition to specific capacity and pumping time, other input values used in the calculations included assigned storage coefficient values ranging from 0.01 to 0.2 and a borehole radius of 0.54 ft (inferred from the volume of filter pack required to backfill the screen zone).

Applying the Brons and Marting method to these inputs yielded the lower-bound hydraulic conductivity estimates shown in Figure F-8.6-1. Depending on the assumed storage coefficient value, the calculated lower-bound hydraulic conductivity values ranged from approximately 2.2 to 2.3 ft/d. This was consistent with the values obtained from test analysis which produced an average maximum hydraulic conductivity value of 2.6 ft/d and suggested a fairly efficient well.

### F-8.7 Effect of Drop Pipe Drainage

Figure F-8.7-1 provides an illustration of the effects of drop pipe drainage (leaky coupling joints) on the time-drawdown data. The plot shows time-drawdown graphs for (1)) the initial start of trial 1, (2) the trial 1 restart, (3) trial 2, and (4) the 24-h test. Theoretically, because the pumping rate was the same for each test, all tests should have produced identical plots (except perhaps for slight differences in the trial 1 restart because of the immediately antecedent drawdown and recovery). Nevertheless, the early data from the tests differed dramatically. This phenomenon can limit the usefulness of early pumping data. In the specific case of R-67, this effect was not harmful because inevitable storage effects compromised the early data anyway. For pumping tests on other wells, however, where storage effects can be eliminated, drop pipe drainage can detract from the value of the early time-drawdown data.

Fortunately, the recovery data are not affected in the same way. Figure F-8.7-2 shows recovery data recorded following trials 1 and 2 and the 24-h pumping test, illustrating the good data agreement among all of the tests. In general, the recovery data are reliable for determining aquifer characteristics, except for the early storage-affected data.

### F-8.8 Packer Deflation

Water leaking through the drop pipe coupling joints flowed into the annular space between the drop pipe and well casing above the inflatable packer and remained there until the packer was deflated at the end of the 24-h recovery period. This can be seen in the head buildup that occurred when the packer was deflated.

Figure F-8.8-1 shows the head buildup above the static water level during the first 40 min following packer deflation. As shown on the graph, the greatest head measured was 130 ft above the static level. The actual maximum height of water buildup in the annulus was not known because the head data were measured at 1-min intervals—not sufficient frequency to capture the maximum head position. It was certain, however, that the initial head following packer deflation would have been greater than the first measurement shown on the graph.

It was not possible to extrapolate what the maximum head buildup might have been because the exact time of packer deflation was not known. When the packer was bled, the pressurized nitrogen gas escaped slowly so there was no way to know at what point the pressure had been reduced sufficiently to allow movement of trapped water downward past the packer. The only certainty was that the packer deflated between 0 and 1 min on the graph in Figure F-8.8-1.

## F-9.0 SUMMARY

Pumping tests were conducted on R-67 to gain an understanding of the hydraulic characteristics of the aquifer and estimate safe sampling rates. Testing consisted of a step-drawdown test, two brief trial tests and a 24-h test.

Several important observations and conclusions from the test pumping include the following:

1. A comparison of barometric pressure and R-67 water-level data showed a highly barometrically efficient screen zone. Large changes in barometric pressure caused almost no change in the apparent hydrograph obtained from the well, obtained using a nonvented pressure transducer.
2. Dewatering of the screen and filter pack during development likely trapped air in the filter pack above the well screen creating a storage-like effect on the drawdown and recovery data that persisted for a few minutes.
3. Even though substantial dewatering of the well screen occurred during well purging and development, no dewatering occurred during the step-drawdown test, even at the maximum rate of the pump, although it was clear from the data that modest dewatering would have occurred had the maximum discharge rate been maintained for a longer period. The significant dewatering that occurred during purging/development indicated that either (1) well efficiency improvement had occurred during purging, before the test pumping; or (2) most of the production from R-67 comes from the uppermost portion of the screen.
4. Step-drawdown testing showed largely laminar flow conditions at all pumping rates.
5. Extrapolations of the 24-h pumping test data indicated that R-67 can produce 6.5 gpm for up to 2 h (typically enough time for taking water samples) and approximately 6.3 gpm for 24 h. If most of the production to R-67 is at the top of the well screen, however, permissible pumping rates would be somewhat less.
6. The estimated transmissivity of the screened interval (or a sediment thickness modestly greater that the screen length) was 400 gpd/ft, making the upper-bound hydraulic conductivity 19.6 gpd/ft$^2$, or 2.6 ft/d.
7. The specific capacity of R-67 implied lower-bound hydraulic conductivity values in the range of 2.2 to 2.3 ft/d consistent with the results of the hydraulic analyses (less than or equal to 2.6 ft/d) and suggested a fairly efficient screen zone in R-67.
8. The test analyses combined with the specific capacity data bracketed the hydraulic conductivity between approximately 2.2 and 2.6 ft/d.
9. Late drawdown and recovery data suggested an overall transmissivity of the unconsolidated deposits at the site of just over 2500 gpd/ft—between 1 and 2 orders of magnitude less than transmissivity values observed in the Miocene trough downgradient of R-67.
10. The pipe couplings in the drop pipe string leaked water into the annulus between the drop pipe and well casing, forming voids in the drop pipe during down time and causing chaotic changes in discharge rate when the pump was started.

