DEPARTMENT OF ENERGY
Environmental Management Los Alamos Field Office (EM-LA)
Los Alamos, New Mexico 87544

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Hazardous Waste Bureau

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

Dear Mr. Kieling:

Subject: Submittal of the Completion Report for Regional Aquifer Well R-69, Revision 1

Enclosed please find two hard copies with electronic files of the "Completion Report for Regional Aquifer Well R-69, Revision 1." The report incorporates revisions based on comments received from the New Mexico Environment Department on May 15, 2019. The U.S. Department of Energy Environmental Management Los Alamos Field Office/ Newport News Nuclear BWXT-Los Alamos, LLC, response to these comments, submitted by email in July 2019, is also enclosed.

If you have any questions, please contact Mark Everett at (505) 309-1367 (mark.everett@em-la.doe.gov) or Cheryl Rodriguez at (505) 257-7941 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Arturo Q. Duran
Compliance and Permitting Manager
Environmental Management
Los Alamos Field Office

Enclosures:

1. Two hard copies with electronic files – Completion Report for Regional Aquifer Well R-69, Revision 1 (EM2019-0335)
2. Response to Draft New Mexico Environment Department Comments on the Completion Report for Regional Aquifer Well R-69, Dated March 2019 (EM2019-0053)

cc (letter with hard-copy enclosure[s]):
M. Everett, N3B
C. Rodriguez, EM-LA

cc (letter with CD enclosure[s]):
L. King, EPA Region 6, Dallas, TX
R. Martinez, San Ildefonso Pueblo, NM
D. Chavarria, Santa Clara Pueblo, NM
S. Yanicak, NMED
P. McGuire, N3B
emla.docs@em.doe.gov
N3B Records
Public Reading Room (EPRR)
PRS Website

cc (letter emailed without enclosure[s]):
W. Alexander, N3B
E. Day, N3B
M. Erwin, N3B
E. Evered, N3B
M. Everett, N3B
D. Holgerson, N3B
J. Hyatt, N3B
D. Katzman, N3B
K. Lebak, N3B
J. Legare, N3B
F. Lockhart, N3B
E. Lowes, N3B
P. Maestas, N3B
J. Moore, N3B
G. Morgan, N3B
L. Patten, N3B
G. Pool, N3B
B. Robinson, N3B
T. Vigil, N3B
S. White, N3B
J. Yarbrough, N3B
A. Duran, EM-LA
T. McCrory, EM-LA
D. Nickless, EM-LA

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October 2019
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Completion Report for Regional Aquifer Well R-69, Revision 1

EM2019-0335

Completion Report for Regional Aquifer Well R-69, Revision 1

October 2019

Responsible program director:

Printed Name	Signature	Title	Organization	Date
Bruce Robinson		Program Director	Water Program	10/21/2019

Responsible N3B representative:

Printed Name	Signature	Title	Organization	Date
Erich Evered		Program Manager	N3B Environmental Remediation Program	10/21/2019

Responsible DOE EM-LA representative:

Printed Name	Signature	Title	Organization	Date
Arturo Q. Duran		Compliance and Permitting Manager	Office of Quality and Regulatory Compliance	10/30/19

EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for regional aquifer monitoring well R-69, located in Technical Area 14 at Los Alamos National Laboratory, Los Alamos, New Mexico. The R-69 monitoring well was installed to address the relation of the RDX (Royal Demolition Explosive and associated high-explosive compounds) flow paths between wells R-68 and R-18, which includes an understanding of the northern extent of perched-intermediate groundwater and whether the perched zone is hydrologically connected to the regional aquifer north of R-68. Well R-69 provides information on the hydraulics in the distal portion of the plume, which is important for estimating the concentration of RDX near the water table in the R-18 area. The R-69 well will also be useful for filling in data gaps for the regional aquifer at two discrete depth intervals and for long-term performance monitoring of any corrective action measures that may be implemented.

Installation of the well fulfills a recommendation made in the “Groundwater Investigation Work Plan for Consolidated Unit 16-021(c)-99, including Drilling Work Plans for Wells R-68 and R-69.” Groundwater chemistry data from this well and characterization within the vadose zone during drilling helps constrain the nature and extent of perched-intermediate groundwater and contamination in the regional aquifer originating from infiltration along Cañon de Valle. Water-level data from this well provides important information for the elevation of the regional water table and groundwater flow direction north of Cañon de Valle.

The R-69 monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was terminated at a depth of 1203.5 ft below ground surface (bgs) and the borehole was completed using only potable water and air. Well R-69 was drilled to a total depth of 1443.4 ft bgs.

The following geologic formations were encountered at R-69: Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, and the Puye Formation.

Well R-69 was completed as a dual-screen well, allowing evaluation of water quality and water levels at two discrete depth intervals near the depths of the well R-68 and R-18 screened intervals within the regional aquifer. Well screens are isolated by a packer as part of the permanent sampling system to hydraulically isolate each zone. Both the upper and lower 20-ft-long screen intervals are within the Puye Formation. The top of the upper screened interval is set at 1310 ft bgs and the lower screened interval is set at 1375.5 ft bgs. The static depth to water after well installation was measured at 1292.5 ft bgs.

The well was completed in accordance with the New Mexico Environment Department–approved well design. Both well screen completion zones were developed, and the regional aquifer groundwater met target water-quality parameters in both zones. Aquifer testing in both screened intervals indicates regional aquifer monitoring well R-69 will perform effectively in meeting the planned objectives. A dual-port sampling system and transducers were placed within each screened interval, and groundwater sampling at R-69 is being performed as part of the annual Interim Facility-wide Groundwater Monitoring Plan.

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Acronyms and Abbreviations

APV	access port valve
amsl	above mean sea level
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
DTW	depth to water
EES	Earth and Environmental Sciences (Laboratory division)
Eh	oxidation-reduction potential
EPA	Environmental Protection Agency (U.S.)
F	filtered
FD	field duplicate
FTB	field trip blank
GEL	GEL Laboratories, LLC
gpd	gallons per day
HE	high explosives
HEXP	high explosive analytical suite
hp	horsepower
I.D.	inside diameter
LANL	Los Alamos National Laboratory
LIC	liquid inflation chamber
MST	Mountain Standard Time
N3B	Newport News Nuclear BWXT-Los Alamos, LLC
NAD	North American Datum
ND	not detected
NMED	New Mexico Environment Department
NMOSE	New Mexico Office of the State Engineer
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
RDX	Royal Demolition Explosive
S1	screen 1
S2	screen 2

SOP	standard operating procedure
SVOC	semivolatile organic compound
TD	total depth
TNT	trinitrotoluene
TOC	total organic carbon
TPMC	TerranearPMC, LLC
UF	unfiltered
VOC	volatile organic compound
WCSF	waste characterization strategy form
WDS	water disposal system

1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and the dedicated sampling system installation for regional aquifer monitoring well R-69. The R-69 monitoring well borehole was drilled in accordance with the New Mexico Environment Department–(NMED-) approved “Summary Report for R-68 and Drilling Work Plan for R-69, Revision 1” (LANL 2017, 602646; NMED 2017, 602697) between August 18 and September 15, 2018, and completed between September 20 and October 24, 2018, at Los Alamos National Laboratory (LANL or the Laboratory).

Well R-69 is located within the Laboratory’s Technical Area 14 in Los Alamos County, New Mexico (Figure 1.0-1) to fulfill a recommendation in the “Groundwater Investigation Work Plan for Consolidated Unit 16-021(c)-99, including Drilling Work Plans for Wells R-68 and R-69” (LANL 2016, 601779).

The R-69 monitoring well was installed to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the Compliance Order on Consent (Consent Order) and the NMED-approved drilling work plans (LANL 2016, 601779; NMED 2016, 601855; LANL 2017, 602646). Specifically, R-69 was installed to address the relation of the RDX (Royal Demolition Explosive and associated high-explosive [HE] compounds) flow paths between R-68 and R-18, which includes an understanding of the northern extent of perched-intermediate groundwater and whether the perched zone is hydrologically connected to the regional aquifer north of R-68. Well R-69 provides information on the hydraulics (vertical gradient) in the distal portion of the plume, which is important for estimating the concentration of RDX near the water table in the R-18 area. In addition, R-69 addresses data gaps for regional aquifer monitoring at two discrete depth intervals in the regional aquifer.

The location for R-69 was selected because of its relative proximity to both R-18 and R-68. This location was selected to provide a better understanding of the increasing concentrations of RDX observed in R-18, which is screened from 69 ft to 92 ft below the regional water table. Water-level data from R-69 will be used to verify the groundwater flow direction in this area and may help to determine the source of contamination at R-18 based on groundwater flow direction. Additionally, the location for R-69 will make it useful for long-term performance monitoring of any corrective measures that may be implemented to protect the regional aquifer.

Secondary objectives included identifying and establishing water levels in perched-intermediate aquifers, if present, collecting samples of drill cuttings for lithologic description, and acquiring borehole geophysical data. The R-69 borehole was drilled to a total depth (TD) of 1443.4 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals from ground surface to TD. A monitoring well was installed with 20-ft, dual-screened intervals at 1310 ft bgs and 1375.5 ft bgs within the Puye Formation. The depth to water (DTW) of 1292.5 ft bgs was recorded on October 25 after well installation.

Post-installation activities included well development, aquifer testing, surface completion, 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 records, logbooks, and daily activity reports. Records, including field reports, field logs, and survey information, are on file at Newport News Nuclear BWXT-Los Alamos, LLC (N3B) Records Management. This report contains brief descriptions of activities and supporting figures, tables, and appendixes associated with the R-69 project.

2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide activities associated with the drilling, installation, and development of regional aquifer well R-69:

- "Groundwater Investigation Work Plan for Consolidated Unit 16-021(c)-99, Including Drilling Work Plans for Wells R-68 and R-69" (LANL 2016, 601779);
- "Summary Report for R-68 and Drilling Work Plan for R-69, Revision 1" (LANL 2017, 602646; NMED 2017, 602697);
- "Field Implementation Plan for Regional Aquifer Well R-69" (TerranearPMC 2016, 602451);
- "IWD [Integrated Work Document] for Drilling and Installation of LANL Wells R-68 and R-69" (TerranearPMC 2016, 602452);
- "Storm Water Pollution Prevention Plan, Regional Wells (R-Wells) Drilling, Los Alamos National Laboratory, Revision 1" (LANL 2014, 601293);
- "Waste Characterization Strategy Form (WCSF) for Regional Well R-68" (LANL 2016, 601994) and "Amendment #1 to the Waste Characterization Strategy Form (WCSF) for Regional Well R-68, (EP2016-0149)" (LANL 2016, 602000).

3.0 DRILLING ACTIVITIES

This section describes the drilling approach and provides a chronological summary of field activities conducted at monitoring well R-69.

3.1 Drilling Approach

The drilling method, equipment, and drill-casing sizes for the R-69 monitoring well were selected to retain the ability to investigate and case or seal off any perched groundwater encountered above the regional aquifer. Further, the drilling approach ensured that a sufficiently sized drill casing was used to meet the required 2-in. minimum annular thickness of the filter pack around a 5.88-in.–outside diameter (O.D.) well screen.

Dual-rotary drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-69 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 Atlas Copco towable air compressors. Four sizes of A53 grade B flush-welded mild carbon-steel casing (18-in. and 16-in. O.D., and 12-in. and 10-in. inside diameter [I.D.]) were used for the R-69 project.

The dual-rotary drilling technique at R-69 used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all within the vadose zone) included potable water and a mixture of potable water with Baroid AQF-2 foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of the foaming agent was terminated at 1203.5 ft bgs, roughly 100 ft above the expected top of the regional aquifer. No additives, other than potable water, were used for drilling below 1203.5 ft bgs. Total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-69 Well

The DR-24HD drill rig, drilling equipment, and supplies were mobilized to the R-69 drill site between July 19 and July 27, 2018. The equipment and tooling were decontaminated and inspected before mobilization to the site. Site preparation work was performed concurrently with mobilization activities by J.B. Henderson, under the direction of TerranearPMC, LLC (TPMC) personnel. Site Preparation included installation of a 12-mil high-strength, laminated polyethylene film liner into the cuttings/drill-fluid pit and installation of temporary horse fencing with an access gate around the pit.

On July 28, drilling of the monitoring well borehole began at 0900 hr using dual-rotary methods with a 17-in. underreaming hammer bit and 18-in. drill casing. The 18-in. surface casing was advanced to 52.6 ft bgs through unit 3t and into unit 3 of the Tshirege Member of the Bandelier Tuff on July 28. Open-hole drilling commenced on July 29 using a 17-in. hammer bit. Open-hole drilling proceeded through the Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, the Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed of the Otowi Member, and into the Puye Formation to 741 ft bgs. N3B recorded natural gamma-ray, induction, and video logs in the open hole on July 31.

Between July 31 and August 4, a 16-in. casing string was installed in the open borehole. From August 4 through August 10, a 16-in. underreaming hammer bit was used to advance the 16-in. casing through the Puye Formation to 764.2 ft bgs. On August 11, a decision was made to plug and abandon the borehole when the bottom of the drill casing incurred damage. The damage was due to an obstruction in the borehole that deflected and pinched the casing, obstructing passage of the 16-in. underreaming drill bit through the last 2 ft of casing and through the casing shoe.

Between August 12 and 13, the borehole was plugged and abandoned from 765.4 to 20.1 ft bgs with hydrated 3/8-in. bentonite chips and from 20.1 ft bgs to surface with Portland Type I/II cement mixed at a ratio of 6 gal. municipal water to one 94-lb bag of cement. The plugging record for State Engineer Well Number RG-97398 (R-69) was sent to the New Mexico Office of the State Engineer (NMOSE) on September 13 (NMOSE 2018, 700323).

On August 14, the drill rig was moved 15 ft west to a second borehole location. Between August 14 and August 18, 16-in. drill casing was trimmed for re-use. The 18-in. surface casing was advanced with a 17-in. button-tooth hammer bit to 16.6 ft bgs in unit 3t of the Tshirege Member of the Bandelier Tuff on August 18.

Open-hole drilling of the second borehole commenced on August 20 using a 17-in. button-tooth tricone bit. The button-tooth tricone bit was used to reduce washout, which was experienced during drilling of the first boring. Drilling proceeded through the Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, the Otowi Member of the Bandelier Tuff, and into the Guaje Pumice Bed to 683 ft bgs.

The 16-in. casing string was installed between August 21 and August 24. The second borehole was advanced with 16-in. casing and a 16-in. underreaming hammer bit from 683 to 905 ft bgs through the Guaje Pumice Bed into the Puye Formation on August 25 and 26. The 16-in. casing shoe was successfully cut on August 27 at 899.1 ft bgs.

A 12-in. casing string was installed to a depth of 905 ft bgs between August 27 and August 29. The 12-in. casing string and an underreaming hammer bit were advanced through the Puye Formation to 1264.5 ft bgs between August 29 and September 1. The 12-in. casing shoe was successfully cut on September 3 at 1257.1 ft bgs.

Between September 4 and September 13, a 10-in. casing string was installed to a depth of 1265 ft bgs. The 10-in. casing string and an underreaming hammer bit were advanced through the Puye Formation to a TD of 1443.4 ft bgs on September 15 at 2305 hr. After TD was reached, water levels were recorded in the borehole. The 10-in. casing shoe was successfully cut on September 16 at 1439.5 ft bgs. No bentonite seal was installed because no perched water zones had been observed. On September 17, a natural gamma-ray log was recorded by N3B.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-69. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-69 monitoring well borehole at 5-ft intervals from ground surface to the TD of 1443.4 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected by the site geologist from the drilling discharge hose, 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 screened the cuttings, and HE spot testing was performed before the cuttings were removed from the site. All screening measurements were below background values and/or negative for HE. The cuttings samples were delivered to N3B at the conclusion of drilling activities.

The stratigraphy at well R-69 is summarized in section 5.1, and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

4.2.1 Suspected Perched Water Samples

Two samples of suspected perched groundwater were collected from the annulus for screening purposes during well construction, between the 16-in. open hole and 5-in. well casing. The initial (first encounter) sample was collected for anions and cations analysis, tritium, the NMED HE suite (NMED HEXP), alkalinity, metals, RDX, and LANL's Earth and Environmental Sciences 6 (EES-6) tracer analysis. A second sample (intermediate) was collected for the same analytical suite. Whether the water for these samples was introduced water or native groundwater was not determined. HE was not detected in these samples, indicating the water was likely municipal water introduced during drilling or well construction. Table 4.2-1 presents a summary of screening samples collected during the R-69 monitoring well installation.

Note that these samples of suspected perched groundwater were collected during well construction and not during drilling operations. Per the field implementation plan, perched intermediate groundwater was anticipated between 680 ft bgs and 875 ft bgs; however, no actual perched water was observed in these zones during drilling operations. Further details regarding the events surrounding observation, monitoring, and sampling of the annular water are presented in Section 9.2.

4.2.2 Well Development Samples

A total of four groundwater samples were collected during well development. Three samples were collected from screen 2 and one sample was collected from screen 1 for total organic carbon (TOC) analysis on November 3 and 4.

4.2.3 Aquifer Test Samples

A total of 26 groundwater-screening samples (13 samples from each screen) were collected from screen 1 and screen 2 during the aquifer test for RDX and TOC analysis between November 9 and November 19.

Table 4.2-1 presents a summary of screening samples collected during the R-69 monitoring well installation. The TOC and RDX results and field water-quality parameters are presented in Appendix B.

4.2.4 Groundwater Characterization Samples

Groundwater characterization samples were collected from the completed well in accordance with the Consent Order. For the first year, the samples are being analyzed for a full suite of constituents in accordance with the requirements of the "Interim Facility-Wide Groundwater Monitoring Plan" following aquifer testing. Analytical results of these samples will be reported in the next periodic monitoring report.

5.0 GEOLOGY AND HYDROGEOLOGY

The geologic and hydrogeologic features encountered at R-69 are summarized below. The N3B geology task leader and project site geologist examined cuttings and the natural gamma-ray log to determine geologic contacts and hydrogeologic conditions. Drilling observations and water-level measurements were used to identify groundwater encountered at R-69.

5.1 Stratigraphy

Rock units for the R-69 borehole are presented below in order of youngest to oldest in stratigraphic occurrence. Lithologic descriptions are based on binocular microscope analysis of drill cuttings collected from the discharge hose. Figure 5.1-1 illustrates the stratigraphy at R-69. A detailed lithologic log for R-69 is presented in Appendix A.

Fill, Pad Material (0–5 ft bgs)

Fill was encountered from 0 to 5 ft bgs. Fill contains random fill fragments from a borrow source for drill pad construction material.

Unit 3t, Tshirege Member of the Bandelier Tuff, Qbt 3t (5–30 ft bgs)

The upper part of unit 3 is further subdivided into unit 3t (transition) in the western part of the Laboratory. Unit 3t of the Tshirege Member of the Bandelier Tuff was encountered from 5 ft to 30 ft bgs. Unit 3t is moderately to strongly welded crystal-rich tuff.

Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (30–150 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff was encountered from 30 ft to 150 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 (150–250 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff was encountered from 150 ft to 250 ft bgs. Unit 2 represents a moderately to strongly welded devitrified rhyolitic ash-flow tuff (i.e., ignimbrite) 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 (250–280 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff was encountered from 250 ft to 280 ft bgs. Unit 1v is a poorly to strongly 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 1v, Cobble Zone, Qbt 1v (280–293 ft bgs)

The Cobble Zone interval was encountered from 280 ft to 293 ft bgs. The Cobble Zone interval is a poorly welded, devitrified rhyolitic ash-flow tuff that is pumiceous, generally lithic-poor, and crystal-bearing to locally crystal-rich, in origin. Generally, no difference in cuttings from the unit 1v of the Tshirege Member of the Bandelier Tuff can be observed. This zone has been worked over into a cobble zone in and from the same source. The zone is cobble size in appearance. Cuttings commonly contain numerous fragments of indurated crystal-rich tuff with devitrified pumice.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (293–320 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 293 ft to 320 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 (320–410 ft bgs)

The Cerro Toledo interval was encountered from 320 ft to 410 ft bgs. The Cerro Toledo interval is a sequence of poorly consolidated tuffaceous and volcaniclastic sediments that occur 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 (410–675 ft bgs)

The Otowi Member of the Bandelier Tuff was encountered from 410 ft to 675 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 generally of intermediate volcanic composition, including porphyritic dacites.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (675–690 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 675 ft to 690 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 (690–1443.4 ft bgs)

Puye Formation volcaniclastic sediments were encountered from 690 ft to TD at 1443.4 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.

5.2 Groundwater

Drilling at R-69 proceeded without any indications of groundwater to approximately 764 ft bgs at the first R-69 borehole, based on borehole interrogation at each rod/casing connection. The first borehole was terminated at this depth. No intermediate perched water was observed at the second R-69 well location either. Regional groundwater was first observed at approximately 1308 ft bgs, near the predicted depth of 1301 ft bgs, during drilling and advancing the 10-in. casing. The 10-in. cased borehole was subsequently advanced to TD, 1443.4 ft bgs.

On September 10, the initial groundwater level reading after landing the 10-in. casing at TD was 1257 ft bgs. Groundwater levels were periodically monitored during demobilization of drilling equipment and mobilization of well construction equipment, with recordings up to 1294.3 ft bgs on September 20 before well construction. The DTW in the completed well was 1292.5 ft bgs on October 25.

Table 5.2-1 presents a summary of water levels recorded during R-69 drilling.

6.0 BOREHOLE LOGGING

A video log was recorded on July 31, 2018 (at the original borehole location) after the 17-in. open hole was drilled to 741 ft bgs. A second video log (Appendix C) was recorded on September 11 (at the final borehole location) after the 10-in. open hole was drilled to 1263.7 ft bgs. A natural gamma-ray log (Appendix D) was recorded on September 17 from surface to 1443 ft bgs after the borehole was advanced to TD. A summary of the geophysical logging run is presented in Table 6.0-1.

7.0 WELL INSTALLATION R-69 MONITORING WELL

The R-69 dual-screen regional well was installed between September 20 and October 24, 2018.

7.1 Well Design

The R-69 well was designed in accordance with Consent Order guidance, and NMED approved the final well design before the well was installed (Appendix E). The well was designed with two screened intervals, the first between 1310 ft and 1330.2 ft bgs and the second between 1375.5 ft and 1395.8 ft bgs, to monitor groundwater quality within two discrete zones of the regional aquifer.

7.2 Well Construction

From September 17 to 20, 2018, the workover rig, well components, and initial well construction materials were mobilized to the site, and the stainless-steel well casing, screens, and tremie pipe were thoroughly cleaned.

The R-69 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-O.D. type A304 pickled and passivated stainless-steel beveled casing fabricated to American Society for Testing and Materials 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 nominal 2-in. steel tremie pipe was used to deliver backfill and annular fill materials downhole during well construction. Short lengths of 16-in. (5.9-ft casing and shoe, from 899.1 ft to 905.0 ft bgs), 12-in. (7.4-ft casing and shoe, from 1257.1 ft to 1264.5 ft bgs), and 10-in. (1.9-ft casing and shoe, from 1439.5 to 1443.4 ft bgs) casing stubs remain in the borehole. The 16-in. and 12-in. casing stubs were entombed in the upper bentonite seal. The 10-in casing stub is partially entombed in slough and the lower bentonite seal at the bottom of the borehole, 33.3 ft beneath the bottom of the well.

The 18-in. surface conductor casing became stuck and could not be retracted (15.0-ft casing, from 1.7 ft to 16.6 ft bgs). The request to leave the conductor casing in place was submitted to NMOSE on November 16 and approved on November 28 (N3B 2018, 700132; NMOSE 2018, 700340). The top of the 18-in. casing was cut at 1.7 ft bgs and cemented in place.

A 10.4-ft-long stainless-steel sump was placed below the bottom of the well screen. The well casing was started into the borehole on September 20 at 1440 hr. The well casing was hung by wireline with the bottom at 1406.2 ft bgs. Stainless-steel centralizers (two sets of four) were welded to the well casing approximately 2.0 ft above and below each 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 27 after the bottom of the borehole was measured at 1443.2 ft bgs (approximately 0.2 ft of slough had accumulated in the borehole). The bentonite backfill was installed between September 27 and 29 from 1443.2 ft to 1401.2 ft bgs using 30.5 ft^3 of 3/8-in. bentonite chips. Table 7.2-1 presents a summary of calculated volumes and annular materials used.

The filter pack was installed between September 29 and October 1 from 1401.2 ft to 1370.5 ft bgs using 22.0 ft^3 of 10/20 silica sand. The actual volume of filter pack sand was 39% greater than the calculated volume and is likely the result of an oversized borehole caused by sloughing in the unconsolidated Puye Formation in some areas. The filter pack was surged to promote settling and topped off. The fine-sand collar was installed above the filter pack from 1370.5 ft to 1368.6 ft bgs using 4.8 ft^3 of 20/40 silica sand.

From October 2 to 4, a TAM packer was decontaminated, tested, and installed at 1350.5 ft bgs, between the well screens, to prevent differential head pressures from disturbing the lower-screen filter pack during installation of the intermediate seal. From October 4 to 6, the intermediate bentonite seal was installed from 1368.6 ft to 1335.6 ft bgs using 25.7 ft^3 of 3/8-in. bentonite chips. On October 7, the TAM Packer was removed.

The upper-screen filter pack was installed between October 7 and 9 from 1335.6 ft to 1305.3 ft bgs using 25.5 ft^3 of 10/20 silica sand. The actual volume of filter pack sand was 45% greater than the calculated volume and is likely the result of an oversized borehole caused by sloughing in the unconsolidated Puye Formation in some areas. The filter pack was surged to promote settling. The fine-sand collar was installed above the filter pack from 1305.3 ft to 1303.3 ft bgs using 2.0 ft^3 of 20/40 silica sand.

From October 10 to 24, the upper bentonite seal was installed from 1303.3 ft to 100.1 ft bgs using 1490.3 ft^3 of 3/8-in. bentonite chips.

On October 24, a cement seal was installed from 100.1 to 29.28 ft bgs. Installation of the cement seal was paused until approval was obtained from NMOSE to leave the stuck 18-in. conductor casing in place. This decision was made after several unsuccessful attempts were made to lift the casing using the 72k pump hoist rig and casing jacks capable of exerting approximately 350,000 lb of lifting force. A total 14.9 ft of 18-in. casing was left in the borehole between 1.7 and 16.6 ft bgs.

On December 5, the remaining cement seal was installed from 29.3 to 3.8 ft bgs. The cement seal used 193.9 ft^3 of Portland Type I/II cement. This volume exceeded the calculated volume of 136.6 ft^3 by 30% and is likely the result of cement loss to the near-surface formations.

Operationally, well construction proceeded 12 hr/day, 7 days/wk through the screened intervals and 24 hr/d, 7 days/wk thereafter from September 20 to October 24.

8.0 POST-INSTALLATION ACTIVITIES

Following well installation at R-69, the well was developed and aquifer pumping tests were conducted. A dedicated dual-zone submersible single-pump sampling system, including an isolation packer and two transducers, were installed; the wellhead and surface pad were constructed, and a geodetic survey was performed. Disposition of drill cuttings and groundwater will follow the NMED-approved decisions trees for land application of drill cuttings and groundwater requirements. Site restoration will be completed following final disposition.

8.1 Well Development

The well was developed between October 25 and November 4, 2018. Initially, the screened intervals were swabbed and bailed to remove formation fines in the filter pack and well sump. Bailing continued until water clarity visibly improved. Final development was performed with a submersible pump by lowering and raising the pump intake through the screen interval.

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 sand-pump bailing tool, a 4.0-in.-O.D. by 10.0-ft-long stainless-steel bailer with a total capacity of 12 gal., was used to remove approximately 16 gal. of predominantly filter-pack sand from the sump. The tool was repeatedly lowered by wireline to the bottom of the well, filled, withdrawn from the well, and emptied into the cuttings pit. Approximately 686 gal. of groundwater was removed during bailing activities.

After swabbing and bailing on October 27 and 29, a 10-horsepower (hp), 4-in. Berkeley submersible pump was deployed into the well. The screen 2 interval was pumped from top to bottom and from bottom to top in 2-ft increments on November 2. On November 3, screen 2 was pumped until parameters stabilized with the pump shroud intake set at the bottom of screen 2 and packers deployed above and below the screened interval. The screen 1 interval was pumped from top to bottom and from bottom to top in 2-ft increments during the night shift on November 3. On November 4, screen 1 was pumped until parameters stabilized with the pump shroud intake set at the bottom of screen 1 and packers deployed above and below the screened interval.

During development, the pumping rate in screen 1 varied from 14.4 to 18.9 gal./min. The pumping rate in screen 2 varied from 15.4 to 16.5 gal./min. The average pumping rates for screen 1 and 2 were 16.1 and 15.7 gal./min, respectively. Approximately 38,161 gal. of groundwater was purged with the submersible pump during well development.

Total Volumes of Introduced and Purged Water

During drilling, approximately 4861 gal. of potable water was added from 100 ft above the top of the regional aquifer to the TD of the borehole at 1443 ft bgs. Approximately 21,176 gal. was added during installation of the annular fill. In total, approximately 26,050 gal. of potable water was introduced to the borehole below 1182 ft bgs during project activities.

Approximately 38,161 gal. of groundwater was purged at R-69 during well development activities. Another 52,799.2 gal. was purged from screen 1 and 67,312.4 gal. from screen 2 during aquifer testing for a total of 120,112 gal. The total amount of groundwater removed during post-installation activities was 158,958.6 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 ppm 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. In screen 1, the final parameters at the end of well development were pH of 7.49, temperature of 12.8ºC, specific conductance of 120.2 µS/cm, and turbidity of 1.7 NTU. In screen 2, the final parameters at the end of well development were pH of 7.71, temperature of 12.4ºC, specific conductance of 126.3 µS/cm, and turbidity of 1.1 NTU. Table B-2.3-1 in Appendix B shows field parameters and purge volumes measured during well development.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-69 between November 6 and 19, 2018. Several short-duration tests with short-duration recovery periods were performed on the first day of testing each of the two screen intervals. A 72-hr test followed by a 24-hr recovery period completed the testing of each screen interval.

A 10-hp pump was used for the aquifer tests. Approximately 120,112 gal. of groundwater was purged during aquifer testing. Turbidity, temperature, pH, DO, ORP, and specific conductance were measured during the aquifer test. Measured parameters are presented in Appendix B. The R-69 aquifer test results and analysis are presented in Appendix F. Data collected during the aquifer test are provided as Attachment F-1, on CD included with this document.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-69 was installed on January 11 through 17, 2019. The system is a Baski Inc.-manufactured system that utilizes a single 5-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump capable of purging each screened interval discretely via pneumatically actuated access port valves. One 1-in. stainless-steel check valve is installed within the pump shroud above the pump body. A weep valve was installed at the bottom of the uppermost pipe joint to protect the pump column from freezing. The system includes a Viton-wrapped isolation packer between the screen intervals. Pump riser pipe consists of threaded and coupled nonannealed (pickled), passivated 1-in.-diameter stainless steel. Two 1-in.-diameter polyvinyl chloride (PVC) tubes were installed along with and banded to the pump riser for dedicated transducers. The tubes are 1.0-in.-I.D. flush-threaded schedule 80 PVC pipe. The upper PVC transducer tube is equipped with two 5-ft sections of 0.010-in. slot screen with a threaded end cap at the bottom of the tube. The lower PVC transducer tube is equipped with a flexible nylon tube that extends from a threaded end cap at the bottom of the PVC tube through the isolation packer to measure water levels in the lower screen interval. Two In-Situ Level Troll 500 transducers were installed in the PVC tubes to monitor water levels in each screen interval. Post-installation construction and sampling system component installation details for R-69 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes. Figure 8.3-1c presents a performance curve for the submersible pump installed. Appendix G is the R-69 sampling system test report.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 10 in. thick, was installed at the R-69 wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad provides 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. A total of four removable bollards, painted and covered with yellow bollard covers for protection and visibility, were set at the outside edges of the pad to protect the well from traffic. 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 December 19, 2018 (Table 8.5-1). The survey data conformed 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 pin in the concrete pad, the top of the well casing, and the top of the protective casing for the R-69 monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-69 project included drilling fluids, purged groundwater, drill cuttings, decontamination water, New Mexico Special Waste, and contact waste. A summary of the waste characterization samples collected during drilling, construction, and development of the R-69 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled and characterized in accordance with the R-68 waste characterization strategy form (WCSF) and Amendment #1 to the WCSF (LANL 2016, 601994; LANL 2016, 602000).

Fluids produced during drilling, well development, and aquifer testing are expected to be land-applied, treated at the HE treatment facility, or disposed of off-site after a review of associated analytical results per the WCSF and land-application criteria standard operating procedure (SOP) “Land Application of Groundwater.” If it is determined that any fluids generated during drilling are nonhazardous/nonradioactively contaminated (NH/NR), but cannot meet the criteria for land application, they will be disposed of at an authorized facility. If analytical data indicate the drilling fluids are hazardous/NR or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

Analytical data for the development/purge water from screen 1, screen 2, and co-mingled waters were reviewed by TPMC between December 12 and December 20, 2018 under the following water disposal system (WDS) numbers: 102626 (screen 1), 102568 (screen 2), and 102569 (co-mingled). The development/purge water from screen 1, screen 2, and co-mingled waters are characterized as HE NH/NR and do not meet the land application criteria. The development/purge waters will be treated on-site, re-sampled, and if land application criteria are met, then the water will be land-applied.

Analytical data for the drilling fluids that were used during well drilling was reviewed by TPMC on November 8, under WDS #102455. The drilling fluids were determined to be NH/NR, and do not meet the land application criteria. 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 land-application criteria SOP “Land Application of Drill Cuttings.” If cuttings pass land-application criteria, they will be used to backfill the pit.

Analytical data for the drill cuttings were reviewed under WDS #102461 on November 20 by TPMC and the cuttings were determined to meet land application criteria. N3B reviewed the analytical data and approved the cuttings land application decision tree, Land App ID: N3B-2018-027, on December 3.

Decontamination fluid used for cleaning equipment was containerized in four poly tanks at R-69 and the Pajarito Laydown Yard. All four of the decontamination fluid tanks at R-69 have been sampled, and analytical data are pending. TPMC anticipates that all decontamination fluids will be characterized as NH/NR 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

Drilling, sampling, and well construction at R-69 were performed as specified in the approved drilling work plan for well R-69 (LANL 2016, 601779; NMED 2016, 601855), with the exception of the following deviation.

9.1 R-69 Borehole 1 Plug and Abandonment

On August 11, a decision was made to plug and abandon the borehole when the bottom of the drill casing incurred damage while drilling in the Puye Formation at 764.2 ft bgs. The damage was caused by an obstruction in the borehole that deflected and pinched the casing, obstructing passage of the 16-in. underreaming drill bit through the last 2 ft of casing and through the casing shoe.

The borehole was plugged and abandoned from 765.4 to 20.1 ft bgs with hydrated 3/8-in. bentonite chips and from 20.1 ft bgs to surface with Portland Type I/II cement mixed at a ratio of 6 gal. municipal water to one 94 lb bag of cement. The plugging record for State Engineer Well Number RG-97398 (R-69) was sent to NMOSE on September 13.

The drill rig was moved 15 ft west to a second borehole location where the borehole was successfully advanced to the planned total depth.

9.2 Water-Level Monitoring and Sampling during Well Construction

On October 15 at 1320 hr, the upper bentonite seal had been installed to 930.2 ft bgs; the bottom of the 16-in. casing was at 905 ft bgs. The 12-in. drill casing was tripped out entirely over the next 27 hr. At 1618 hr on October 16, before resumption of upper bentonite seal installation, the water level in the annulus was tagged at 873 ft bgs, indicating 57.2 ft of water in the annulus. The expectation was that most or all water introduced to the annulus to hydrate bentonite backfill would have infiltrated into the surrounding formation over the 27-hr hiatus in well construction. There was an observed presence of over 57 ft of annular water in a zone where perched water was anticipated during the drilling phase of work. This led to the conjecture that naturally occurring perched formation water may be the source of the water now present in the annulus, although this was not observed during drilling operations. Another water-level measurement was collected 10 min later at 872.7 ft bgs, 0.3 ft higher. This rising water-level measurement provided further evidence for the presence of a natural perched water source adjacent to the well.

To enhance hydraulic communication between the surrounding formation and well annulus, 18 ft of 16-in. casing was removed, and 4.5 hr later, the water level was measured at 864.4 ft bgs, an 8.3 ft rise. Water levels were collected for the next 34 hr and 10 min at intervals ranging from 15 min to 2 hr. At 2155 hr on October 17, two more 16-in. casing joints, totaling 39.2 ft in length, were removed, raising the bottom of the casing to 841.7 ft bgs. Water levels reached the maximum height of 841.9 ft bgs at 0600 hr on October 18. Measured water levels started to descend slowly, 0.2 ft over the next 4 hr of monitoring. The final tag of water-level monitoring was 842.1 ft bgs, and the following day at 1050 hr, the top of the backfill was measured at 924.2 ft bgs, indicating approximately 24.9 vertical ft of water and 6 ft of slough had entered the borehole annulus, respectively, since October 16.

Samples of the suspected perched groundwater were collected from the well annulus on October 17 and 19 and analyzed for explosives, alkalinity, tritium, tracer anions, and metals. Table 4.2-1 presents a summary of screening samples collected during the R-69 monitoring well installation.

On October 17, N3B directed TPMC to collect the “first-encounter” perched-water sample. This sample of suspected perched groundwater was collected with disposable bailers from the upper 20.23 ft of the water column, 849.12 to 869.35 ft bgs.

The “intermediate-encounter” perched-water sample was collected on October 19 from the annulus as directed by N3B. At the time of sample collection, the top of the bentonite seal was 924.6 ft bgs and the water level was measured at 842.1 ft bgs. This sample of suspected perched groundwater was collected with disposable bailers from between 850.8 ft bgs (bottom of 2-in. tremie pipe) and 911.6 ft bgs.

10.0 ACKNOWLEDGMENTS

Holt Services, Inc., drilled and installed the R-69 monitoring well.

David C. Schafer designed, implemented, and analyzed the aquifer tests, and supervised installation and testing of the Baski dual-zone sampling system.

TPMC provided oversight on all preparatory and field-related activities and prepared fact sheets and reports.

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

The following reference list includes documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ERID, ESHID, or EMID. This information is also included in text citations. ERIDs were assigned by the Laboratory's Associate Directorate for Environmental Management (IDs through 599999); ESHIDs were assigned by the Laboratory's Associate Directorate for Environment, Safety, and Health (IDs 600000 through 699999); and EMIDs are assigned by N3B (IDs 700000 and above). IDs are used to locate documents in N3B's Records Management System and in the Master Reference Set. The NMED Hazardous Waste Bureau and N3B maintain copies of the Master Reference Set. The set ensures that NMED has the references to review documents. The set is updated when new references are cited in documents.