## F-10.0 REFERENCES

*The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID or ESH ID. This information is also included in text citations. ER IDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESH IDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.*

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

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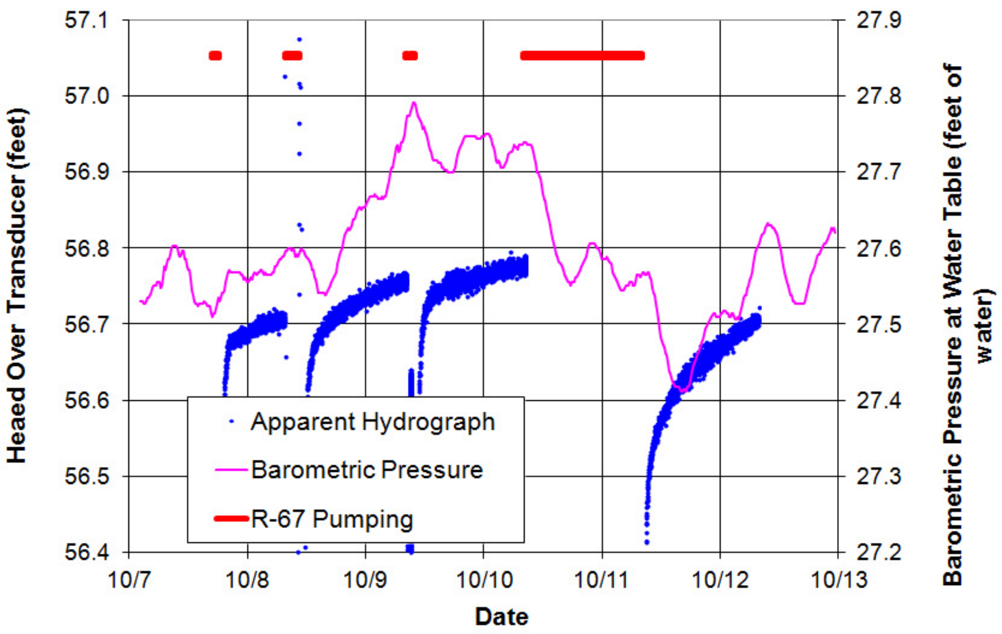