LANL (Los Alamos National Laboratory), June 26, 2014. "Storm Water Pollution Prevention Plan, Regional Wells (R-Wells) Drilling, Los Alamos National Laboratory, Revision 1," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2014, 601293)

LANL (Los Alamos National Laboratory), September 2016. "Groundwater Investigation Work Plan for Consolidated Unit 16-021(c)-99, Including Drilling Work Plans for Wells R-68 and R-69," Los Alamos National Laboratory document LA-UR-16-26493, Los Alamos, New Mexico. (LANL 2016, 601779)

LANL (Los Alamos National Laboratory), November 15, 2016. "Waste Characterization Strategy Form (WCSF) for Regional Well R-68," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2016, 601994)

LANL (Los Alamos National Laboratory), November 21, 2016. "Amendment #1 to the Waste Characterization Strategy Form (WCSF) for Regional Well R-68 (EP2016-0149)," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2016, 602000)

LANL (Los Alamos National Laboratory), September 2017. "Summary Report for R-68 and Drilling Work Plan for R-69, Revision 1," Los Alamos National Laboratory document LA-UR-17-28551, Los Alamos, New Mexico. (LANL 2017, 602646)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), November 16, 2018. "Deviation Request to Leave 18-in-Diameter Surface Casing in Place at Los Alamos National Laboratory Well R-69 (RG 97398)," N3B letter (N3B-18-0320) to R. Martinez (NMOSE) from F. Lockhart (N3B) and C.L. Rodriguez (EM-LA), Los Alamos, New Mexico. (N3B 2018, 700132)

NMED (New Mexico Environment Department), September 27, 2016. "Approval, Groundwater Investigation Work Plan for Consolidated Unit 16-021(c)-99, Including Drilling Work Plans for Wells R-68 and R-69," New Mexico Environment Department letter to D. Hintze (DOE-EM-LA) and M. Brandt (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2016, 601855)

NMED (New Mexico Environment Department), October 23, 2017. "Approval, Summary Report for R-68 and Drilling Work Plan for R-69, Revision 1," New Mexico Environment Department letter to D. Hintze (DOE-NA-LA) and B. Robinson (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2017, 602697)

NMOSE (New Mexico Office of the State Engineer), September 13, 2018. “Plugging Record for RG-97398 [R-69],” Santa Fe, New Mexico. (NMOSE 2018, 700323)

NMOSE (New Mexico Office of the State Engineer), November 28, 2018. “Variance to Annular Seal Requirement for Well RG-97398 (R-69),” NMOSE letter to Environmental Management from R. Martinez (NMOSE), Santa Fe, New Mexico. (NMOSE 2018, 700340)

TerranearPMC, December 2016. “Field Implementation Plan for Regional Aquifer Well R-68,” Los Alamos, New Mexico. (TerranearPMC 2016, 602451)

TerranearPMC, December 14, 2016. “IWD [Integrated Work Document] for Drilling and Installation of LANL Wells R-68 and R-69,” Los Alamos, New Mexico. (TerranearPMC 2016, 602452)

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

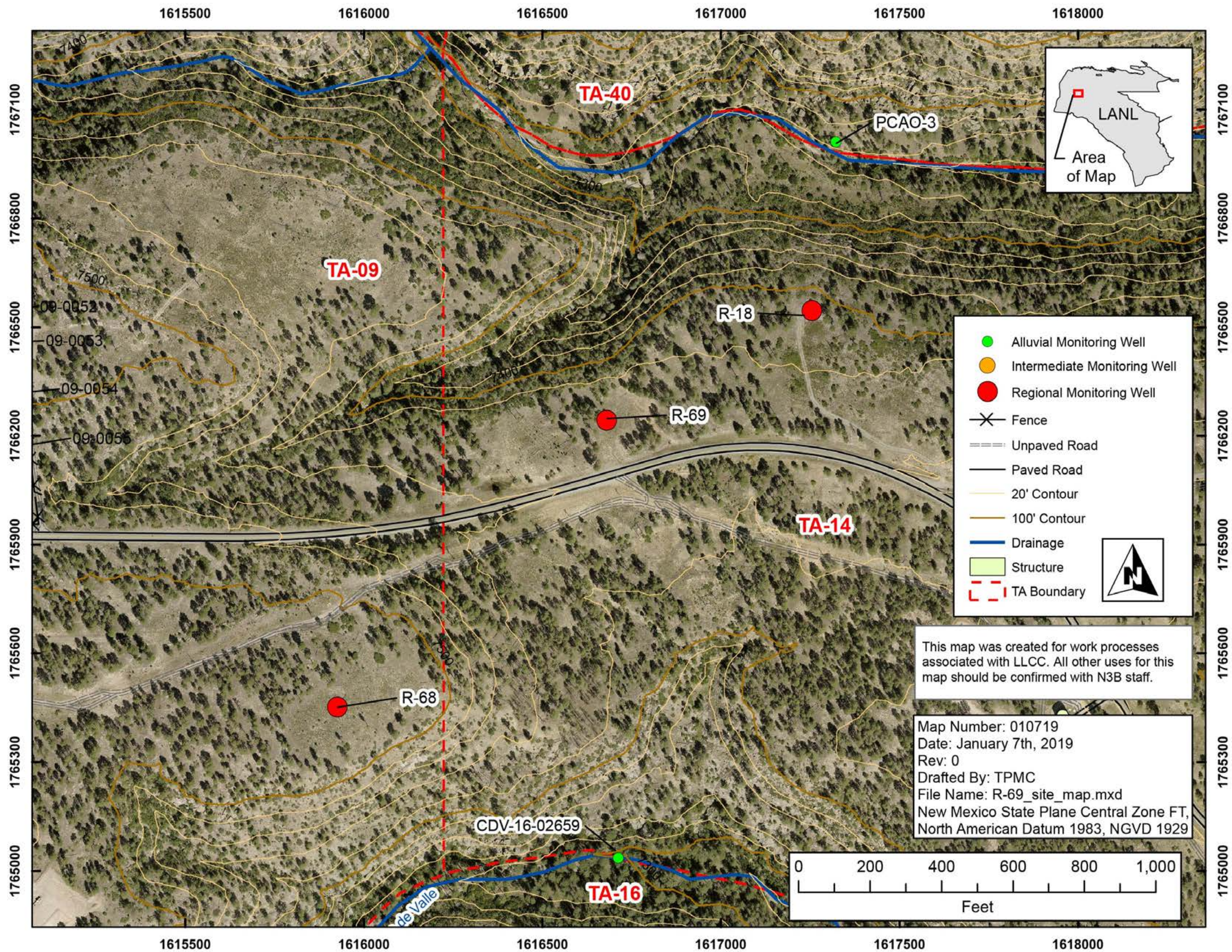


Figure 1.0-1 **Location of monitoring well R-69**

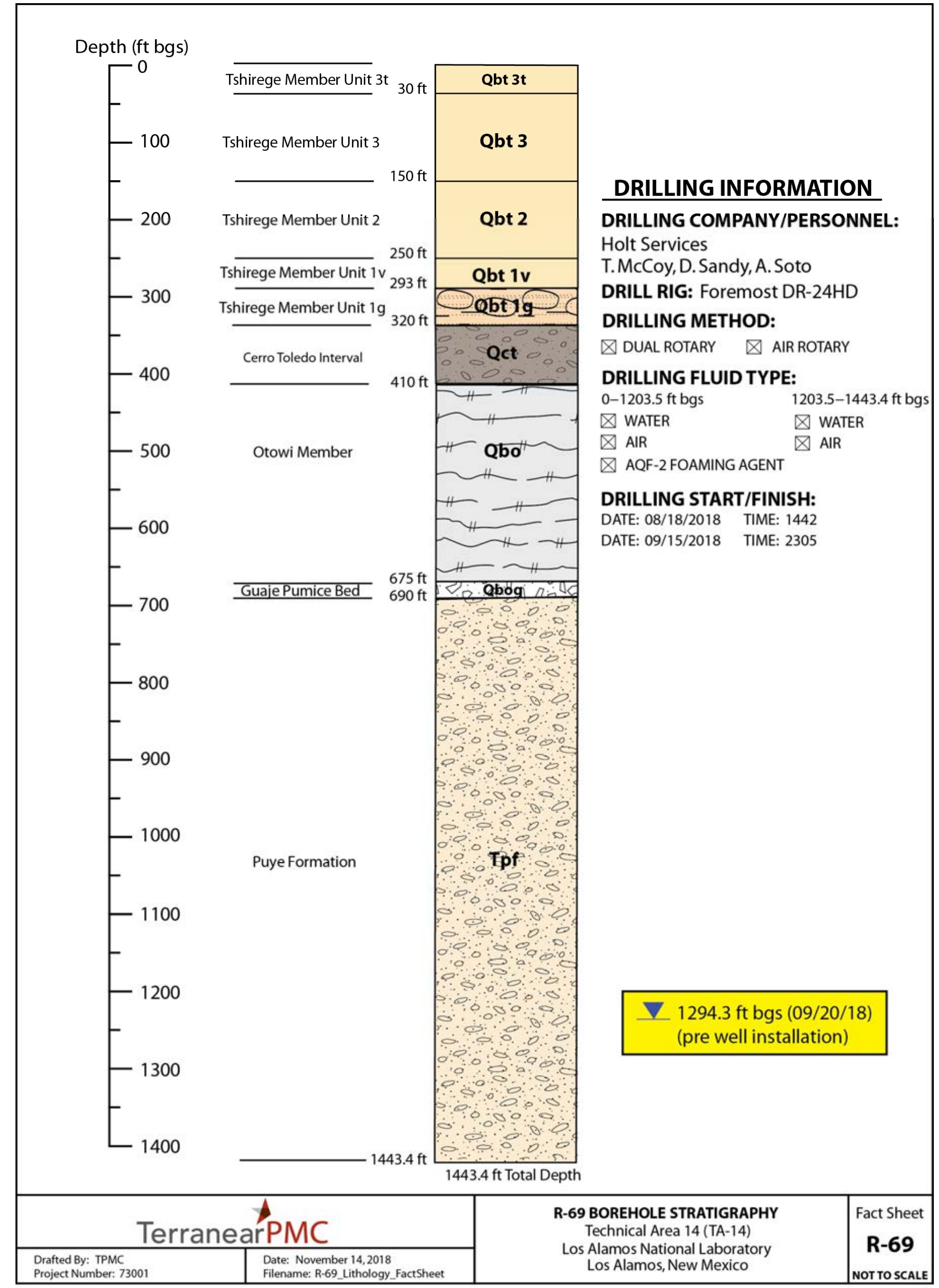


Figure 5.1-1 Monitoring well R-69 borehole stratigraphy

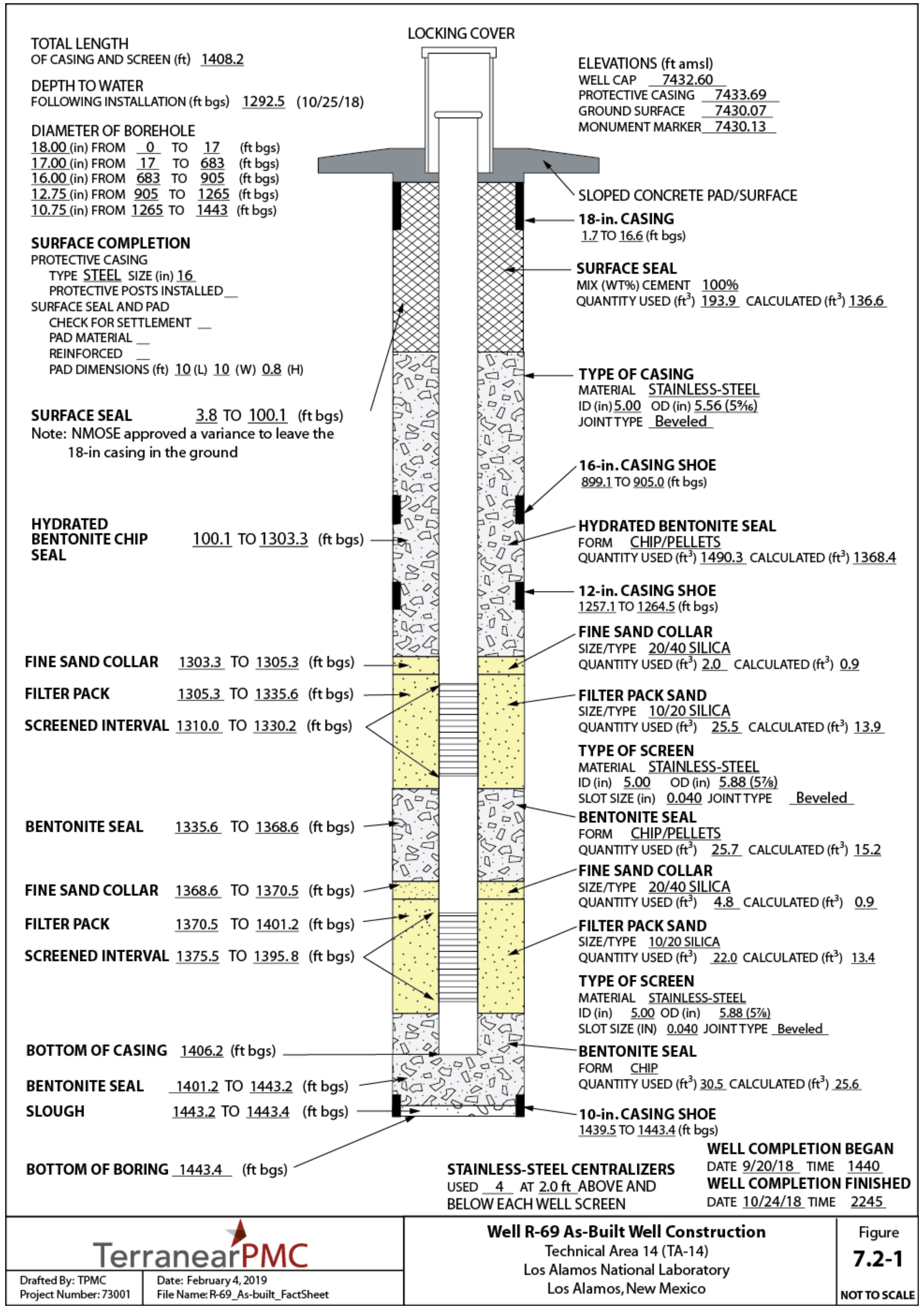


Figure 7.2-1 Monitoring well R-69 as-built well construction diagram

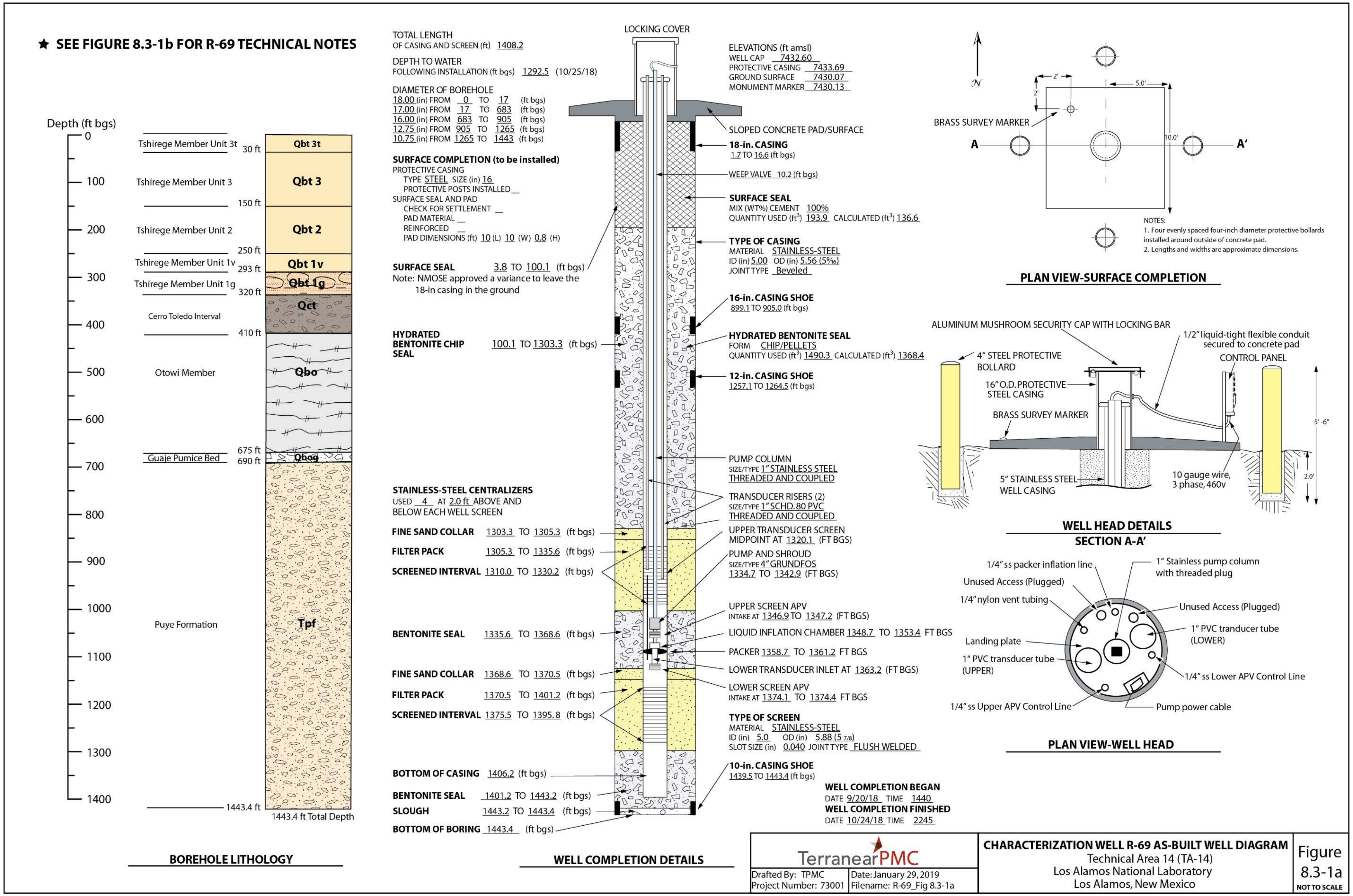


Figure 8.3-1a Monitoring well R-69 as-built diagram with borehole lithology and technical well completion details

R-69 TECHNICAL NOTES[1]:

SURVEY INFORMATION[2]

Brass Marker

Northing:	1766245.23 ft
Easting:	1616676.41 ft
Elevation:	7430.13 ft AMSL

Well Casing (top of stainless steel)

Northing:	1766243.19 ft
Easting:	1616680.12 ft
Elevation:	7432.60 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

N3B Video (X2), Gamma Spectroscopy

DRILLING INFORMATION

Drilling Company
Holt Services, Inc.

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam

MILESTONE DATES

Drilling

Start:	08/18/2018
Finished:	09/15/2018

Well Completion

Start:	09/20/2018
Finished:	10/24/2018

Well Development

Start:	10/25/2018
Finished:	11/04/2018

WELL DEVELOPMENT

Development Methods
Swabbing, bailing, and pumping
Total Volume Purged: 38,847 gal. (both screens)

Parameter Measurements
(Final, upper screen/lower Screen)

pH:	7.5 / 7.7
Temperature:	12.8 / 12.4°C
Specific Conductance:	120 / 126 µS/cm
Turbidity:	1.7 / 1.1 NTU

AQUIFER TESTING

Constant Rate Pumping Test
Upper Screen/Lower Screen

Water Produced:	50,906 / 65,731 gal.
Average Flow Rate:	11.8 / 15.2 gpm
Performed on:	11/09-12/2018 and 11/16-19/2018

DEDICATED SAMPLING SYSTEM

Pump
Make: Grundfos
Model: 10S501125CBM
S/N: P117461001
Environmental retrofit

Motor
Make: Franklin Electric
Model: 2343278602G
5 HP, 3-phase, 460V

Pump Shroud
Baski, Inc. custom 4.75" O.D. stainless steel body
set from 1334.7 to 1342.9 ft bgs

Liquid Inflation Chamber
Baski, Inc. custom 4.75" O.D. stainless steel body
set from 1348.7 to 1353.4 ft bgs

Packer
Baski, Inc. custom inflatable packer
set from 1358.7 to 1361.2 ft bgs

Access Port Valves
Baski, Inc. normal 4.75" O.D. stainless steel housing and screen
Upper screen APV intake at 1346.9 to 1347.2 ft bgs
Lower screen APV intake at 1374.1 to 1374.4 ft bgs

Pump Column
1-in. threaded/coupled NUE sch 60 stainless steel tubing
Weep valve installed at 10.2 ft bgs
Check valve installed inside top of pump shroud

Transducer Tubes
2 × 1-in flush threaded sch 80 PVC tubing
Upper tubing with 0.020-in slot screen at 1323.0 to 1323.3 ft bgs
Lower tubing with 1/4" X12" long screens within tubing
and terminating below packer at 1363.2 to 1363.9 ft bgs

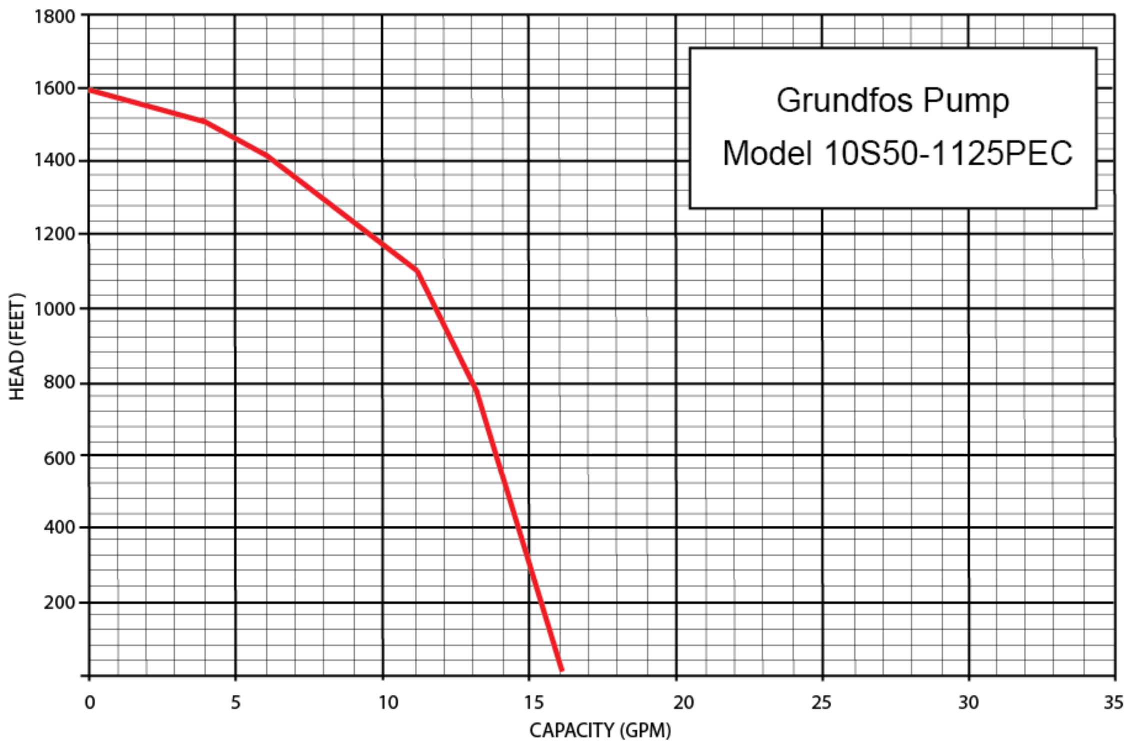
Transducers
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
Upper S/N: 630921
Lower S/N: 630919

Notes:
[1] For more information see *Completion Report for Regional Aquifer Well R-69*, March 2019.
[2] 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.

TerranearPMC		R-69 TECHNICAL NOTES Technical Area 14 (TA-14) Los Alamos National Laboratory Los Alamos, New Mexico	Fig. 8.3-1b NOT TO SCALE
Drafted By: TPMC Project Number: 73001	Date: January 18, 2019 Filename: R-69_Technical_Notes		

Figure 8.3-1b As-built technical notes for monitoring well R-69

R-69 PUMP CURVE:



TerranearPMC

Drafted By: TPMC Project Number: 73001	Date: Jan. 31, 2019 Filename: R69_PumpCurves_Fig8-3-1c	**R-69 DEDICATED PUMP PERFORMANCE CURVE** Technical Area 14 (TA-14) 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-69

Table 3.1-1
Fluid Quantities Used during R-69 Drilling and Well Construction

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling					
8/18/2018	0–16.6	550	550	0	0
8/20/2018	16.6–143	2900	3450	28	28
8/21/2018	143–683[a]	5025	8475	63	91
8/25/2018	670–771[a]	1975	10,450	62	153
8/26/2018	771–905[a]	3850	14,300	179	332
8/27/2018	905	200	14,500	0	332
8/29/2018	904–951[a]	1200	15,700	21	353
8/30/2018	951–1124[a]	4750	20,450	108	461
8/31/2018	1124–1203.51[a]	1645	22,095	42	503
9/1/2018	1182–1264.49[a]	1645	23,740	n/a[b]	n/a
9/2/2018	1258.3	150	23,890	n/a	n/a
9/3/2018	1257.3	0	23,890	n/a	n/a
9/14/2018	1265–1282	300	24,190	n/a	n/a
9/15/2018	1265–1443.36[a]	1121	25,311	n/a	n/a
Well Construction					
9/27/2018	1440.99–1438[c]	264	25,575	n/a	n/a
9/28/2018	1438–1427[c]	667	26,242	n/a	n/a
9/29/2018	1427–1401[c]	1994	28,236	n/a	n/a
9/30/2018	1401–1372[d]	1303	29,539	n/a	n/a
10/1/2018	1372–1371[d]	223	29,762	n/a	n/a
10/2/2018	1371–1368[d]	666	30,428	n/a	n/a
10/3/2018	1369–1366	330	30,758	n/a	n/a
10/4/2018	1366–1361	470	31,228	n/a	n/a
10/5/2018	1361–1338[c]	1817	33,045	n/a	n/a
10/6/2018	1338–1335[c]	392	33,437	n/a	n/a
10/7/2018	1335–1327[d]	487	33,924	n/a	n/a
10/8/2018	1327–1305[d]	1439	35,363	n/a	n/a
10/9/2018	1305–1304[d]	721	36,084	n/a	n/a
10/10/2018	1305–1264[c, d]	2917	39,001	n/a	n/a
10/12/2018	1264–1241	1964	40,965	n/a	n/a
10/13/2018	1241–1185	8069	49,034	n/a	n/a
10/14/2018	1185–966	7048	56,082	n/a	n/a
10/15/2018	966–930	1155	57,237	n/a	n/a

Table 3.1-1 (continued)

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
10/19/2018	930–837	5690	62,927	n/a	n/a
10/20/2018	837–706	5965	68,892	n/a	n/a
10/21/2018	706–387	3796	72,688	n/a	n/a
10/22/2018	387–113	1929	74,617	n/a	n/a
10/24/2018	113–29	682	75,299	n/a	n/a
12/4/2018	29–5	204	75,503	n/a	n/a
12/5/2018	5–4	6	75,509	n/a	n/a
12/6/2018	4–3	2	75,601	n/a	n/a
Total Water Volume (gal.)					
R-69			75,601		

[a] Clean out borehole.

[b] n/a = Not applicable.

[c] Drill out bentonite seal.

[d] Install filter pack or transition sand.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Well Construction, Well Development, and Aquifer Testing at Well R-69

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Well Construction—Suspected Perched Groundwater					
R-69	CACV-18-160551	10/17/2018	849.12–866.35	Perched groundwater, first encounter (UF[a]), bailed	Explosives, alkalinity, tritium, metals, tracer
R-69	CACV-18-160552	10/17/2018	849.12–866.35	Perched groundwater, first encounter (F[b]), bailed	Anions, cations
R-69	CACV-18-163946	10/19/2018	842.06–914.59	Perched groundwater, intermediate (UF), bailed	Explosives, alkalinity, tritium, metals, tracer
R-69	CACV-18-163948	10/19/2018	842.06–914.59	Perched groundwater, intermediate (F), bailed	Anions, cations
R-69	CACV-18-163947	10/19/2018	842.06–914.59	Perched groundwater, intermediate (FD[c], UF), bailed	NMED HEXP, RDX, EES-6 tracer
R-69	CACV-18-163949	10/19/2018	842.06–914.59	Perched groundwater, intermediate (FD, F), bailed	Anions, cations
Well Development					
R-69 S2[d]	CACV-19-164252	11/3/2018	1395.62	Groundwater, pumped	TOC
R-69 S2	CACV-19-164253	11/3/2018	1395.62	Groundwater, pumped	TOC
R-69 S2	CACV-19-164254	11/3/2018	1395.62	Groundwater, pumped	TOC
R-69 S1[e]	CACV-19-164242	11/4/2018	1330.57	Groundwater, pumped	TOC
Aquifer Test					
R-69 S2	CACV-19-164724	11/9/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164725	11/9/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164726	11/10/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164745	11/10/2018	1393.82	Groundwater, pumped (UF)	TOC
R-69 S2	CACV-19-164727	11/10/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164728	11/10/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164729	11/11/2018	1393.82	Groundwater, pumped (UF)	RDX

Table 4.2-1 (continued)

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
R-69 S2	CACV-19-164746	11/11/2018	1393.82	Groundwater, pumped (UF)	TOC
R-69 S2	CACV-19-164746	11/11/2018	1393.82	Groundwater, pumped (UF)	TOC
R-69 S2	CACV-19-164730	11/11/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164731	11/11/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164732	11/12/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S2	CACV-19-164747	11/12/2018	1393.82	Groundwater, pumped (UF)	TOC
R-69 S2	CACV-19-164733	11/12/2018	1393.82	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164714	11/16/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164715	11/16/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164716	11/17/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164717	11/17/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164742	11/17/2018	1310–1330.22	Groundwater, pumped (UF)	TOC
R-69 S1	CACV-19-164718	11/17/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164719	11/18/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164720	11/18/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164743	11/18/2018	1310–1330.22	Groundwater, pumped (UF)	TOC
R-69 S1	CACV-19-164721	11/18/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164722	11/19/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164723	11/19/2018	1310–1330.22	Groundwater, pumped (UF)	RDX
R-69 S1	CACV-19-164744	11/19/2018	1310–1330.22	Groundwater, pumped (UF)	TOC

[a] UF = Unfiltered.
[b] F = Filtered.
[c] FD = Field duplicate.
[d] S2 = Screen 2.
[e] S1 = Screen 1.

Table 5.2-1
Water Levels Recorded during R-69 Drilling

Borehole Depth (ft bgs)	Date	Time	Water Level (ft bgs)
1261.00	9/4/2018	700	1252.80
1260.55	9/5/2018	2202	1254.39
1260.55	9/6/2018	645	1254.24
1260.35		1830	1254.73
1261.05	9/7/2018	640	1255.04
1262.37		0010	1255.05
1263.70	9/10/2018	2100	1256.95
1443.38	9/15/2018	510	1297.53
		525	1297.43
		540	1297.38
		555	1297.33
1443.48	9/18/2018	1730	1294.43
		1745	1294.43
		1800	1294.48
1443.18	9/19/2018	645	1294.4
		806	1294.38
		842	1294.98
		1110	1294.36
		1210	1294.31
		1310	1294.31
		1410	1294.27
		1510	1294.25
		1610	1294.26
		1710	1294.22
1443.18	9/20/2018	700	1294.25
		800	1294.26
		1300	1294.25
		2030	1294.25

Table 6.0-1
R-69 Geophysical Logging Runs

Date	Logging Interval	Description
7/31/2018	187–730 ft bgs	Laboratory video run through 17-in. open hole to 741 ft bgs at original well location
9/11/2018	0–1255 ft bgs	Laboratory video run to 1255 ft bgs at final well location
9/17/2018	75–1440 ft bgs	Gamma spectroscopy through 10-in. casing from 75 ft to 1443 ft bgs at final well location

Table 7.2-1
R-69 Monitoring Well Annular Fill Materials

Material	Calculated Volume	Actual Volume
Upper surface seal: cement slurry	136.6 ft^3	193.9 ft^3
Upper bentonite seal: chips/pellets	1368.4 ft^3	1490.3 ft^3
Upper fine sand collar: 20/40 silica sand	0.9 ft^3	2.0 ft^3
Upper filter pack sand: 10/20 silica sand	13.9 ft^3	25.5 ft^3
Middle bentonite seal: chips/pellets	15.2 ft^3	25.7 ft^3
Lower fine sand collar: 20/40 silica sand	0.9 ft^3	4.8 ft^3
Lower filter pack sand: 10/20 silica sand	13.4 ft^3	22.0 ft^3
Lower bentonite seal	25.6 ft^3	30.5 ft^3

Table 8.5-1
R-69 Survey Coordinates

Identification	Northing	Easting	Elevation
R-69 brass cap embedded in pad	1766245.23	1616676.41	7430.13
R-69 ground surface near pad	1766247.80	1616674.65	7430.07
R-69 top of stainless-steel well casing	1766243.19	1616680.12	7432.60
R-69 top of 16-in. protective casing	1766242.61	1616679.26	7433.69

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-69

Location ID	Sample ID	Date Collected	Description	Sample Type
R-69	WST14-18-160331	7/28/2018	Drill fluids VOC[a]/SVOC[b] initial sample–original location (UF[c])	Liquid
R-69	WST14-18-160332	7/28/2018	Drill fluids VOC/SVOC initial sample–original location (UF) FD[d]	Liquid
R-69	WST14-18-160333	7/28/2018	Drill fluids VOC/SVOC initial sample–original location (UF) FTB[e]	Liquid
R-69	WST14-18-160334	8/04/2018	Drill fluids VOC/SVOC midpoint sample–original location (UF)	Liquid
R-69	WST14-18-160335w	8/04/2018	Drill fluids VOC/SVOC midpoint sample–original location (UF) FD	Liquid
R-69	WST14-18-160336	8/04/2018	Drill fluids VOC/SVOC midpoint sample–original location (UF) FTB	Liquid
R-69	WST14-18-160960	8/25/2018	Drill fluids VOC/SVOC midpoint sample–final location (UF)	Liquid
R-69	WST14-18-160963	8/25/2018	Drill fluids VOC/SVOC midpoint sample–final location (UF) FD	Liquid
R-69	WST14-18-160996	8/25/2018	Drill fluids VOC/SVOC midpoint sample–final location (UF) FTB	Liquid
R-69	WST14-18-160961	9/15/2018	Drill fluids VOC/SVOC final sample–final location (UF)	Liquid
R-69	WST14-18-160964	9/15/2018	Drill fluids VOC/SVOC final sample–final location (UF) FD	Liquid
R-69	WST14-18-160967	9/15/2018	Drill fluids VOC/SVOC final sample–final location (UF) FTB	Liquid
R-69	WST14-18-160446	9/24/2018	Drill fluids waste characterization sample suite (F[f])	Liquid
R-69	WST14-18-160447	9/24/2018	Drill fluids waste characterization sample suite (UF)	Liquid
R-69	WST14-18-160317	7/28/2018	Drill cuttings VOC/SVOC initial sample–original location	Solid
R-69	WST14-18-160319	7/28/2018	Drill cuttings VOC/SVOC initial sample–original location (FTB)	Solid
R-69	WST14-18-160318	7/28/2018	Drill cuttings VOC/SVOC initial sample–original location (FD)	Solid
R-69	WST14-18-160320	8/04/2018	Drill cuttings VOC/SVOC midpoint sample–original location	Solid
R-69	WST14-18-160321	8/04/2018	Drill cuttings VOC/SVOC midpoint sample–original location (FTB)	Solid
R-69	WST14-18-160322	8/04/2018	Drill cuttings VOC/SVOC midpoint sample–original location (FD)	Solid
R-69	WST14-18-160941	8/25/2018	Drill cuttings VOC/SVOC midpoint sample–final location	Solid
R-69	WST14-18-160938	8/25/2018	Drill cuttings VOC/SVOC midpoint sample–final location (FTB)	Solid
R-69	WST14-18-160935	8/25/2018	Drill cuttings VOC/SVOC midpoint sample–final location (FD)	Solid
R-69	WST14-18-160943	9/15/2018	Drill cuttings VOC/SVOC final sample–final location	Solid

Table 8.6-1 (continued)

Location ID	Sample ID	Date Collected	Description	Sample Type
R-69	WST14-18-160940	9/15/2018	Drill cuttings VOC/SVOC final sample–final location (FTB)	Solid
R-69	WST14-18-160937	9/15/2018	Drill cuttings VOC/SVOC final sample–final location (FD)	Solid
R-69	WST14-18-160444	9/23/2018	Drill cuttings waste characterization sample suite	Solid
R-69	WST14-18-160445	9/23/2018	Drill cuttings waste characterization sample suite (FTB)	Solid
R-69	WST14-18-165951	12/20/2018	Decontamination fluids waste characterization suite (UF) Tank ID 1094	Liquid
R-69	WST14-18-165953	12/20/2018	Decontamination fluids waste characterization suite (UF) Tank ID 1094	Liquid
R-69	WST14-18-165950	12/20/2018	Decontamination fluids waste characterization suite (F) Tank ID 1094	Liquid
R-69	WST14-18-165952	12/20/18	Decontamination fluids waste characterization suite (UF) FD; Tank ID 1094	Liquid
R-69	WST14-18-165945	12/20/2018	Decontamination fluids waste characterization suite (UF) Tank ID 1092)	Liquid
R-69	WST14-18-165948	12/20/2018	Decontamination fluids waste characterization suite (UF) Tank ID 1092	Liquid
R-69	WST14-18-165947	12/20/2018	Decontamination fluids waste characterization suite (FTB) Tank ID 1092	Liquid
R-69	WST14-18-165946	12/20/2018	Decontamination fluids waste characterization suite (F) Tank ID 1092	Liquid
R-69	WST14-18-165005	12/17/2018	NM Special Waste characterization suite (UF) Bin ID 1091	Solid
R-69	WST14-18-165000	12/17/2018	NM Special Waste characterization suite (FTB) Bin ID 1091	Solid
R-69	WST14-18-165006	12/17/2018	NM Special Waste characterization suite (UF) Bin IDs 1090 and N3B001	Solid
R-69	WST14-18-165001	12/17/2018	NM Special Waste characterization suite (FTB) Bin IDs 1090 and N3B001	Solid

[a] VOC = Volatile organic compound.

[b] SVOC = Semivolatile organic compound.

[c] UF = Unfiltered.

[d] FD= Field duplicate.

[e] FTB = Field trip blank.

[f] F = Filtered.

Appendix A

Borehole R-69 Lithologic Log

<table>
<tr><td colspan="2">BOREHOLE IDENTIFICATION (ID): R-69</td><td colspan="2">TECHNICAL AREA (TA): 14</td></tr>
<tr><td colspan="2">DRILLING COMPANY:
Holt Drilling Services</td><td>START DATE/TIME: 8/18/18; 1442</td><td>END DATE/TIME: 9/15/18; 2305</td></tr>
<tr><td colspan="2">DRILLING METHOD:
Dual Rotary</td><td>MACHINE: Foremost DR-24 HD</td><td>SAMPLING METHOD: Grab</td></tr>
<tr><td colspan="3">GROUND ELEVATION: 7430.07 ft amsl</td><td>TOTAL DEPTH: 1443.4 ft</td></tr>
<tr><td colspan="2">DRILLERS: D. Sandy, M. McCoy, A. Soto</td><td colspan="2">SITE GEOLOGISTS: E. Tow, T. Sower, J. Jordan, L. Anderson, T. Hermes</td></tr>
<tr><td>DEPTH (ft bgs)</td><td>LITHOLOGY</td><td>LITHOLOGIC SYMBOL</td><td>NOTES</td></tr>
<tr><td>0–5</td><td>Fill:
Fill Material— Grayish orange (10YR 7/4), random fill fragments from unknown source. Pad build material.</td><td>FILL</td><td>Fill, encountered from 0 to 5 ft bgs, is 5 ft thick.
Note: Drill cuttings for descriptive analysis were collected at 5-ft intervals from ground surface to borehole TD at 1443.4 ft bgs.
The Fill/Qbt 3t contact, estimated at 5 ft bgs, is based on visual examination of cuttings.</td></tr>
<tr><td>5–30</td><td>UNIT 3t OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:
Rhyolitic Tuff—Medium gray (N5), strongly welded, crystal-bearing tuff with minor lithic fragments.
5’-30’ WR/+10F: 80-90% welded ash flow tuff fragments; 10-20% quartz and sanidine crystals; trace rhyolitic and dacitic lithic clasts.
+35F: 70-90% welded ash flow tuff fragments; 10-30% quartz and sanidine crystals; trace rhyolitic and dacitic lithic clasts.</td><td>Qbt 3t</td><td>Unit 3t of the Tshirege Member of the Bandelier Tuff (Qbt 3t), encountered from 5 to 30 ft bgs, is approximately 25 ft thick.
The Qbt 3t/Qbt 3 contact, estimated at 30 ft bgs, is based on visual examination of cuttings.</td></tr>
<tr><td>30–55</td><td>UNIT 3 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:
Rhyolitic Tuff—Light gray (N7), moderately welded, crystal-bearing tuff with minor lithic fragments.
30’ -55’ WR/+10F: 40-55% welded ash flow tuff fragments; 40-55% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts.
+35F: 70-90% quartz and sanidine crystals; 10-30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts.</td><td>Qbt 3</td><td>Unit 3 of the Tshirege Member of the Bandelier Tuff (Qbt 3), encountered from 30 to 150 ft bgs, is approximately 120 ft thick.</td></tr>
</table>