Figure F-7.0-1 Well R-67 apparent hydrograph

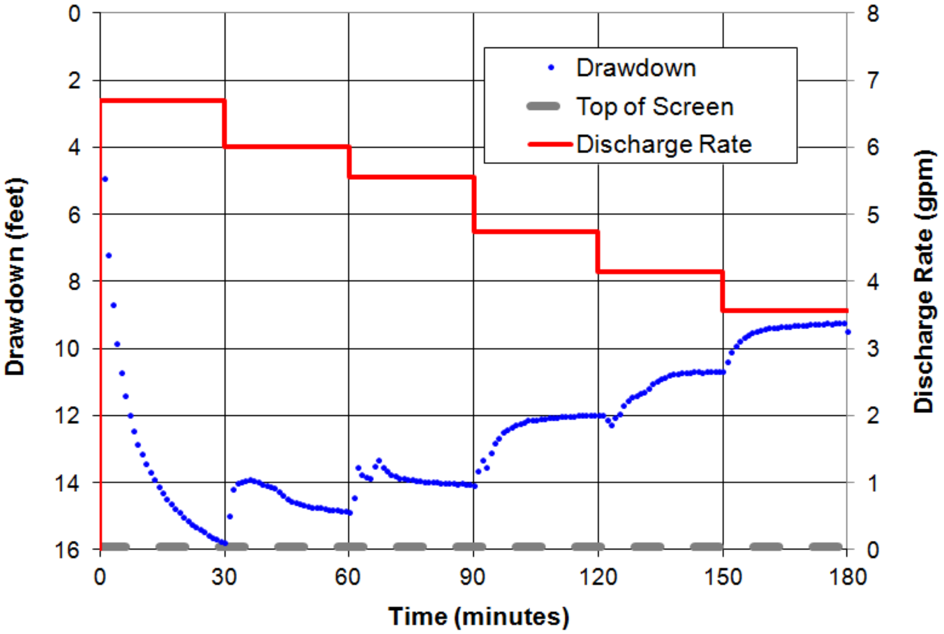

Figure F-8.1-1 Well R-67 step-drawdown test

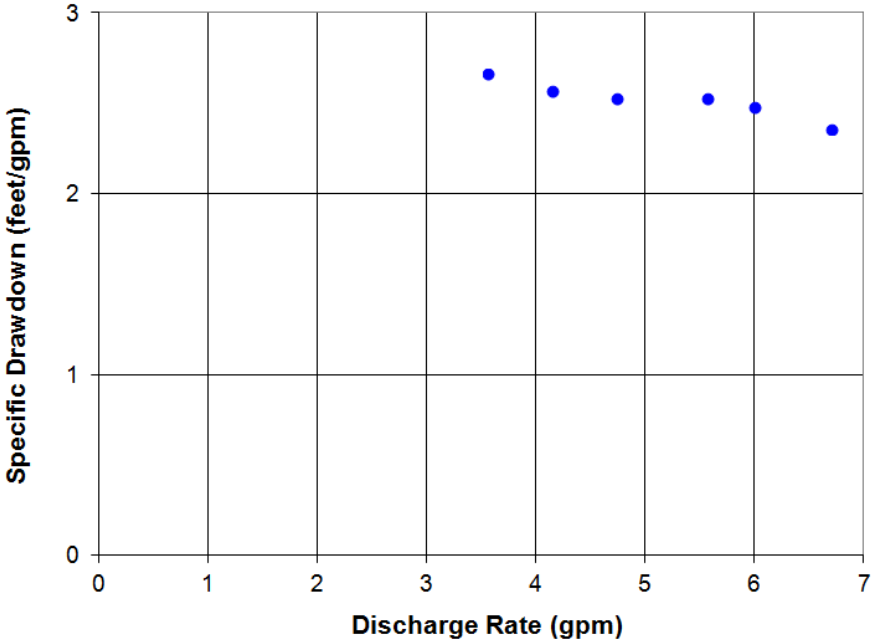

Figure F-8.1-2  Well R-67 specific drawdown

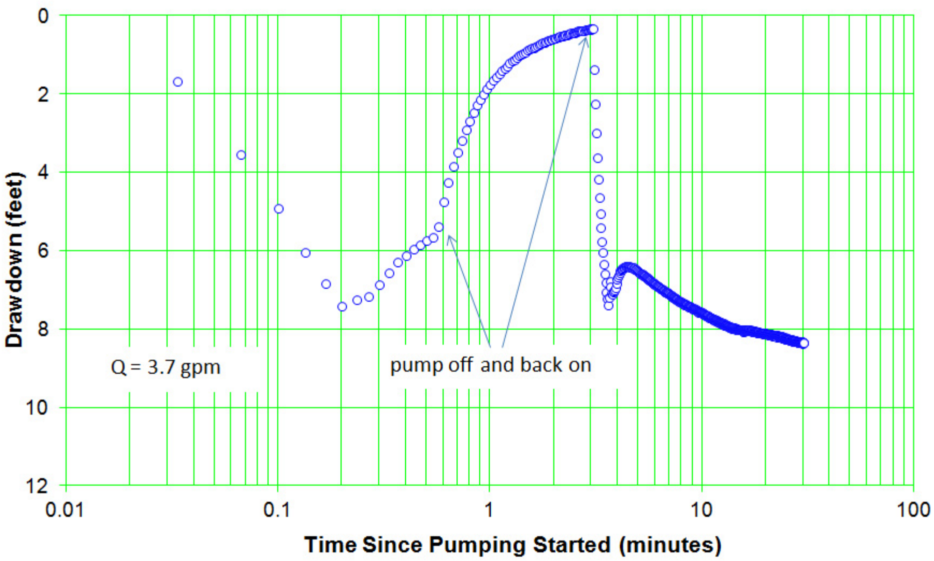

Figure F-8.2-1  Well R-67 trial 1 drawdown

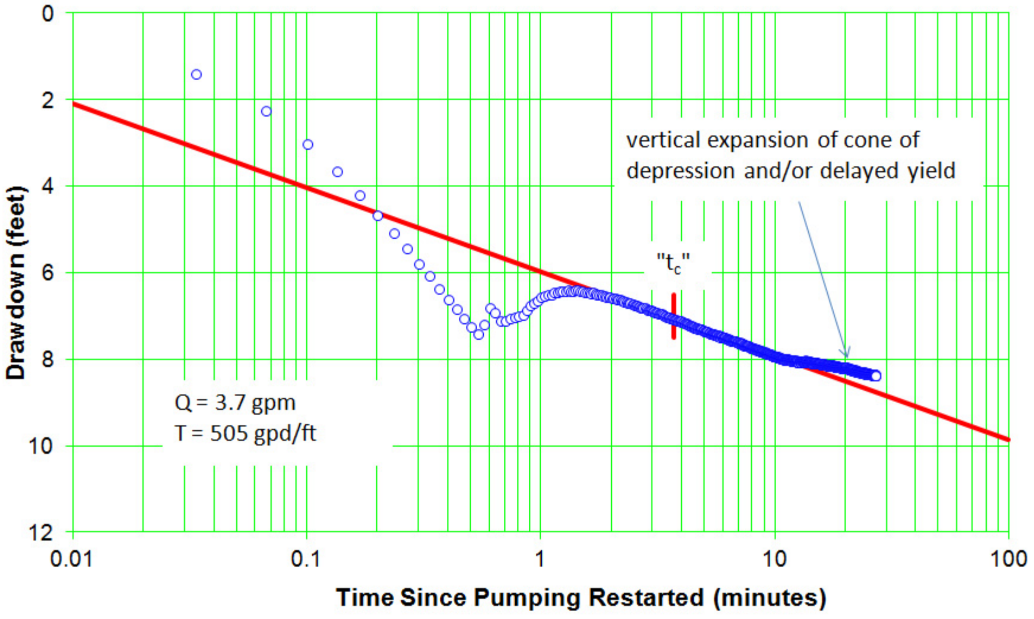