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
55–75	Rhyolitic Tuff—Pale yellowish brown (10YR 6/2), moderately welded, crystal-bearing tuff with minor lithic fragments. 55’-75’ WR/+10F: 40-55% welded ash flow tuff fragments; 40-55% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts. +35F: 70-90% quartz and sanidine crystals; 10-30% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts.	Qbt 3	
75–150	Rhyolitic Tuff— Light gray (N7), moderately welded, crystal-bearing tuff with minor lithic fragments 75’-150’ WR/+10F: 40-55% welded ash flow tuff fragments; 40-55% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts. +35F: 90-95% quartz and sanidine crystals; 5-10% welded ash flow tuff fragments; trace rhyolitic and dacitic lithic clasts.	Qbt 3	The Qbt 3/Qbt 2 contact, estimated at 150 ft bgs, is based on natural gamma logging and visual examination of cuttings.
150–165	**UNIT 2 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—Light gray (N7) to Dark yellowish orange (10YR 6/6), strongly welded, crystal-rich tuff. 150’-165’ WR/+10F: 55-60% welded ash flow tuff fragments; 40% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts. +35F: 70-80% quartz and sanidine crystals; 20-30% 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 150 to 250 ft bgs, is approximately 100 ft thick.
165–215	Rhyolitic Tuff— Light gray (N7) to Dark yellowish orange (10YR 6/6), strongly welded, crystal-rich tuff. 165’-215’ WR/+10F: 85-95% welded ash flow tuff fragments; 5-15% quartz and sanidine crystals. +35F: 70-90% welded ash flow tuff fragments; 10-30% quartz and sanidine crystals.	Qbt 2	
215–250	Rhyolitic Tuff— Med. light gray (N6) to Dark yellowish orange (10YR 6/6), strongly welded, crystal-rich tuff. 215’-250’ WR/+10F: 85-95% welded ash flow tuff fragments; 5-15% quartz and sanidine crystals. +35F: 60% welded ash flow tuff fragments; 40% quartz and sanidine crystals.	Qbt 2	The Qbt 2/Qbt 1v contact, estimated at 250 ft bgs, is based on natural gamma logging and visual examination of cuttings.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
250–255	**UNIT 1v OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff— Medium gray (N5) to Light brownish gray (5YR 6/1), strongly welded, crystal-rich tuff. 250'-255' WR/+10F: 85-95% welded ash flow tuff fragments; 5-15% quartz and sanidine crystals. +35F: 50% welded ash flow tuff fragments; 50% quartz and sanidine crystals.	Qbt 1v	Unit 1v of the Tshirege Member of the Bandelier Tuff (Qbt 1v), encountered from 250 to 280 ft bgs, is approximately 30 ft thick.
255–275	Rhyolitic Tuff— Medium gray (N5) to Light brownish gray (5YR 6/1), poorly welded, crystal-rich tuff with minor devitrified pumice. 255'-275' WR: 60-70% ash-flow tuff fragments; trace devitrified pumice; 30-40% quartz and sanidine crystals. +10F: 75-85% rhyolitic tuff fragments; 15-25% euhedral quartz and sanidine crystals; trace pumice clasts. +35F: 70-80% quartz and sanidine crystals; 20-30% rhyolitic tuff fragments.	Qbt 1v	
275–280	Rhyolitic Tuff— Medium gray (N5) to Light brownish gray (5YR 6/1), strongly welded, crystal-rich tuff. 275'-280' WR/+10F: 60-70% welded ash flow tuff fragments; 30-40% quartz and sanidine crystals. +35F: 70-80% quartz and sanidine crystals; 20-30% welded ash flow tuff fragments.	Qbt 1v	The Qbt 1v/Cobble zone contact, estimated at 280 ft bgs, is based on natural gamma logging and visual examination of cuttings.
280–293	**Cobble Bed**— Rhyolitic Tuff— Medium gray (N5) to Light brownish gray (5YR 6/1), poorly welded, crystal-rich tuff with minor devitrified pumice. 280'-293' WR: 70-80% quartz and sanidine crystals; 20-30% ash-flow tuff fragments; trace devitrified pumice. +10F: 30-70% rhyolitic tuff fragments; 30-70% euhedral quartz and sanidine crystals; trace pumice clasts. +35F: 80-90% quartz and sanidine crystals; 10-20% rhyolitic tuff fragments.	Qbt 1v	The Cobble Zone, encountered from 280 to 293 ft bgs, is approximately 13 ft thick. The Cobble zone/Qbt 1g contact, estimated at 293 ft bgs, is based on natural gamma logging.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
293–315	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—Light gray (N6 to N7) with grayish orange pink (5YR 7/2) to pale brown (5YR 5/2), poorly welded, crystal-rich tuff with minor glassy pumice. 293'-315' WR/+10F: 70-80% ash-flow tuff fragments; 20-30% quartz and sanidine crystals; <5% dacite lithics; trace devitrified pumice. +35F: 80-90% quartz and sanidine crystals; 10-20% rhyolitic tuff fragments; trace lithic fragments.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 293 to 320 ft bgs, is approximately 27 ft thick.
315–320	Rhyolitic Tuff— Light gray (N6 to N7) with grayish orange pink (5YR 7/2) to pale brown (5YR 5/2), poorly welded, crystal-rich tuff with abundant glassy pumice. 315'-320' WR/+10F: 30-50% quartz and sanidine crystals; 20-40% white to orange pumice clasts; 10-20% dacite lithics; <10% ash-flow tuff fragments. +35F: 70-60% pumice clasts; 30-40% quartz and sanidine crystals; 5-10% ash-flow tuff fragments; trace lithic fragments.	Qbt 1g	The Qbt 1g/Qct contact, estimated at 320 ft bgs, is based on natural gamma logging and visual examination of cuttings.
320–340	**CERRO TOLEDO INTERVAL** Volcaniclastic Sediments—silt to sand size angular quartz grains with orange oxidation staining, reworked white and orange pumice clasts, and dacite and rhyolite clasts. 320'-340' WR: 20-50% quartz grains; 20-50% white to orange pumice clasts; 10-40% dacite clasts. +10F: 30-70% dacite and rhyolite clasts; 30-70% pumice clasts; 5-15% angular quartz grains; +35F: 60% angular quartz grains; 30% pumice clasts; 10% volcanic clasts.	Qct	The Cerro Toledo interval (Qct), encountered from 320 to 410 ft bgs, is approximately 90 ft thick.
340–385	Volcaniclastic Sediments—silt to sand size angular quartz grains with orange oxidation staining, reworked white and orange pumice clasts, and dacite and rhyolite clasts. 340'-385' WR/+10F: 50-70% dacite clasts; 10-30% quartz grains; 5-20%; white to orange pumice clasts. +35F: 30% angular quartz grains; 40% volcanic clasts; 30% pumice clasts.	Qct	The Qct/Qbo contact, estimated at 410 ft bgs, is based on natural gamma logging, and visual examination of cuttings.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
385–410	Volcaniclastic Sediments—silt to sand size angular quartz grains with more orange oxidation staining, reworked white and more orange and red pumice clasts, and dacite and rhyolite clasts. 385'-410' WR/+10F: 50-60% dacite clasts; 20-30% quartz grains; 5-20%; white to orange pumice clasts. ++35F: 20-30% angular quartz grains; 40-60% volcanic clasts; 20-30% pumice clasts.	Qct	The Qct/Qbo contact, estimated at 410 ft bgs, is based on natural gamma logging, and visual examination of cuttings.
410–430	**OTOWI MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff— Med. light gray (N6) to grayish orange (10YR 7/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 410'-430' WR: 40-60% white to orange pumices; 20-40% dacite lithics; 10-20% quartz grains. +10F: 30-50% dacite and rhyolite lithics; 30-50% pumice clasts; 10-20% quartz grains. +35F: 30-40% angular quartz grains; 30-35% pumice; 30-35% volcanic lithics.	Qbo	The Otowi Member of the Bandelier Tuff (Qbo), encountered from 410 to 675 ft bgs, is approximately 265 ft thick.
430–470	Rhyolitic Tuff— Dark gray (N3) to grayish orange (10YR 7/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 430'-470' WR/+10F: 50-70% dacite lithics; 30-50% white to orange pumice. +35F: 40-60% pumice; 30-50% angular quartz grains; 5-10% volcanic lithics.	Qbo	Note: No return at 440 – 445 ft sample
470–495	Rhyolitic Tuff— Dark gray (N3) to grayish orange (10YR 7/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 470'-495' WR/+10F: 60-70% dacite lithics; 30-40% white to orange pumice. +35F: 40-60% volcanic lithics; 30-50% pumice; 5-10% angular quartz grains.	Qbo	
495–520	Rhyolitic Tuff— Medium gray (N5) to grayish orange (10YR 7/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 495'-520' WR: 55-70% dacite lithics; 20-30% white to orange pumice; 10-15% quartz grains. +10F: 50-80% dacite and rhyolite lithics; 20-50% pumice. +35F: 40-60% angular quartz grains; 30-50% pumice; 5-10% volcanic lithics.	Qbo	
520–540	Rhyolitic Tuff—Medium gray to white (N5-N9) with some grayish brown (5YR 3/2), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 520'-540' WR/+10F: 40-50% white pumice; 40-50% dacite lithics; 5-10% quartz grains. +35F: 40-50% volcanic lithics; 40-50% pumice; 5% angular quartz grains.	Qbo	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
540–560	Rhyolitic Tuff— Medium gray to white (N5-N9) with some grayish brown (5YR 3/2), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 540’-560’ WR/+10F: 40-50% white pumice; 40-50% dacite lithics; 5-10% quartz grains. +35F: 50-60% pumice; 30-40% volcanic lithics; 5% angular quartz grains.	Qbo	
560–585	Rhyolitic Tuff— Medium gray to white (N5-N9) with some grayish brown (5YR 3/2), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 560’-585’ WR/+10F: 50-60% white pumice; 30-40% dacite lithics; 5-10% quartz grains. +35F: 40-50% volcanic lithics; 30-40% pumice; 5-15% angular quartz grains.	Qbo	
585–600	Rhyolitic Tuff— Medium gray to white (N5-N9) with some grayish brown (5YR 3/2), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 585’-600’ WR/+10F: 60-70% white pumice; 20-30% dacite lithics; 5-10% quartz grains. +35F: 50-60% white pumice; 20-30% dacite lithics; 10-20% quartz grains.	Qbo	
600–615	Rhyolitic Tuff— Medium gray to white (N5-N9) with some grayish brown (5YR 3/2), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 600’-615’ WR/+10F: 55-65% white pumice; 15-25% dacite lithics; 10-15% quartz grains. +35F: 45-55% white pumice; 15-25% dacite lithics; 20-30% quartz grains.	Qbo	
615–650	Rhyolitic Tuff— Medium gray to white (N5-N9) with some grayish brown (5YR 3/2), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 615’-650’ WR/+10F: 70-80% white pumice; 10-20% dacite lithics; 5-10% quartz grains. +35F: 70-80% white pumice; 10-20% dacite lithics; 5-10% quartz grains.	Qbo	this
650–675	Rhyolitic Tuff— Medium gray to white (N5-N9) with some moderate brown (5YR 4/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 650’-675’ WR/+10F: 60-70% white pumice; 10-20% dacite lithics; 10-20% quartz grains. +35F: 60-70% white pumice; 10-20% dacite lithics; 10-20% quartz grains.	Qbo	The Qbo/Qbog contact, estimated at 675 ft bgs, is based on natural gamma logging and visual examination of cuttings.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
675–685	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—Dark gray to white (N3-N9) to grayish orange pink to moderate brown (5YR 7/2-5YR 4/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 675’-685’ WR/+10F: 50-70% white pumice; 30-50% gray dacite or red-purple rhyolite lithics; trace quartz crystals. +35F: 50-60% rounded white pumice; 40-50% rounded gray dacite or red-purple rhyolite lithic fragments; 5-10% quartz crystals.	Qbog	The Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog), encountered from 675 to 690 ft bgs, is approximately 15 ft thick.
685–690	Rhyolitic Tuff— Dark gray to white (N3-N9) to grayish orange pink to moderate brown (5YR 7/2-5YR 4/4), poorly welded, pumice- and lithic-rich, crystal-poor tuff. 685’-690’ WR/+10F: 40-60% white pumice; 40-60% gray dacite or red-purple rhyolite lithics; trace quartz crystals. +35F: 50-60% rounded white pumice; 40-50% rounded gray dacite or red-purple rhyolite lithic fragments; 5-10% quartz crystals.	Qbog	The Qbog/Tpf contact, estimated at 690 ft bgs, is based on visual examination of cuttings and natural gamma logging.
690–705	**PUYE FORMATION** Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 690’-705’ WR/+10F/+35F: 99-100% subangular to subrounded clasts of dacite and rhyolite; <1% devitrified white pumice clasts (possibly falling from above); trace quartz grains in +35F.	Tpf	The Puye Formation (Tpf), encountered from 690 to 1443.4 ft bgs, is at least 753.4 ft thick.
705–850	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 705’-850’ WR/+10F/+35F: 99-100% angular to subangular clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: More angular in this interval.
850–895	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 850’-895’ WR/+10F/+35F: 99-100% rounded to subrounded clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: Increased rounding in this interval.
895–985	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 895’-985’ WR/+10F/+35F: 99-100% subangular to subrounded clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: slightly more angular in this interval.
985–1140	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 985’-1140’ WR/+10F/+35F: 99-100% angular to subangular clasts of dacite and rhyolite up to 15mm; trace quartz grains in +35F.	Tpf	Note: Even more angular in this interval.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
1140–1270	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 1140'-1270' WR/+10F/+35F: 99-100% subangular to subrounded clasts of dacite and rhyolite up to 15mm; trace quartz grains in +35F.	Tpf	
1270–1285	Volcaniclastic Sediments—varicolored, slightly darker color, grains of dacite and rhyolite. 1270'-1285' WR/+10F/+35F: 99-100% rounded to subrounded clasts of dacite and rhyolite down to less than 1 mm (very fine grained) and up to 20mm; trace quartz grains in +35F.	Tpf	Note: finer grain material from this interval on.
1285–1320	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 1285'-1320' WR/+10F/+35F: 99-100% rounded to subrounded clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	
1320–1355	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 1320'-1355' WR/+10F/+35F: 99-100% subrounded to subangular clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	
1355–1380	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 1355'-1380' WR/+10F/+35F: 99-100% angular to subangular clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: More angular in this interval.
1380–1410	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 1380'-1410' WR/+10F/+35F: 99-100% subangular to subrounded clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	
1410–1443.4	Volcaniclastic Sediments—varicolored grains of dacite and rhyolite. 1410'-1443.4' WR/+10F/+35F: 99-100% rounded to subrounded clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: Increased rounding in this interval. Total Depth = 1443.4 ft bgs

Borehole Lithologic Log (continued)

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

Qf = Post-Tshirege alluvial fan deposit

Qbt 4 = Unit 4 of the Tshirege Member of the Bandelier Tuff

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

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 (vapor-phase) 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

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in

1 in = 25.4 mm

Appendix B

Groundwater Screening Analytical Results for Well R-69

B-1.0 GROUNDWATER SCREENING ANALYSES AT R-69

Well R-69 is a regional aquifer monitoring well with two well screens from 1310 to 1330.2 ft below ground surface (bgs) (screen 1) and 1375.5 to 1395.8 bgs (screen 2) within the Puye Formation. This appendix presents screening analytical results for samples collected during well development and aquifer testing at R-69.

B-1.1 Laboratory Analyses

Six perched groundwater screening samples were collected during drilling and analyzed for anions, cations, metals, tritium, the New Mexico Environment Department (NMED) high explosives suite (NMED HEXP), alkalinity, RDX (Royal Demolition Explosive), Los Alamos National Laboratory's (LANL's) Earth and Environmental Sciences 6 (EES-6) tracer analysis, HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), and trinitrotoluene (TNT).

Four groundwater samples were collected during development and analyzed for total organic carbon (TOC) only.

Twenty-six groundwater samples were collected during aquifer testing. LANL's EES-14 analyzed the development samples for TOC and RDX and the aquifer test samples for RDX.

Tables B-1.0-1 and B-1.0-2 list the R-69 samples submitted for TOC analyses.

B-1.2 Field Analyses

Additionally, groundwater field parameters were collected from a flow-through cell at regular intervals during well development and aquifer testing and measured for pH, specific 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 below the target concentration of 2.0 mgC/L in 11 groundwater samples collected during well development and aquifer testing at well R-69 (Table B-1.0-1 and Table B-1.0-2). All TOC analysis were performed according to U.S. Environmental Protection Agency (EPA) method SW-846:9060.

B-2.2 RDX

Samples were collected for RDX screening during aquifer testing and well construction as shown in Tables B-2.2-1 and B-2.2-2. Tables B-2.2-1 and B-2.2-2 also summarize sample depths and pertinent metrics for the samples collected. All RDX (EES-6) and HEXP (GEL Laboratories, LLC) analyses were performed according to EPA method SW-846:8330.

B-2.3 Field Parameters

B-2.3.1 Well Development

Table B-2.3-1 presents results of field parameters, consisting of pH, temperature, DO, ORP, specific conductance, and turbidity, measured during well development and aquifer performance testing conducted at R-69. Well development was initially conducted for 4 days. Aquifer testing was then conducted for 10 days. These activities were conducted consecutively, and the field parameters are summarized below.

Twenty measurements of pH and temperature varied from 7.48 to 8.13 and from 11.80°C to 14.80°C, respectively, in groundwater pumped from well R-69 screen 2 during development. Concentrations of DO varied from 7.42 to 9.16 mg/L during this phase of pumping at well R-69 screen 2. Noncorrected ORP values varied from 221.6 to 326.4 mV during well development of R-69 screen 2.

Specific conductance generally decreased from 123.4 to 121.1 µS/cm and turbidity values averaged 3.39 nephelometric turbidity units (NTU) except for three anomalous spikes during well development of R-69 screen 2. Corrected oxidation-reduction potential (Eh) values, determined from field ORP measurements, varied from 421.6 mV to 526.40 mV (Table B-2.3-1).

Sixteen measurements of pH and temperature varied from 7.48 to 7.85 and from 14.90°C to 12.40°C, respectively, in groundwater pumped from well R-69 screen 1 during development. Concentrations of DO varied from 7.12 to 8.11 mg/L during this phase of pumping at well R-69 screen 1. Noncorrected ORP values varied from 225.40 to 331.2 mV during well development of R-69 screen 1. Specific conductance generally decreased from 137.7 to 126.3 µS/cm and turbidity values averaged 2.08 NTU except for six readings that appeared to be influenced by effervescence adhering to the probe throughout development of R-69 screen 1. Corrected Eh values, determined from field ORP measurements, varied from 425.40 mV to 531.20 mV (Table B-2.3-1).

B-2.3.2 Aquifer Testing

Hourly measurements of pH and temperature varied from 7.55 to 7.63 and from 15.59°C to 16.13°C, respectively, in groundwater pumped from well R-69 screen 2 during the 72-hr aquifer test. Concentrations of DO varied from 2.65 to 4.52 mg/L during this phase of pumping at well R-69 screen 2. Noncorrected ORP values varied from 114.2 to 202.0 mV during aquifer testing of R-69 screen 2. Specific conductance generally decreased from 129.3 to 118.7 µS/cm and turbidity values averaged 0.99 NTU, excluding the first reading of 11.9 at the start of the aquifer test. Corrected Eh values, determined from field ORP measurements, varied from 228.7 mV to 483.4 mV (Table B-2.3-1).

Hourly measurements of pH and temperature varied from 7.73 to 7.84 and from 13.99°C to 15.72°C, respectively, in groundwater pumped from well R-69 screen 1 during the 72-hr aquifer test. Concentrations of DO varied from 8.16 to 9.16 mg/L during this phase of pumping at well R-69 screen 1. Noncorrected ORP values varied from 28.70 to 279.6 mV during aquifer testing of R-69 screen 1. Specific conductance generally decreased from 129.3 to 118. µS/cm and turbidity values averaged 0.69 NTU. Corrected Eh values, determined from field ORP measurements, varied from 314.2 mV to 402.0 mV (Table B-2.3-1).

One temperature-dependent correction factor was used to calculate Eh values from field ORP measurements: 200.0 mV at 15°C. Figures B-2.3-1 and B-2.3-2 show the field parameters measured over the course of well development and aquifer testing.

The flow-through cell meter failed for 8 hr during well development and for 17 hr during the aquifer test of screen 1. While the flow-through cell meter was not operational, parameters were recorded manually and entered in the field logbook.

B-3.0 SUMMARY OF SCREENING ANALYTICAL RESULTS

B-3.1 Total Organic Carbon

TOC concentrations in screen 1 and 2 intervals were below the target level of 2.0 mg/L and turbidities were 1.7 and 1.1 NTU, respectively, at the end of well development. Well R-69 will be sampled monthly for 1 yr and data collected will be assessed and incorporated into the "Interim Facility-Wide Groundwater Monitoring Plan." Data from ongoing sampling at R-69 will be analyzed and presented in the Technical Area 16 260 monitoring group annual periodic monitoring report.

B-3.2 RDX Aquifer Performance Testing

Samples were collected for RDX analysis at 8-hr intervals during aquifer performance testing for both screen 1 and screen 2. The pump shroud intake was set at 1393.82 ft bgs in screen 2 and at 1342.25 ft bgs in screen1. RDX results for screen 1 ranged between 29.41 and 22.07 µg/L over 10 samples collected with an average detection of 26.34 µg/L. RDX results for screen 2 ranged between 39.45 to 26.43 µg/L over 10 samples collected with an average detection of 30.61 µg/L.

B-3.3 RDX Well Construction Potential Perched Water

Samples were collected for RDX analysis when potential perched water was observed during well construction. RDX results for all three samples collected were nondetections.

Table B-1.0-1
TOC Results for Groundwater Screening Samples Collected during Well Development at Well R-69

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis	TOC Concentration (mg/L)
Well Development						
R-69 S1[a]	CACV-19-164242	11/4/2018	1330.57	Groundwater, pumped	TOC	0.58
R-69 S2[b]	CACV-19-164252	11/3/2018	1393.82	Groundwater, pumped	TOC	0.50
R-69 S2	CACV-19-164253	11/3/2018	1393.82	Groundwater, pumped	TOC	0.48
R-69 S2	CACV-19-164254	11/3/2018	1393.82	Groundwater, pumped	TOC	0.50

[a] S1 = Screen 1.

[b] S2 = Screen 2.

Table B-1.0-2
TOC Results for Groundwater Screening Samples Collected during Aquifer Testing at Well R-69

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis	TOC Concentration (mg/L)
Aquifer Testing						
R-69 S1[a]	CACV-19-164742	11/17/2018	1330.2	Groundwater, pumped	TOC	0.46
R-69 S1	CACV-19-164743	11/18/2018	1330.2	Groundwater, pumped	TOC	0.45
R-69 S1	CACV-19-164737	11/19/2018	1330.2	Groundwater, pumped	TOC	0.42
R-69 S1	CACV-19-164744	11/19/2018	1330.2	Groundwater, pumped	TOC	0.44
R-69 S2[b]	CACV-19-164745	11/10/2018	1375.5	Groundwater, pumped	TOC	0.83
R-69 S2	CACV-19-164746	11/11/2018	1375.5	Groundwater, pumped	TOC	0.55
R-69 S2	CACV-19-164747	11/12/2018	1375.5	Groundwater, pumped	TOC	0.44

[a] S1 = Screen 1.

[b] S2 = Screen 2.

Table B-2.2-1
RDX Results for Groundwater Screening Samples
Collected during Aquifer Testing at Well R-69

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis	RDX Concentration (µg/L)
Aquifer Testing						
R-69 S2	CACV-19-164724	11/9/2018	1393.8	Groundwater, pumped	RDX (EES-6)	31.66
R-69 S2	CACV-19-164725	11/9/2018	1393.8	Groundwater, pumped	RDX (EES-6)	39.45
R-69 S2	CACV-19-164726	11/10/2018	1393.8	Groundwater, pumped	RDX (EES-6)	31.94
R-69 S2	CACV-19-164727	11/10/2018	1393.8	Groundwater, pumped	RDX (EES-6)	34.39
R-69 S2	CACV-19-164728	11/10/2018	1393.8	Groundwater, pumped	RDX (EES-6)	30.57
R-69 S2	CACV-19-164729	11/11/2018	1393.8	Groundwater, pumped	RDX (EES-6)	28.10
R-69 S2	CACV-19-164730	11/11/2018	1393.8	Groundwater, pumped	RDX (EES-6)	28.12
R-69 S2	CACV-19-164731	11/11/2018	1393.8	Groundwater, pumped	RDX (EES-6)	27.78
R-69 S2	CACV-19-164732	11/12/2018	1393.8	Groundwater, pumped	RDX (EES-6)	27.64
R-69 S2	CACV-19-164733	11/12/2018	1393.8	Groundwater, pumped	RDX (EES-6)	26.42
R-69 S1	CACV-19-164714	11/16/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	22.65
R-69 S1	CACV-19-164715	11/16/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	27.45
R-69 S1	CACV-19-164716	11/17/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	27.32
R-69 S1	CACV-19-164717	11/17/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	24.31
R-69 S1	CACV-19-164718	11/17/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	29.41
R-69 S1	CACV-19-164719	11/18/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	22.07
R-69 S1	CACV-19-164720	11/18/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	25.01
R-69 S1	CACV-19-164721	11/18/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	29.41
R-69 S1	CACV-19-164722	11/19/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	27.32
R-69 S1	CACV-19-164723	11/19/2018	1310–1330.2	Groundwater, pumped	RDX (EES-6)	28.42

Table B-2.2-2
Summary of RDX Results for Groundwater Screening Samples Collected during Well Construction at Well R-69

Location ID	Sample ID	Date Collected	Collection Depth	Sample Type	Analysis	RDX Concentration (µg/L)
Well Construction - Perched Groundwater						
R-69	CACV-18-160551	10/17/2018	849.12–866.35	Groundwater, bailed first encounter	HEXP (GEL[a])/RDX (EES-6)	2.00/ND[b]
R-69	CACV-18-163946	10/19/2018	842.06–914.59	Groundwater, bailed intermediate	HEXP (GEL)/RDX (EES-6)	2.00/ND[b]
R-69	CACV-18-163947	10/19/2018	842.06–914.59	Groundwater, bailed intermediate (duplicate)	HEXP (GEL)/RDX (EES-6)	2.00/ND[b]

[a] GEL = GEL Laboratories, LLC, Division of the GEL Group, Inc., Charleston, SC.

[b] ND = Not detected.

Table B-2.3-1
Purge Volumes and Field Parameters during Well Development and Aquifer Testing at R-69

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/2/2018	NR*–2-ft increment step through development screen 2											10228.00
Well Development–Screen 2												
11/3/2018	7:44	8.13	11.80	9.16	221.60	421.60	137.70	1.30	1395.62	NR	6.00	6.00
	8:44	7.48	12.00	8.22	288.90	488.90	133.80	7.20		14.69	921.00	927.00
	9:44	7.51	12.10	8.32	297.70	497.70	133.10	1.80		15.10	906.00	1833.00
	10:15	7.55	13.20	8.63	297.60	497.60	132.70	1.70		15.03	466.00	2299.00
	10:45	7.58	12.50	8.74	310.00	510.00	131.50	2.10		15.03	451.00	2750.00
	11:15	7.61	13.20	8.77	315.60	515.60	131.20	1.20		14.87	446.00	3196.00
	11:45	7.64	13.60	8.69	319.20	519.20	131.10	1.90		14.97	449.00	3645.00
	12:15	7.64	14.80	7.42	321.00	521.00	129.70	105.40		15.03	451.00	4096.00
	12:45	7.69	14.10	8.37	322.60	522.60	130.30	59.00		15.00	450.00	4546.00
	13:15	7.69	12.90	8.59	326.40	526.40	130.10	3.70		14.87	446.00	4992.00
	13:45	7.69	13.60	8.46	325.60	525.60	129.90	22.70		15.20	456.00	5448.00
	14:15	7.66	13.80	8.32	323.00	523.00	129.60	6.50		14.83	445.00	5893.00
	14:45	7.68	14.20	8.23	317.00	517.00	129.20	3.50		14.67	440.00	6333.00
	15:15	7.71	13.40	7.43	313.80	513.80	128.60	4.60		14.87	446.00	6779.00
	15:45	7.66	13.50	7.71	314.70	514.70	128.90	8.50		14.93	448.00	7227.00
	16:15	7.69	13.70	6.31	308.50	508.50	127.90	6.80		14.93	448.00	7675.00
	16:45	7.70	13.60	5.76	304.80	504.80	127.30	2.50		15.15	453.00	8128.00
	17:15	7.71	13.50	6.53	305.50	505.50	127.10	1.80		15.00	451.00	8579.00
	17:45	7.72	13.00	6.53	311.30	511.30	126.70	1.40		15.03	450.00	9029.00
	18:15	7.71	12.40	6.59	315.50	515.50	126.30	1.10		15.00	450.00	9479.00

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/3/2018	NR–2-ft increment step through development screen 1											9895.00
Well Development–Screen 1												
11/4/2018	7:53	7.85	13.30	7.95	225.40	425.40	122.00	184.10	1330.57	16.00	48.00	48.00
	8:53	7.50	12.80	7.68	294.40	494.40	121.30	15.50		15.52	931.00	979.00
	9:45	7.52	13.40	7.71	309.00	509.00	120.60	25.70		15.71	817.00	1796.00
	10:45	7.53	14.20	7.74	315.00	515.00	120.90	4.10		14.42	865.00	2661.00
	11:15	7.52	13.50	8.06	318.00	518.00	121.00	0.90		18.87	566.00	3227.00
	11:45	7.51	14.10	8.11	320.40	520.40	120.70	2.00		16.20	486.00	3713.00
	12:15	7.50	14.90	7.87	317.50	517.50	121.10	54.00		14.37	431.00	4144.00
	12:45	7.51	13.90	7.84	317.80	517.80	120.80	20.10		16.10	483.00	4627.00
	13:15	7.50	14.70	7.94	318.80	518.80	120.70	0.30		16.37	491.00	5118.00
	13:45	7.50	13.90	7.84	323.40	523.40	120.40	0.20		16.37	491.00	5609.00
	14:15	7.49	14.00	7.33	317.80	517.80	120.70	3.00		17.20	516.00	6125.00
	14:45	7.49	14.00	7.45	318.40	518.40	120.30	3.20		15.57	467.00	6592.00
	15:15	7.49	14.40	7.12	317.90	517.90	120.60	17.60		16.73	502.00	7094.00
	15:45	7.48	14.30	7.40	317.70	517.70	120.30	3.50		16.00	480.00	7574.00
	16:15	7.50	12.40	7.60	327.20	527.20	120.70	1.90		16.33	490.00	8064.00
	16:45	7.49	12.80	7.80	331.20	531.20	120.20	1.70		16.50	495.00	8559.00
11/6/2018	NR–Aquifer test preparations (crossover water)											213.50
11/7/2018	NR–Aquifer step test–screen 2											1367.90

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
72-Hour Aquifer Test–Screen 2												
11/9/2018	8:30	7.84	14.73	3.51	111.20	311.20	129.20	11.90	1393.82	15.16	454.80	454.80
	9:30	7.81	15.16	2.88	56.10	256.10	129.30	4.90		14.86	891.50	1346.30
	10:30	7.81	15.28	2.75	28.70	228.70	128.00	1.90		15.23	913.70	2260.00
	11:30	7.80	15.49	3.06	34.00	234.00	127.50	1.50		15.28	916.20	3176.20
	12:30	7.78	15.41	3.39	41.50	241.50	127.10	1.50		15.35	920.00	4096.20
	13:30	7.77	15.13	3.50	50.70	250.70	124.70	1.24		15.34	921.10	5017.30
	14:30	7.76	14.86	3.62	72.80	272.80	124.60	1.14		15.33	920.50	5937.80
	15:30	7.76	14.67	3.76	81.40	281.40	123.10	1.07		15.34	921.30	6859.10
	16:30	7.77	14.76	3.99	91.30	291.30	124.40	1.08		15.35	920.50	7779.60
	17:30	7.76	14.68	3.93	103.50	303.50	123.60	1.05		15.27	917.50	8697.10
	18:30	7.77	15.02	3.23	105.90	305.90	123.40	1.22		14.75	892.10	9589.20
	19:30	7.77	15.02	3.05	95.10	295.10	123.10	1.27		14.75	883.30	10,472.50
	20:30	7.76	14.79	2.95	91.50	291.50	122.90	1.03		14.61	876.30	11,348.80
	21:30	7.76	14.80	2.80	86.00	286.00	122.60	1.51		14.52	871.50	12,220.30
	22:30	7.77	15.00	2.78	87.90	287.90	122.30	1.02		14.55	871.90	13,092.20
	23:30	7.76	14.84	2.75	90.20	290.20	122.00	1.07		14.56	872.50	13,964.70
11/10/2018	0:30	7.76	14.74	2.72	91.70	291.70	121.60	1.00		14.46	870.60	14,835.30
	1:30	7.76	14.72	2.71	93.20	293.20	121.80	1.07		14.67	876.90	15,712.20
	2:30	7.84	14.92	3.03	73.10	273.10	121.60	1.01		14.95	889.30	16,601.50
	3:30	7.76	14.67	3.61	96.10	296.10	121.60	1.01		15.53	918.70	17,520.20
	4:30	7.75	14.65	3.52	101.70	301.70	121.20	1.00		15.47	926.80	18,447.00
	5:30	7.77	14.84	3.65	104.60	304.60	120.90	1.00		15.48	927.70	19,374.70
	6:30	7.77	14.50	3.58	107.00	307.00	121.10	1.00		15.45	927.10	20,301.80
	7:30	7.77	14.72	3.85	97.20	297.20	120.90	1.08		15.50	930.10	21,231.90
	8:30	7.74	14.55	3.96	96.20	296.20	120.80	0.97		15.50	930.10	22,162.00

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	9:30	7.77	15.60	4.09	89.80	289.80	121.30	0.89		15.52	931.20	23,093.20
	10:30	7.75	15.30	4.37	77.80	277.80	121.20	0.95		15.52	931.10	24,024.30
	11:30	7.74	15.24	4.46	74.20	274.20	121.20	0.89		15.53	931.50	24,955.80
	12:30	7.73	15.20	4.52	77.60	277.60	121.00	0.88		15.54	932.30	25,888.10
	13:30	7.74	14.83	4.47	86.80	286.80	120.50	0.73		15.52	931.30	26,819.40
	14:30	7.73	14.79	4.35	108.30	308.30	120.30	0.84		15.51	930.70	27,750.10
	15:30	7.74	14.78	4.33	128.90	328.90	119.90	1.10		15.50	930.20	28,680.30
	16:30	7.74	14.96	4.22	142.10	342.10	120.10	1.03		15.51	930.40	29,610.70
	17:30	7.73	14.72	4.17	152.60	352.60	120.30	0.85		15.48	929.10	30,539.80
	18:30	7.75	14.74	3.74	165.50	365.50	119.30	1.12		15.48	928.70	31,468.50
	19:30	7.75	15.50	3.60	177.30	377.30	120.10	1.03		15.50	928.70	32,397.20
	20:30	7.75	16.13	3.58	187.00	387.00	120.40	0.93		15.42	924.10	33,321.30
	21:30	7.75	15.44	3.47	197.80	397.80	120.00	1.09		15.46	927.10	34,248.40
	22:30	7.74	15.04	3.41	204.50	404.50	120.00	0.89		15.41	924.30	35,172.70
	23:30	7.75	15.55	3.32	207.50	407.50	120.20	0.86		15.39	922.10	36,094.80
11/11/2018	0:30	7.74	15.25	3.26	215.90	415.90	120.00	0.86		15.31	919.10	37,013.90
	1:30	7.75	15.66	3.14	221.50	421.50	119.90	1.14		15.30	918.30	37,932.20
	2:30	7.75	15.63	3.16	227.60	427.60	119.90	0.88		15.31	917.20	38,849.40
	3:30	7.74	15.34	3.14	237.40	437.40	119.80	0.96		14.97	918.80	39,768.20
	4:30	7.74	15.48	3.06	243.30	443.30	119.80	0.85		15.33	917.70	40,685.90
	5:30	7.73	15.77	3.01	247.60	447.60	119.80	0.88		15.32	917.70	41,603.60
	6:30	7.74	15.78	3.09	254.40	454.40	119.60	0.84		15.28	916.50	42,520.10
	7:30	7.75	15.39	3.02	239.50	439.50	119.50	0.65		15.24	914.20	43,434.30
	8:30	7.73	14.77	3.00	231.20	431.20	119.50	0.69		15.17	910.20	44,344.50
	9:30	7.73	14.52	2.90	218.70	418.70	119.40	0.66		14.91	898.20	45,242.70
	10:30	7.73	14.45	3.36	231.20	431.20	119.40	0.74		15.49	913.60	46,156.30

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	11:30	7.73	14.76	3.51	214.70	414.70	119.40	0.74		15.47	928.00	47,084.30
	12:30	7.73	14.49	3.51	227.30	427.30	119.30	0.70		15.47	929.00	48,013.30
	13:30	7.75	14.84	3.39	186.30	386.30	119.30	0.92		15.48	927.00	48,940.30
	14:30	7.74	14.53	3.56	233.80	433.80	119.30	0.83		15.42	926.70	49,867.00
	15:30	7.73	14.36	3.34	252.30	452.30	119.20	0.88		15.40	924.30	50,791.30
	16:30	7.74	15.62	3.24	261.20	461.20	119.20	0.92		15.34	921.20	51,712.50
	17:30	7.76	15.61	3.17	269.80	469.80	119.20	0.70		15.23	915.30	52,627.80
	18:30	7.75	15.91	3.04	274.20	474.20	119.20	0.81		15.13	909.30	53,537.10
	19:30	7.74	15.39	2.95	277.60	477.60	119.10	0.68		15.00	899.30	54,436.40
	20:30	7.75	15.30	2.81	279.30	479.30	119.20	0.82		14.78	889.90	55,326.30
	21:30	7.74	15.10	2.65	280.50	480.50	118.80	0.73		14.56	874.10	56,200.40
	22:30	7.73	14.71	2.83	282.00	482.00	119.10	0.76		14.92	888.10	57,088.50
	23:30	7.73	14.45	3.01	283.40	483.40	118.90	0.68		15.09	902.50	57,991.00
11/12/2018	0:30	7.74	14.78	2.99	281.30	481.30	118.80	0.74		15.33	913.00	58,904.00
	1:30	7.74	14.68	3.17	281.80	481.80	118.80	0.69		15.39	922.90	59,826.90
	2:30	7.74	14.47	3.10	279.60	479.60	118.80	0.63		15.35	920.40	60,747.30
	3:30	7.75	15.10	3.08	278.80	478.80	119.00	0.63		15.30	917.90	61,665.20
	4:30	7.75	14.83	2.98	279.10	479.10	118.90	0.58		15.25	914.30	62,579.50
	5:30	7.74	14.99	2.95	278.60	478.60	118.80	0.61		15.11	907.50	63,487.00
	6:30	7.75	14.96	2.84	278.70	478.70	118.70	0.73		14.98	899.00	64,386.00
	7:30	7.75	14.84	3.06	274.40	474.40	118.80	0.76		15.16	909.50	65,295.50
	7:58	7.75	13.99	3.18	273.70	473.70	118.80	0.74		15.55	435.50	65,731.00
11/15/2018	NR–Aquifer step test–screen 1 (mixed screen 1 and screen 2 water)											1894.20

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
72-Hour Aquifer Test–Screen 1												
11/16/2019	8:30	7.63	14.57	8.94	152.60	352.60	122.70	0.96	1342.25	11.84	359.40	359.40
	9:30	7.61	15.31	8.39	124.50	324.50	123.40	1.34		11.85	711.10	1070.50
	10:30	7.61	15.46	8.39	117.10	317.10	123.40	1.16		11.86	711.40	1781.90
	11:30	7.59	15.47	8.59	117.50	317.50	123.10	1.64		11.85	711.50	2493.40
	12:30	7.59	15.58	8.56	114.20	314.20	123.20	0.77		11.84	710.60	3204.00
	13:30	7.58	15.26	9.05	117.50	317.50	123.00	0.74		11.86	711.60	3915.80
	14:30	7.55	15.00	9.09	134.20	334.20	122.60	0.70		11.84	710.70	4626.50
	15:30	7.58	15.12	9.05	144.10	344.10	122.50	0.76		11.84	710.40	5336.90
	16:30	7.58	15.06	8.92	156.20	356.20	122.70	0.56		11.83	710.10	6047.00
	17:30	7.58	14.97	8.69	166.20	366.20	122.40	0.68		11.82	709.60	6756.60
	18:30	7.60	14.90	8.54	151.90	351.90	122.80	0.78		11.88	711.10	7467.70
	19:30	7.59	15.08	8.87	159.00	359.00	122.50	0.54		12.08	708.80	8176.50
	20:30	7.59	15.13	8.75	162.30	362.30	122.70	0.78		11.80	708.90	8885.40
	21:30	7.58	15.48	8.49	163.70	363.70	122.70	0.58		11.80	708.40	9593.80
	22:30	7.59	15.33	8.62	164.80	364.80	122.40	0.50		11.82	708.90	10,302.70
	23:30	7.58	15.12	8.71	170.80	370.80	122.60	0.71		11.81	708.40	11,011.10
11/17/2018	0:30	7.58	14.78	8.70	169.40	369.40	122.20	0.44		11.82	708.10	11,719.20
	1:30	7.59	14.83	9.11	170.10	370.10	122.50	0.94		11.80	707.00	12,426.20
	2:30	7.59	14.79	8.65	170.20	370.20	122.40	0.48		11.83	709.00	13,135.20
	3:30	7.59	14.94	8.73	168.80	368.80	122.30	0.81		11.80	706.90	13,842.10
	4:30	7.58	14.81	8.76	167.90	367.90	122.10	0.77		11.80	707.60	14,549.70
	5:30	7.59	14.79	8.67	169.70	369.70	122.20	0.49		11.38	694.80	15,244.50
	6:30	7.58	14.71	8.47	169.80	369.80	122.20	0.94		11.76	716.40	15,960.90
	7:30	7.59	14.84	8.90	164.40	364.40	122.40	1.12		11.76	706.10	16,667.00
	8:30	7.59	15.06	8.47	153.50	353.50	122.20	1.96		11.80	707.30	17,374.30