**Figure F-8.2-2 Well R-67 trial 1 restart**

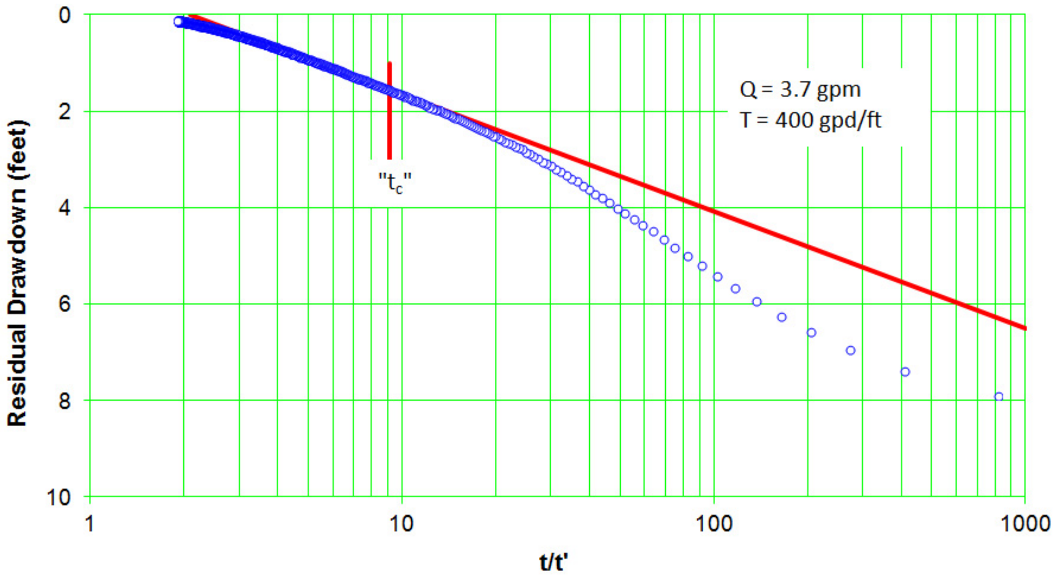

**Figure F-8.2-3 Well R-67 trial 1 recovery**

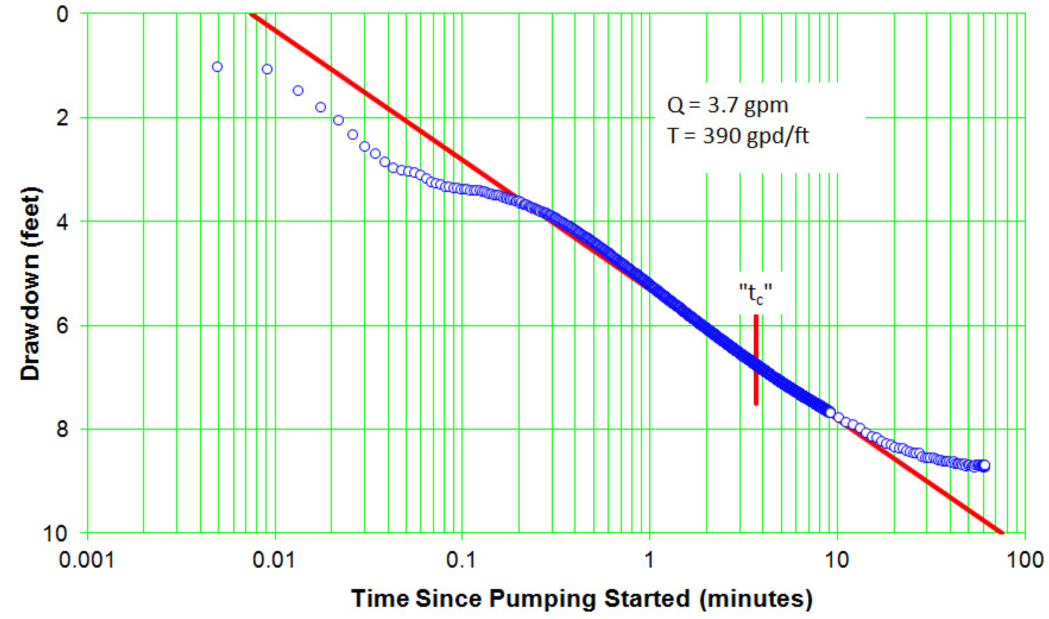

Figure F-8.3-1 Well R-67 trial 2 drawdown

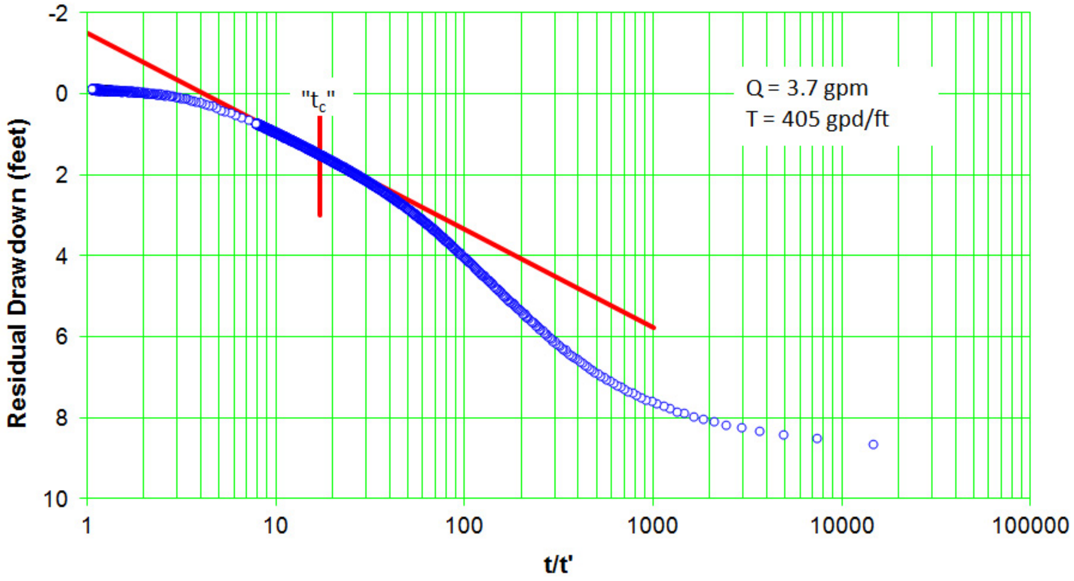

Figure F-8.3-2 Well R-67 trial 2 recovery

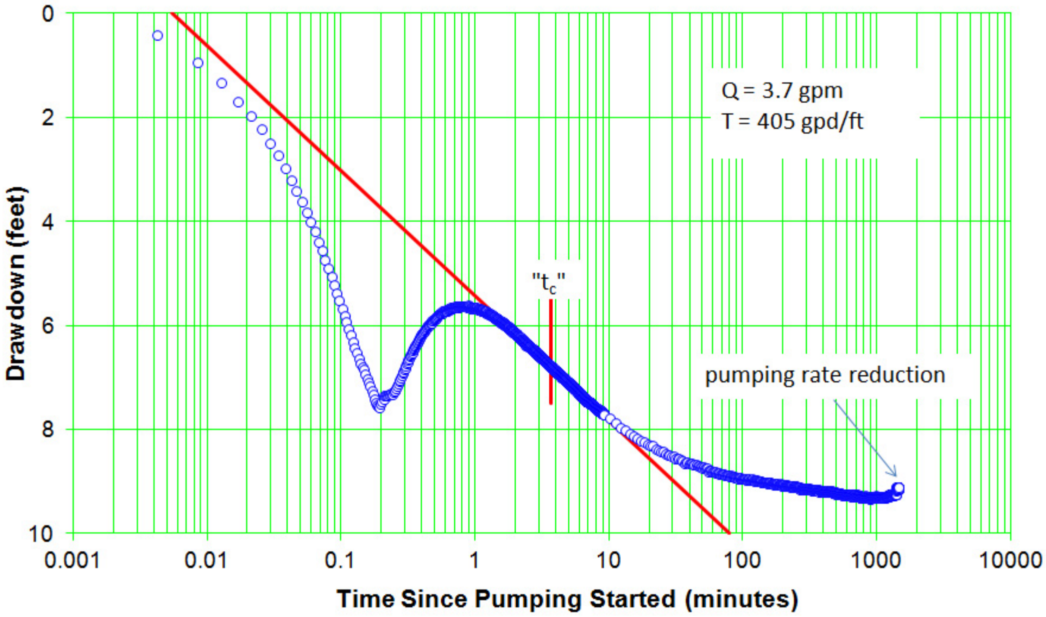

Figure F-8.4-1  Well R-67 drawdown