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	9:30	7.58	15.07	8.44	144.40	344.40	122.10	0.56		11.80	708.10	18,082.40
	10:30	7.58	15.35	8.59	140.70	340.70	122.20	0.57		11.80	708.10	18,790.50
	11:30	7.59	15.59	8.31	131.60	331.60	122.10	0.56		11.80	708.20	19,498.70
	12:30	7.57	15.52	8.32	124.80	324.80	122.60	0.50		11.80	708.00	20,206.70
	13:30	7.56	15.15	8.47	128.50	328.50	122.40	1.11		11.80	708.10	20,914.80
	14:30	7.56	15.02	8.23	141.70	341.70	122.40	0.68		11.80	708.20	21,623.00
	15:30	7.57	15.10	8.48	142.50	342.50	122.30	0.81		11.80	707.90	22,330.90
	16:30	7.56	15.03	8.30	149.30	349.30	122.30	0.51		11.79	707.60	23,038.50
	17:30	7.57	14.81	8.54	156.30	356.30	122.30	0.46		11.78	707.20	23,745.70
	18:30	7.57	14.83	8.26	159.00	359.00	122.20	0.46		11.83	708.50	24,454.20
	19:30	7.57	14.90	8.37	160.70	360.70	122.20	0.45		11.79	706.40	25,160.60
	20:30	7.57	14.89	8.29	163.30	363.30	122.30	0.42		11.78	706.90	25,867.50
	21:30	7.57	14.71	8.39	164.50	364.50	122.30	0.46		11.79	707.20	26,574.70
	22:30	7.57	14.69	8.46	165.50	365.50	122.30	0.41		11.77	707.10	27,281.80
	23:30	7.57	14.44	8.62	167.20	367.20	122.10	0.46		11.77	706.50	27,988.30
11/18/2018	0:30	7.58	14.69	8.21	167.50	367.50	122.30	0.42		11.78	706.40	28,694.70
	1:30	7.57	14.35	8.24	160.70	360.70	122.20	0.50		11.75	705.00	29,399.70
	2:30	7.57	14.68	8.27	164.20	364.20	121.90	0.45		11.77	705.50	30,105.20
	3:30	7.57	14.60	8.37	166.40	366.40	122.00	0.44		11.75	704.50	30,809.70
	4:30	7.58	15.14	8.16	167.80	367.80	122.20	0.47		11.75	705.00	31,514.70
	5:30	7.59	15.72	8.19	167.90	367.90	122.10	0.45		11.74	704.90	32,219.60
	6:30	7.57	14.90	8.21	171.30	371.30	122.30	0.43		11.73	702.70	32,922.30
	7:30	7.56	14.89	8.74	168.10	368.10	122.20	0.48		11.74	704.10	33,626.40
	8:30	7.59	14.81	8.49	160.40	360.40	122.00	0.52		11.75	705.00	34,331.40
	9:30	7.59	15.32	8.59	153.30	353.30	122.20	0.46		11.76	705.60	35,037.00
	10:30	7.57	15.12	8.81	154.30	354.30	122.30	0.58		11.78	706.60	35,743.60

Table B-2.3-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Pump Intake Depth (ft bgs)	Pumping Rate at Time of Field Parameter	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	11:30	7.58	15.39	8.91	138.50	338.50	122.00	0.51		11.79	707.60	36,451.20
	12:30	7.57	15.50	8.72	130.10	330.10	122.10	0.52		11.81	708.20	37,159.40
	13:30	7.56	15.17	9.10	139.00	339.00	122.00	1.04		11.79	707.80	37,867.20
	14:30	7.56	15.05	9.16	155.60	355.60	121.90	0.91		11.79	707.80	38,575.00
	15:30	7.57	14.91	9.01	161.50	361.50	121.80	0.78		11.80	707.80	39,282.80
	16:30	7.57	14.95	9.00	171.50	371.50	121.90	1.51		11.77	706.70	39,989.50
	17:30	7.57	14.85	9.02	185.50	385.50	121.80	0.61		11.77	706.00	40,695.50
	18:30	7.59	14.95	8.62	192.90	392.90	121.90	0.96		11.83	708.10	41,403.60
	19:30	7.57	14.78	8.90	199.30	399.30	123.10	0.43		11.77	705.60	42,109.20
	20:30	7.57	14.78	8.78	197.70	397.70	122.10	0.70		11.78	706.00	42,815.20
	21:30	7.57	14.62	8.62	194.90	394.90	122.00	0.51		11.76	706.90	43,522.10
	22:30	7.58	14.92	8.48	193.40	393.40	122.10	0.47		11.78	707.00	44,229.10
	23:30	7.56	14.72	8.61	195.00	395.00	122.00	0.73		11.75	704.90	44,934.00
11/19/2018	0:30	7.56	14.64	8.43	195.80	395.80	121.90	0.63		11.73	703.50	45,637.50
	1:30	7.57	14.69	8.49	195.50	395.50	121.70	0.55		11.71	702.90	46,340.40
	2:30	7.57	14.62	8.47	196.50	396.50	121.10	0.42		11.73	703.50	47,043.90
	3:30	7.57	14.57	8.69	198.20	398.20	122.00	0.69		11.70	702.30	47,746.20
	4:30	7.56	14.53	8.51	199.20	399.20	121.80	0.48		11.71	702.30	48,448.50
	5:30	7.57	14.52	8.36	200.00	400.00	121.90	0.48		11.70	702.20	49,150.70
	6:30	7.55	14.45	8.28	200.30	400.30	121.90	0.44		11.72	701.10	49,851.80
	6:53	7.57	14.54	9.14	202.00	402.00	121.90	0.44		12.54	351.20	50,203.00
	7:30	7.57	14.97	8.86	198.10	398.10	121.80	0.76		11.71	341.20	50,544.20
	7:58	7.58	14.88	8.93	193.10	393.10	122.00	1.78		12.89	360.80	50,905.00

* NR = Not recorded.

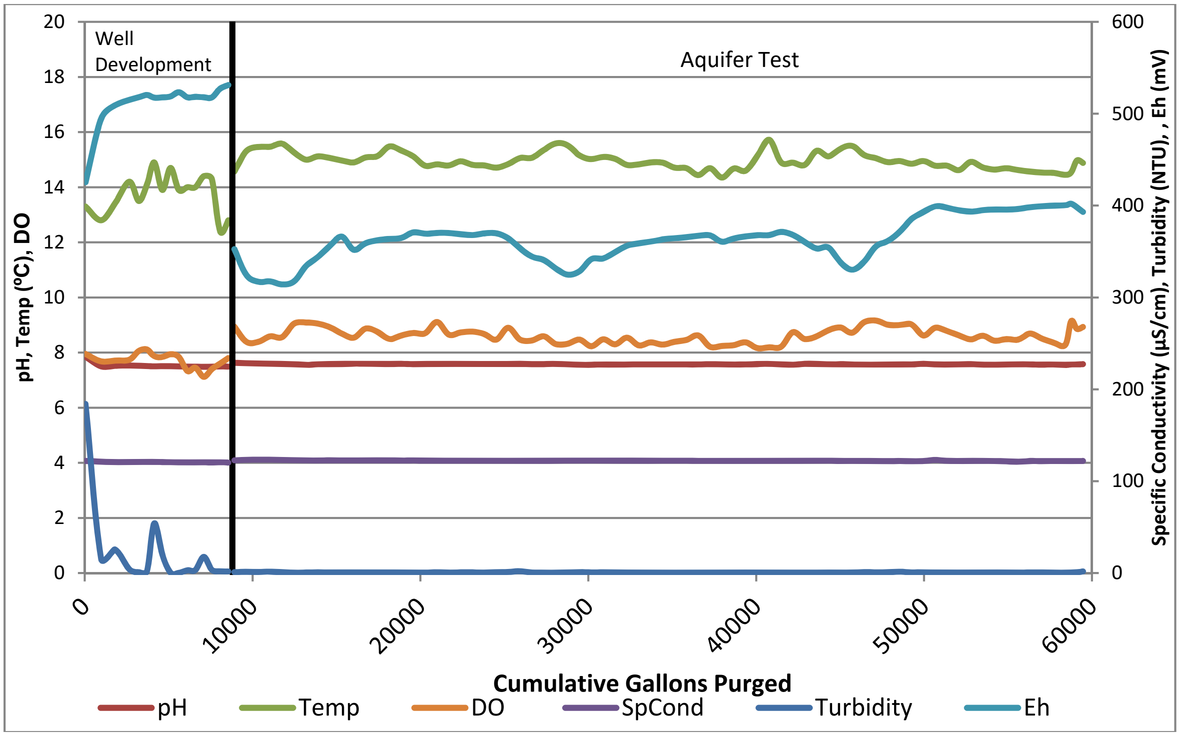


Figure B-2.3-1 Screen 1 field parameters versus volume purged during R-69 well development and aquifer testing

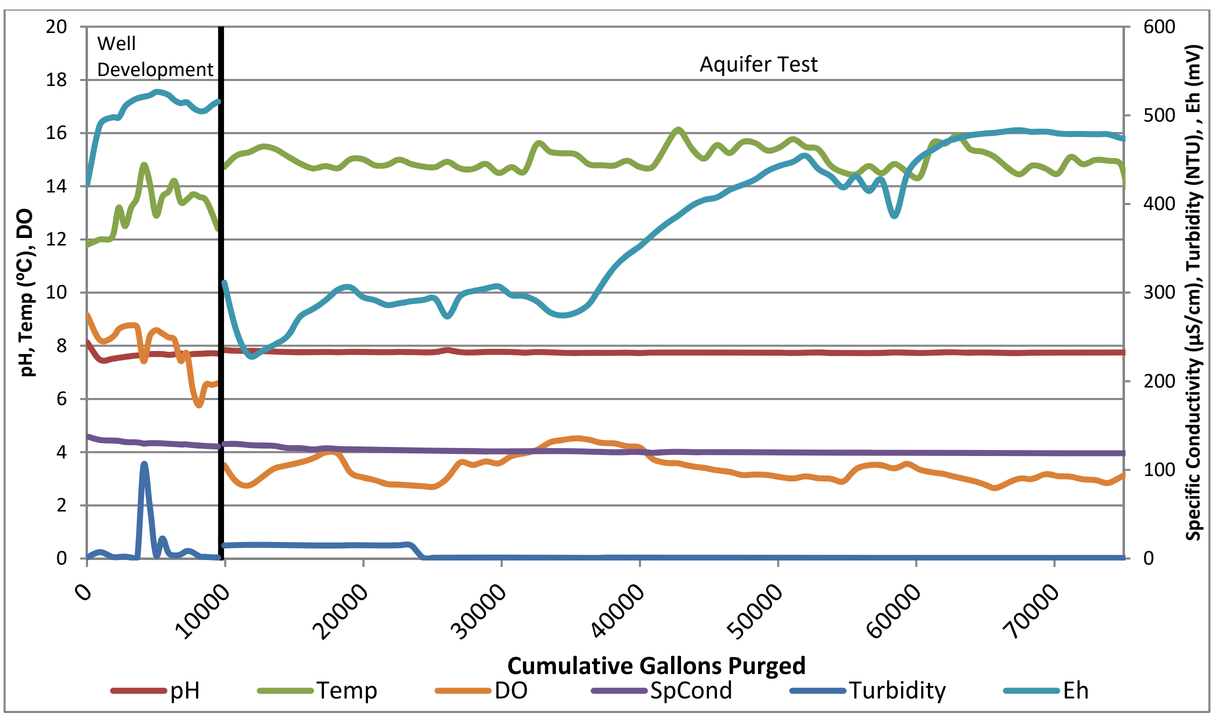


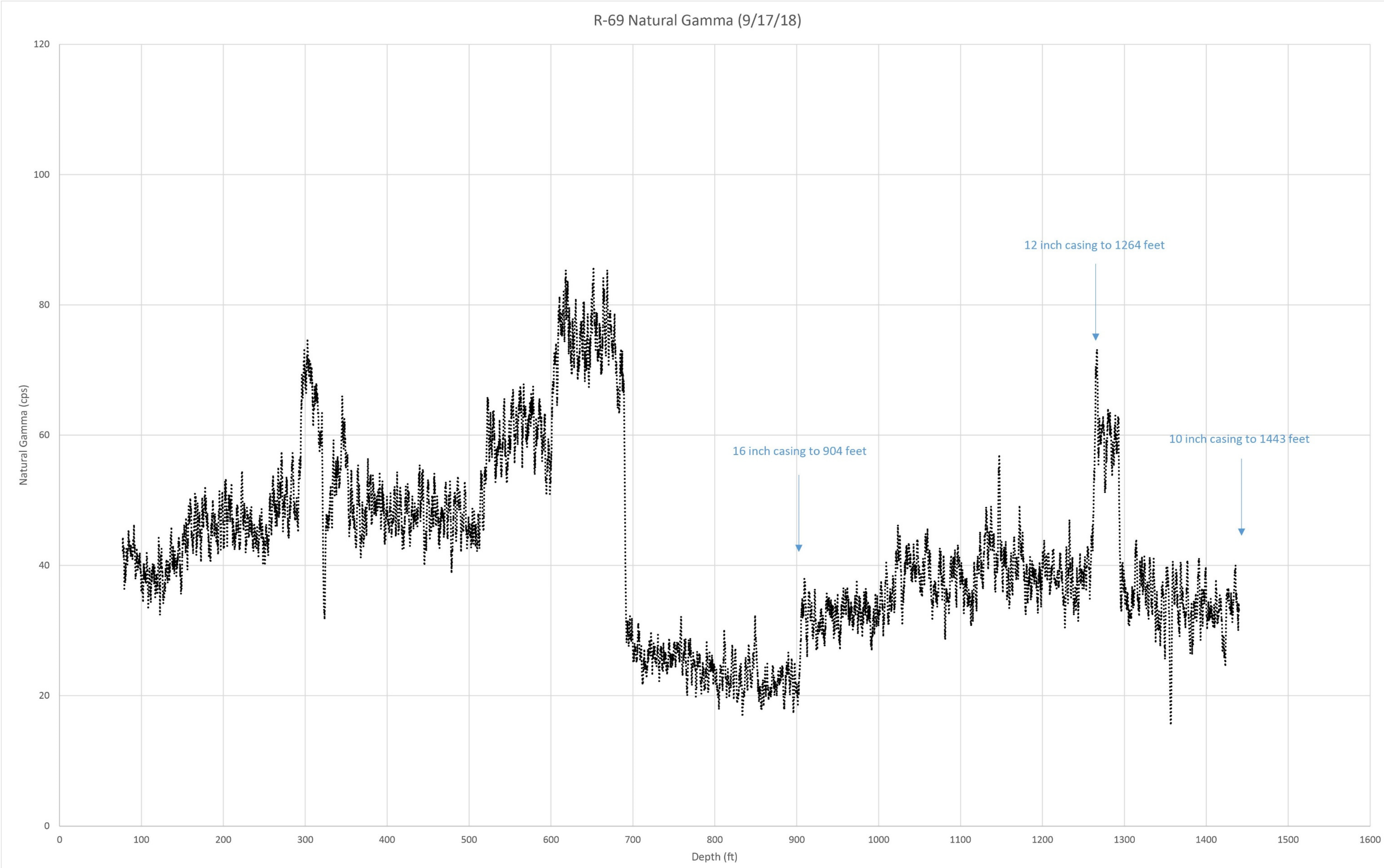
Figure B-2.3-2 Screen 2 field parameters versus volume purged during R-69 well development and aquifer testing

Appendix C

Borehole Video Log
(on DVD included with this document)

Appendix D

Geophysical Log



R-69 Natural Gamma (9/17/18)
Natural Gamma (cps)
Depth (ft)
0
20
40
60
80
100
120
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
16 inch casing to 904 feet
12 inch casing to 1264 feet
10 inch casing to 1443 feet

Appendix E

Final Well Design and
New Mexico Environment Department Approval

From: Andersen, Dane, NMENV <Dane.Andersen@state.nm.us>
Sent: Wednesday, September 19, 2018 4:19 PM
To: Mark C. Everett <mark.everett@em-la.doe.gov>; Dale, Michael, NMENV <Michael.Dale@state.nm.us>; Murphy, Robert, NMENV <Robert.Murphy@state.nm.us>; dylan.boyle2@state.nm.us
Cc: cheryl.rodriguez@em.doe.gov; Hai Shen <hai.shen@em.doe.gov>; Mccrory, Thomas (CONTR) <thomas.mccrory@em.doe.gov>; Bruce A. Robinson <bruce.robinson@em-la.doe.gov>; Joseph A. Legare <joseph.legare@em-la.doe.gov>; Emily M. Day <Emily.Day@em-la.doe.gov>; John McCord <John.McCord@em-la.doe.gov>; Ralph Rupp <Ralph.Rupp@em-la.doe.gov>; Rees Boler <rees.boler@em-la.doe.gov>; Loren R. Sorensen <Loren.Sorensen@EM-LA.DOE.GOV>; Dhawan, Neelam, NMENV <neelam.dhawan@state.nm.us>; Longmire, Patrick, NMENV <Patrick.Longmire@state.nm.us>; Patrick McGuire <Patrick.McGuire@EM-LA.DOE.GOV>
Subject: RE: R-69 proposed well design

Mark,

New Mexico Environment Department (NMED) has reviewed the proposed well design plan (Plan) for monitoring well R-69, and hereby issues this approval. The Plan was received today, September 19, 2017 at 1:03 pm. Note that this approval is based on the information available to NMED at time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned email, and any additional information relevant to the installation of the well as soon as such data or information become available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, the step-drawdown test, and constant-rate aquifer testing at R-69. Please be aware that NMED will need escorts to visit the site during these activities. Please call if you have any questions concerning this approval.

Thank you,

Dane Andersen
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East Building 1
Santa Fe, NM 87505
Phone: (505) 476-6056
Fax: (505) 476-6030

From: Mark C. Everett <mark.everett@em-la.doe.gov>
Sent: Wednesday, September 19, 2018 1:03 PM
To: Dale, Michael, NMENV <Michael.Dale@state.nm.us>; Andersen, Dane, NMENV <Dane.Andersen@state.nm.us>; Murphy, Robert, NMENV <Robert.Murphy@state.nm.us>; Boyle, Dylan, NMENV <Dylan.Boyle2@state.nm.us>
Cc: cheryl.rodriguez@em.doe.gov; Hai Shen <hai.shen@em.doe.gov>; Mccrory, Thomas (CONTR) <thomas.mccrory@em.doe.gov>; Bruce A. Robinson <bruce.robinson@em-la.doe.gov>; Joseph A. Legare

<joseph.legare@em-la.doe.gov>; Emily M. Day <Emily.Day@em-la.doe.gov>; John McCord <John.McCord@em-la.doe.gov>; Ralph Rupp <Ralph.Rupp@em-la.doe.gov>; Rees Boler <rees.boler@em-la.doe.gov>; Loren R. Sorensen <Loren.Sorensen@EM-LA.DOE.GOV>
Subject: R-69 proposed well design

NMED Staff,

Attached, you will find the DOE/N3B proposed design, with narrative, for monitoring well R-69. If the Department agrees with the proposed design, please respond to this email with your concurrence. If you would like to discuss further, I can be reached at this email address or phone number below.