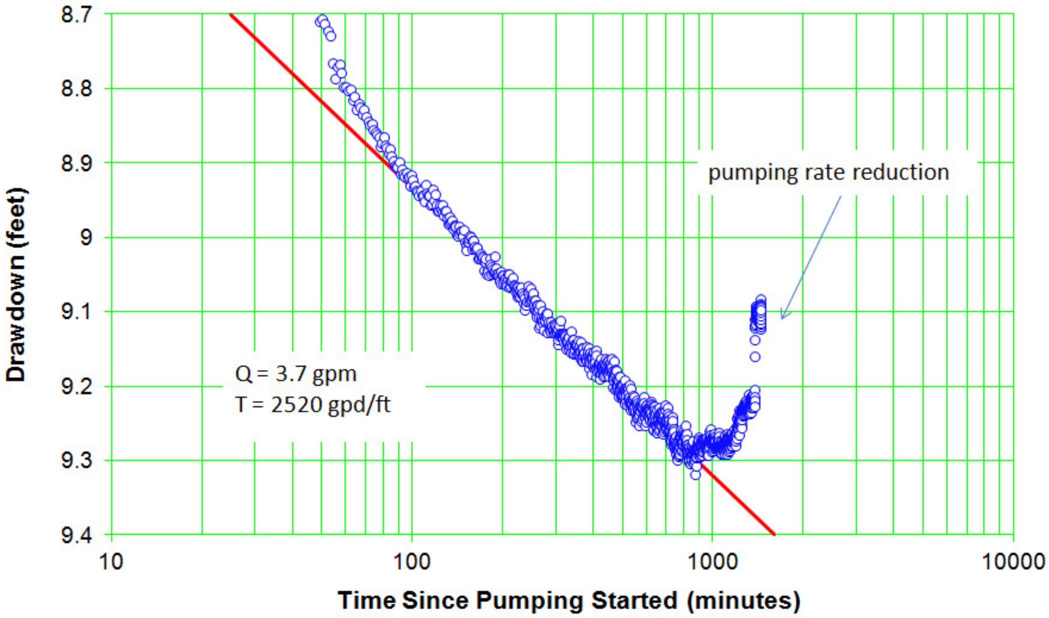

Figure F-8.4-2  Well R-67 late drawdown

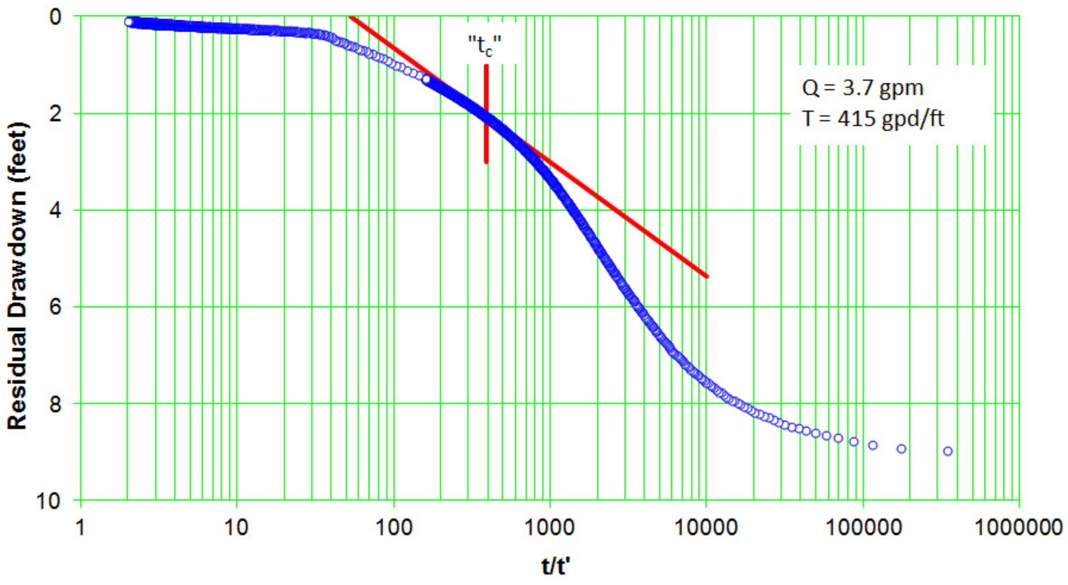

Figure F-8.4-3 Well R-67 recovery

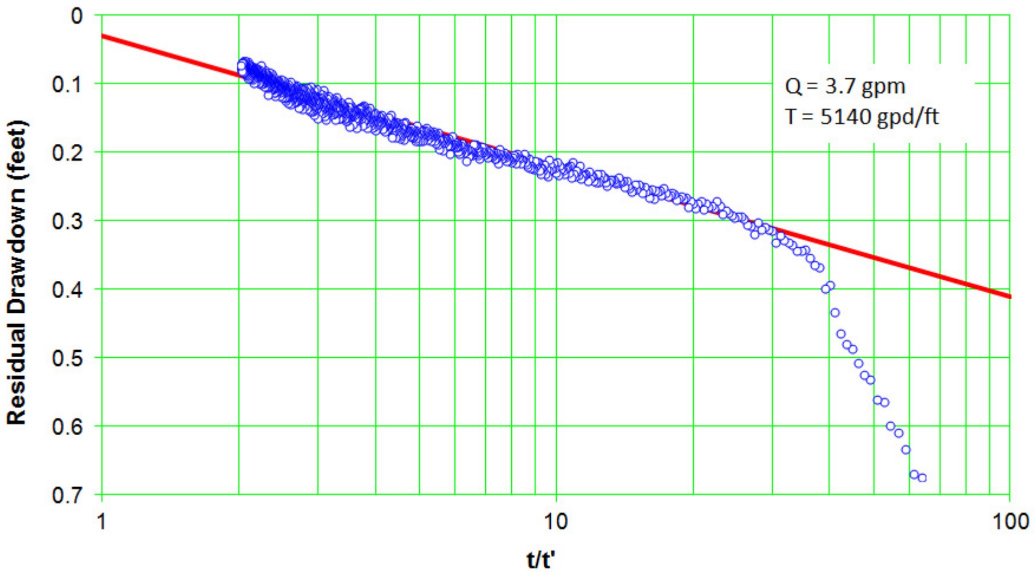

Figure F-8.4-4 Well R-67 late recovery

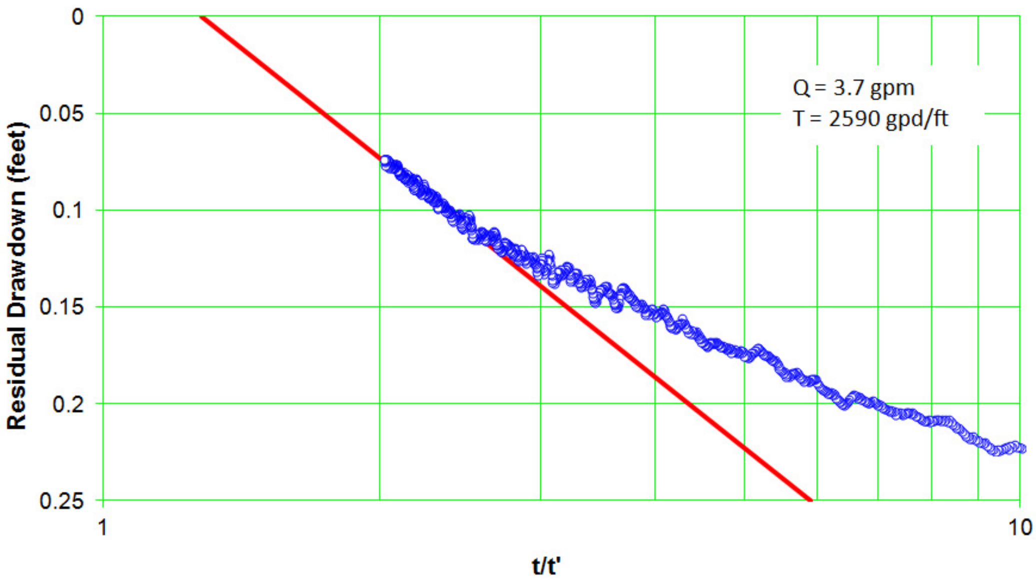

**Figure F-8.4-5  Well R-67 late recovery—rolling average**

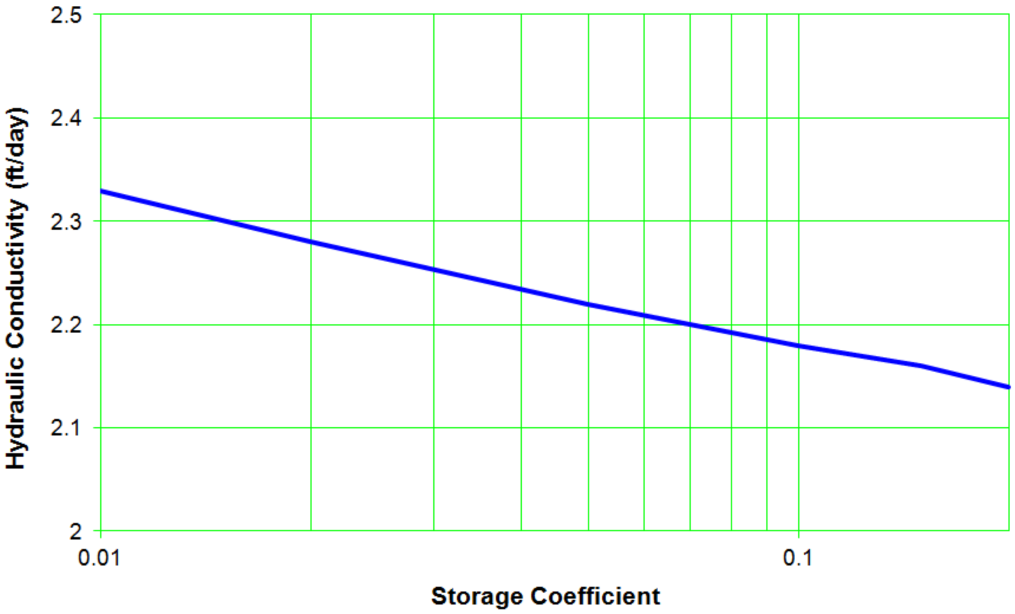

**Figure F-8.6-1  Well R-67 lower-bound hydraulic conductivity**

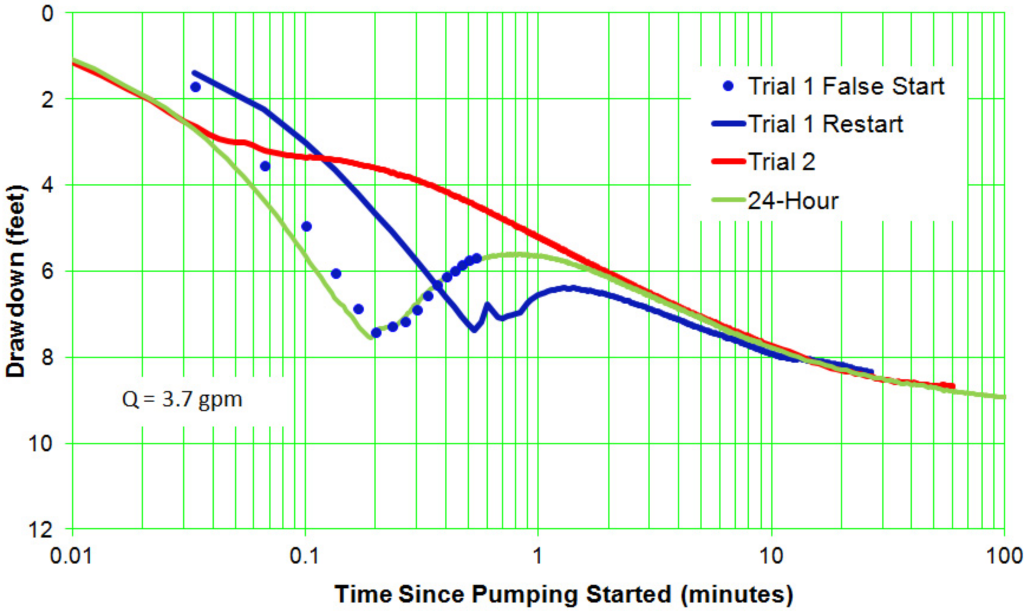

**Figure F-8.7-1  Well R-67 all drawdown tests**

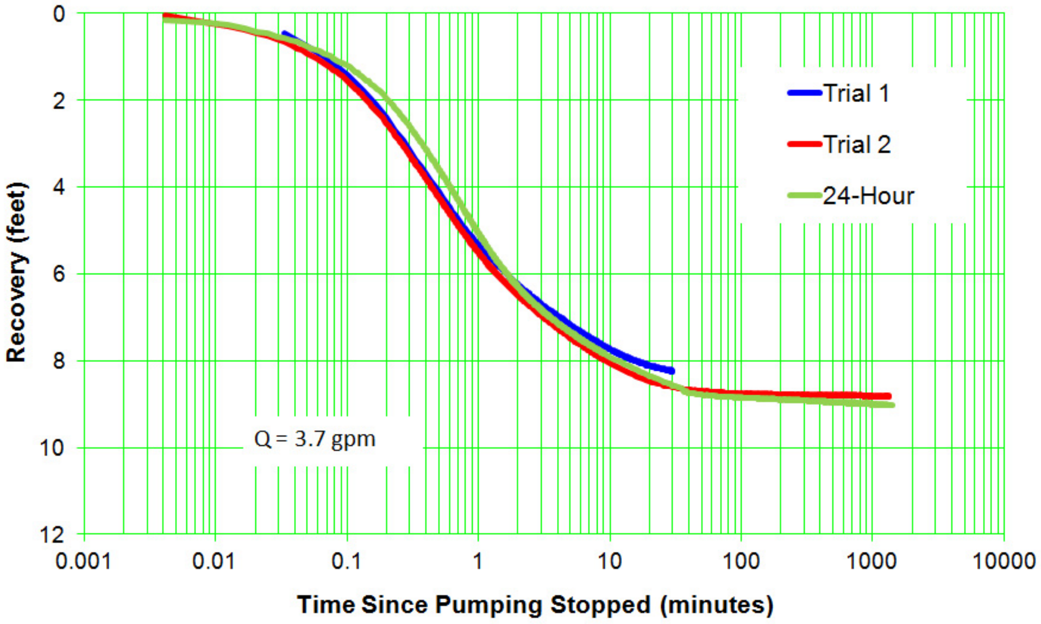

**Figure F-8.7-2  Well R-67 all recovery tests**

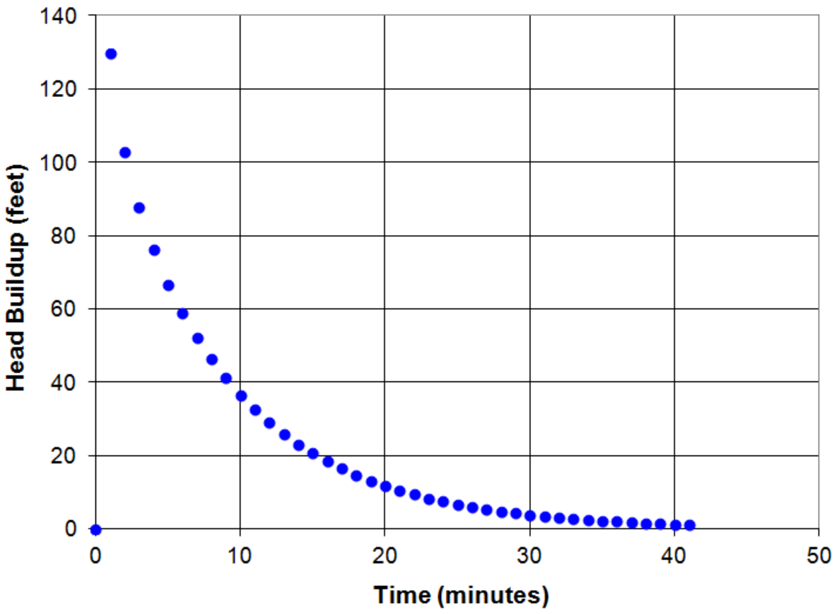

**Figure F-8.8-1** Well R-67 packer deflation

## Table F-8.1-1
## Step Drawdown Data

| Step | Q (gpm) | Drawdown (ft) | Specific Drawdown (ft/gpm) |
|---|---|---|---|
| 1 | 6.70 | 15.78 | 2.36 |
| 2 | 6.00 | 14.87 | 2.48 |
| 3 | 5.56 | 14.06 | 2.53 |
| 4 | 4.74 | 11.96 | 2.52 |
| 5 | 4.15 | 10.65 | 2.57 |
| 6 | 3.56 | 9.47 | 2.66 |

## Table F-8.5-1
## Transmissivity and Hydraulic Conductivity Summary

| Test | Method | T (gpd/ft) | K (gpd/ft$^2$) | K (ft/day) |
|---|---|---|---|---|
| Trial 1 | Drawdown | 505 | 24.8 | 3.3 |
| Trial 1 | Residual Drawdown | 400 | 19.6 | 2.6 |
| Trial 2 | Drawdown | 390 | 19.1 | 2.6 |
| Trial 2 | Residual Drawdown | 405 | 19.9 | 2.7 |
| 24-h Test | Drawdown | 405 | 19.9 | 2.7 |
| 24-h Test | Residual Drawdown | 415 | 20.3 | 2.7 |
| Average | All but Trial 1 Drawdown | 400 | 19.6 | 2.6 |