Sincerely,

Mark Everett, PG
Drilling/Well Maintenance Program Manager
N3B-Los Alamos Water Program
505.309.1367 (cell.)
www.N3B-LA.com/

TOTAL LENGTH
OF CASING AND SCREEN (FT) ___

DEPTH TO WATER
FOLLOWING INSTALLATION (FT BGS) ___

DIAMETER OF BOREHOLE
18.00 (IN) FROM 0 TO 17 (FT BGS)
17.00 (IN) FROM 17 TO 683 (FT BGS)
16.00 (IN) FROM 683 TO 900 (FT BGS)
12.75 (IN) FROM 900 TO 1265 (FT BGS)
10.75 (IN) FROM 1265 TO 1443 (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 TO 100 (FT BGS)

HYDRATED BENTONITE CHIP SEAL 100 TO 1303 (FT BGS)
HYDRATED BENTONITE CHIP SEAL ___ TO ___ (FT BGS)

FINE SAND COLLAR 1303 TO 1305 (FT BGS)
FINE SAND COLLAR ___ TO ___ (FT BGS)
FILTER PACK 1305 TO 1335 (FT BGS)
FILTER PACK ___ TO ___ (FT BGS)
SCREENED INTERVAL 1310 TO 1330 (FT BGS)
SCREENED INTERVAL ___ TO ___ (FT BGS)

BENTONITE SEAL 1335 TO 1368 (FT BGS)
BENTONITE SEAL ___ TO ___ (FT BGS)

FINE SAND COLLAR 1368 TO 1370 (FT BGS)
FINE SAND COLLAR ___ TO ___ (FT BGS)
FILTER PACK 1370 TO 1400 (FT BGS)
FILTER PACK ___ TO ___ (FT BGS)
SCREENED INTERVAL 1375 TO 1395 (FT BGS)
SCREENED INTERVAL ___ TO ___ (FT BGS)

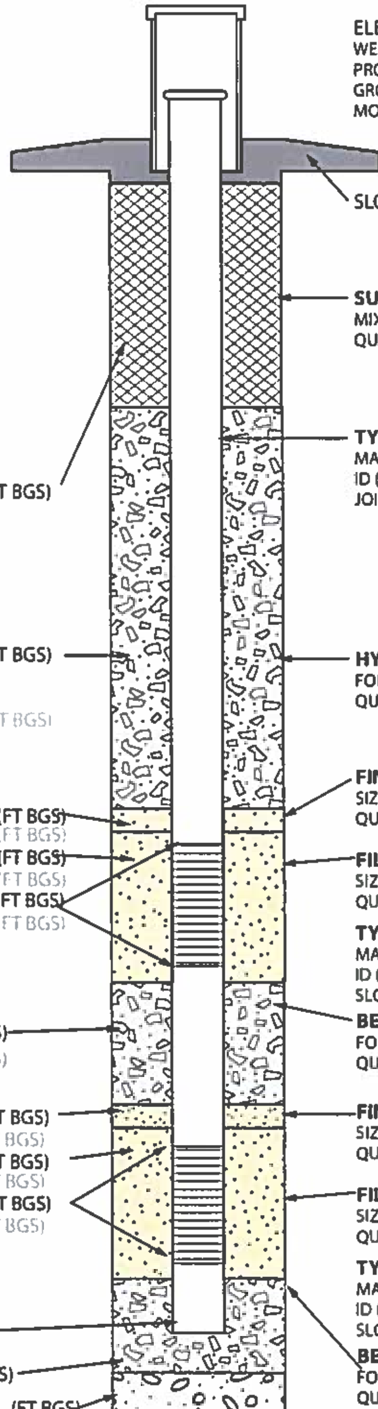
BOTTOM OF CASING 1405 (FT BGS)

BENTONITE SEAL 1400 TO 1443 (FT BGS)

SLOUGH ___ TO 1443 (FT BGS)

BOTTOM OF BORING 1443.38 (FT BGS)

LOCKING COVER



ELEVATIONS (FT AMSL)
WELL CAP TBD
PROTECTIVE CASING TBD
GROUND SURFACE TBD
MONUMENT MARKER TBD

SLOPED CONCRETE PAD/SURFACE

SURFACE SEAL
MIX (WT%) CEMENT ___ BENTONITE ___
QUANTITY USED ___ CALCULATED ___

TYPE OF CASING
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.56 (5⁹⁄₁₆)
JOINT TYPE Beveled

HYDRATED BENTONITE SEAL
FORM CHIP
QUANTITY USED ___ CALCULATED ___

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED ___ CALCULATED ___

FILTER PACK SAND
SIZE/TYPE 10/20 SILICA
QUANTITY USED ___ CALCULATED ___

TYPE OF SCREEN
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.88 (5⅞)
SLOT SIZE (IN) 0.040 JOINT TYPE Beveled

BENTONITE SEAL
FORM CHIP
QUANTITY USED ___ CALCULATED ___

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED ___ CALCULATED ___

FILTER PACK SAND
SIZE/TYPE 10/20 SILICA
QUANTITY USED ___ CALCULATED ___

TYPE OF SCREEN
MATERIAL STAINLESS-STEEL
ID (IN) 5.00 OD (IN) 5.88 (5⅞)
SLOT SIZE (IN) 0.040 JOINT TYPE Beveled

BENTONITE SEAL
FORM CHIP
QUANTITY USED ___ CALCULATED ___

STAINLESS-STEEL CENTRALIZERS
USED 4 AT 2.0 ft ABOVE AND BELOW EACH WELL SCREEN

WELL COMPLETION BEGAN
DATE ___ TIME ___
WELL COMPLETION FINISHED
DATE ___ TIME ___

PROPOSED WELL COMPLETION DEPTHS IN BLACK, ACTUAL DEPTHS IN GRAY

TerranearPMC

Drafted By: TPMC
Project Number: 73001

Date: September 17, 2018
File Name: R-69_ProposedWellDesign_Rev0

Proposed Well Design Characterization Well R-69
Technical Area 14 (TA-14)
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure
R-69
Proposed
NOT TO SCALE

Mark Everett	Mark Everett	Program Manager	N3B	9/20/18
Printed Name	Signature	Title	Organization	Date

R-69 Well Design Plan

Objectives

Regional monitoring well R-69 is located approximately 1100 ft north of Cañon de Valle in TA-14 on a mesa top just north of R-Site Road (Fig. 1). The well site is approximately 644 ft southwest of R-18 and about 1101 ft northeast of monitoring well R-68. With a total depth of 1443 feet and a static water level at 1295.5 feet below bgs, the well will be completed with two screens in the regional aquifer. R-69 is primarily intended to determine the relation of RDX at R-68 and R-18 and understand the northern extent of perched-intermediate groundwater and whether the perched zone is hydrologically connected to the regional aquifer north of R-68. No perched zone was encountered during drilling at R-69. The completed well will provide information about vertical and horizontal hydraulic gradients in the distal portion of the RDX plume and constrain groundwater pathways that result in the RDX contamination in the deep well screen at R-18. Hydrologic data collected at well R-69 will be used to calibrate groundwater models. The two well screens in R-69 provides the ability to monitor RDX concentrations at two discrete depth intervals in the regional aquifer.

Recommended Well Design

The R-69 well was drilled to a depth of 1443 ft bgs and it intersected the regional water level at 1294.4 ft bgs. The well is being developed as a two-screen monitoring interval (Fig. 2). The upper well screen, extending from 1310 ft to 1330 ft bgs consists of a 20-ft stainless-steel, 40 slot, rod-based wire-wrapped interval, whereas the lower screen, extending from 1375 ft to 1395 ft bgs, will be constructed as a 20-ft stainless-steel, 40 slot, rod-based wire-wrapped zone. In the upper well screen interval, a 2 ft, 20/40 sand transition (1303-1305 ft) will be placed above the primary filter pack (1305–1335 ft) of 10/20 sand that encloses the well screen (Fig. 2). In the lower well screen interval, a 2 ft, 20/40 sand transition (1368–1370 ft) will be placed above the primary filter pack of 10/20 sand (1370–1400 ft) that encloses the well screen. The upper and lower screens are submerged 15.6 ft and 80.6 ft below the regional water level, respectively. The filter packs of the two well screens are separated by about 33 ft of bentonite. The proposed well design is shown in Figure 2.

Well Design Considerations

Preliminary lithological logs indicate that the geologic units intersected in the R-69 borehole consist of the Bandelier Tuff, including the Tshirege Member (5-330 ft), Cerro Toledo interval (330-385 ft), Otowi Member (385–670 ft), Guaje Pumice Bed (670-695 ft), and the Puye Formation (695 to TD). The top of regional saturation is within the Puye Formation. Perched groundwater was considered a possibility at R-69 because of its presence at well R-68, but saturated conditions were not encountered while drilling through the vadose zone.

The Puye Formation at R-69 is a typical proximal alluvial fan deposit dominated by boulder and cobble beds and gravelly sand made up of dacitic lava clasts of the Tschicoma Formation. Similar lithological units were encountered in nearby wells R-68 and R-18. Silt- and clay-rich beds are generally absent within the 750-ft-thick Puye interval. Minor silt and clay occurs in the matrix of some coarse conglomeratic deposits and thin silt/clay layers are present between some of the thick conglomerate beds.

The upper R-69 well screen is designed to monitor contamination in the upper part of the regional aquifer downgradient of the water-table screen at well R-68. The deep screen at well R-69 is designed to intersect the groundwater pathways that carry RDX-contaminated groundwater to the well screen at R-18, potentially closer to the point where RDX enters the regional aquifer. The deep screen overlaps the elevation of the well screen at R-18 in order to capture flow paths that follow the ambient hydraulic gradient defined by the northeast dipping regional water table and to capture potential horizontal flow along strata with favorable transmissivities.

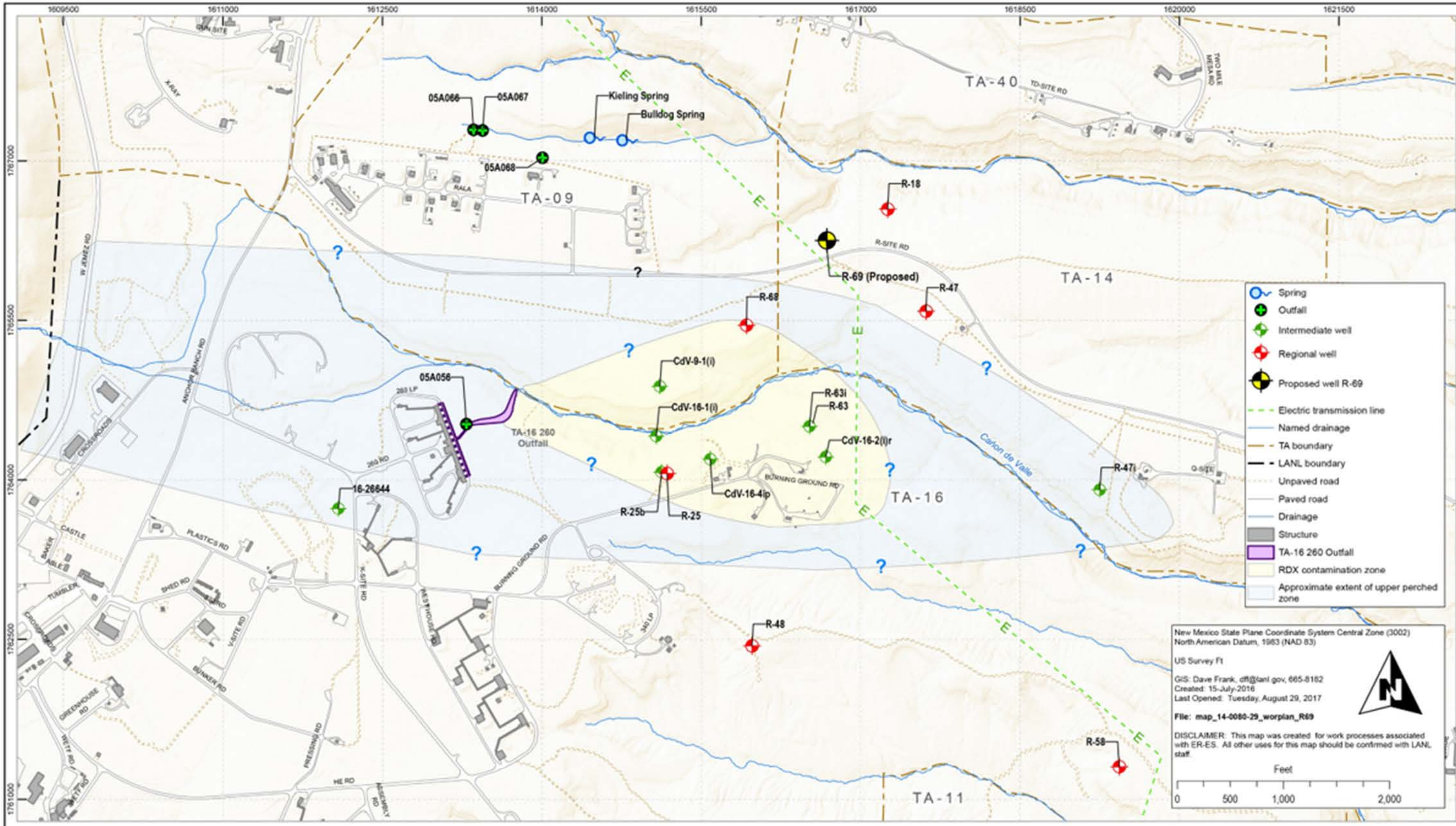


Figure 1 Location map of the R-69 well at TA-16. Other regional wells, including R-18 and R-68 are plotted for reference

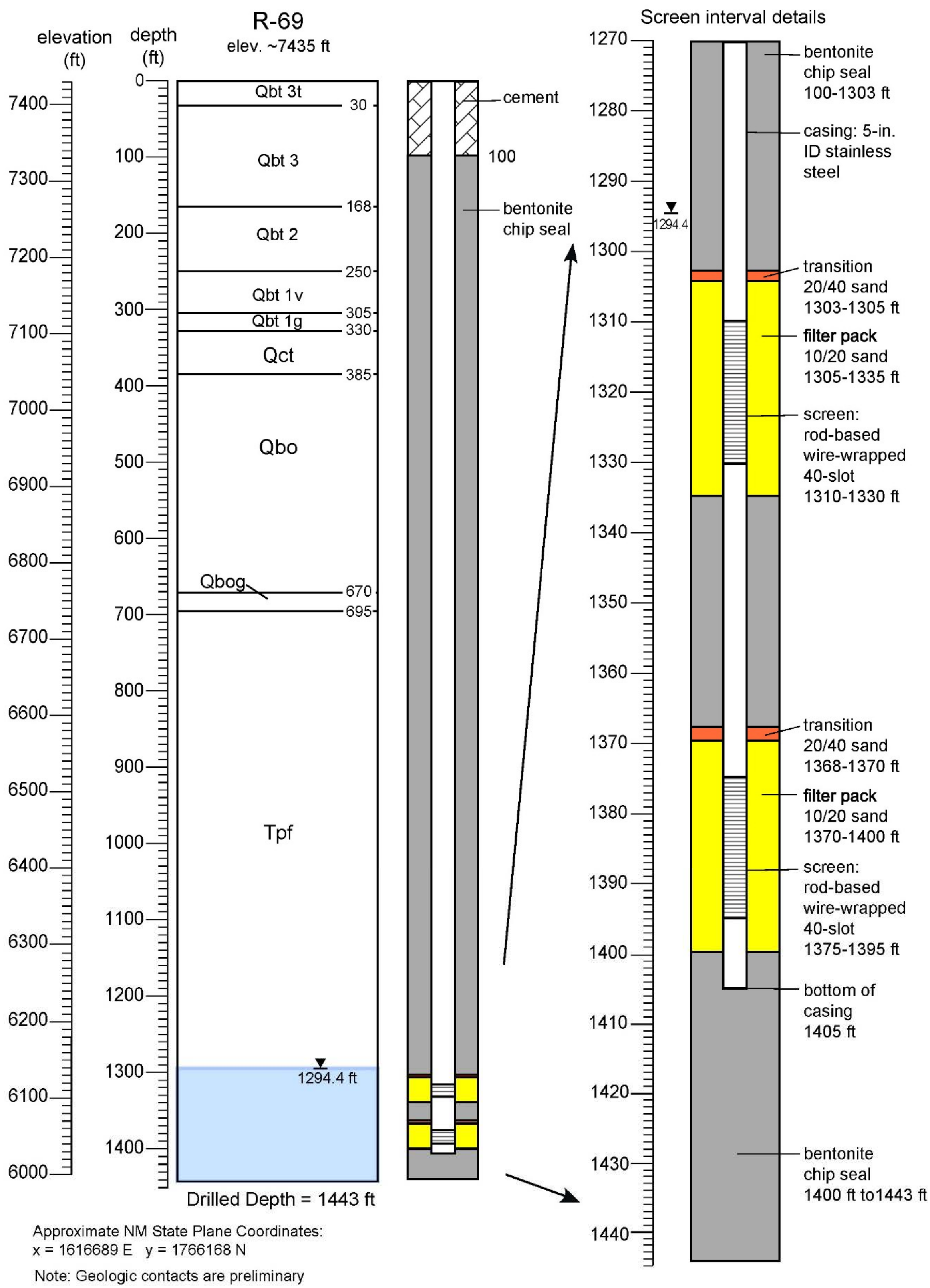


Figure 2 Preliminary lithological types, stratigraphic contacts, and proposed well design for well R-69

Appendix F

Aquifer Testing Report for Well R-69

F-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted in November 2018 at well R-69, a dual-screened regional aquifer well located at Technical Area 14 (TA-14) at Los Alamos National Laboratory (LANL or the Laboratory). The tests on R-69 were conducted to characterize the saturated materials, quantify the hydraulic properties of the screened intervals, and evaluate the hydraulic connection between R-69 and other R-wells in the vicinity, including R-18, R-47, R-63, and R-68. Testing consisted of brief trial pumping, background water-level data collection, and a 72-hr constant-rate pumping test on each of the two screen zones. Data collected during the aquifer test are provided as Attachment F-1, on CD included with this document.

As in most of the R-well pumping tests conducted on the Pajarito Plateau, an inflatable packer system was installed in R-69. A double packer system was used to isolate each pumped zone and to eliminate casing storage effects on the test data so that early drawdown and recovery data could be used in the analysis. This setup was only partially effective at eliminating storage effects. During the first round of pumping, when screen 2 was tested, the packer system leaked nitrogen into the pumped zone, an unfortunate occurrence because the equipment had worked perfectly during development pumping a few days earlier. The nitrogen leak was slow at first but increased later.

It was likely that nitrogen gas leaking into the pumped zone became trapped in the blank casing above the well screen, beneath the upper packer. Gas trapped between the packers expands and contracts in response to pressure changes associated with pumping and recovery. This change in gas volume creates a storage-like effect analogous to that observed when testing is performed without isolation packers.

Following screen 2 testing, the pump and packer system were retrieved and the leaky packer was replaced to prepare for the second round of test pumping (on screen 1). When the equipment was reinstalled, a supplemental test was conducted on screen 2, before testing screen 1, in an attempt to obtain a screen 2 data set free from storage effects.

In addition to the nitrogen gas that was leaked into the well during the initial round of testing, both screen zones produced gas/air continuously during test pumping. This phenomenon has been observed in many of the R-wells across the Plateau. It is possible that some of the compressed air used in the well drilling process had been forced into the aquifer, becoming trapped in the aquifer pores and partially dissolving in the groundwater. Subsequent pumping/drawdown pulled some of the trapped air into the well and allowed the release of some of the dissolved gas, creating an aerated production stream.

Pumping aerated water can affect a pumping test in several ways. First, moving air through the pump can cause cavitation and reduced pump efficiency, resulting in lower yield than expected based on the published pump performance curve. Indeed, in testing R-69, it appeared that the pump operated “off the curve,” producing slightly less flow than indicated by the factory pump curve.

Second, fluctuating quantities of gas entering the pump over time can result in variable yield. There were variations in discharge rates in the R-69 tests not otherwise explainable.

Third, pump cavitation can create shock waves as the gas bubbles expand and collapse violently when being drawn into and moving through the pump. The resulting shock impulses can affect the output of the pressure transducers and cause scatter in the recorded pressure readings from the test.

Finally, some of the gas/air entering the well with the pumped water can accumulate beneath the upper packer in the blank casing above the well screen. When this happens, the storage-like effect from the trapped gas can negate the value of the early pumping and recovery data.

F-1.1 Conceptual Hydrogeology

Well R-69 is completed within Puye deposits. Screen 1 is 20.2 ft long, extending from 1310 to 1330.2 ft below ground surface (bgs). Screen 2 is 20.3 ft long, set between the depths of 1375.5 and 1395.8 ft bgs. The composite static water level measured on November 6, 2018, before testing, was 1293.32 ft bgs. The brass cap elevation (essentially ground surface) at R-69 is 7430.13 ft above mean sea level (amsl), making the composite groundwater elevation 6136.81 ft amsl.

When the pumping system was installed on November 6 and the packers were inflated, the water level in screen 1 rose 0.9 ft and the level in screen 2 declined 4.6 ft, showing a downward gradient head difference of 5.5 ft between the screened intervals.

Contradicting this result, when the packer system was deflated on November 13 at the conclusion of the 72-hr test on screen 2, the water level in screen 1 declined 2.3 ft while that in screen 2 rose 7.5 ft, showing a downward gradient head difference of 9.8 ft. The increase in head differential may have been partly due to the extensive pumping that had occurred in screen 2.

Finally, when the replacement packer system was deflated on November 20 at the conclusion of testing, the water level in screen 1 declined 1.8 ft while that in screen 2 rose 6.6 ft, implying a downward gradient head difference of 8.4 ft, a little less than that observed on November 13. The reduction in head difference from 9.8 to 8.4 ft may be explained by the extensive pumping that had occurred in screen 1 along with continued recovery in screen 2 between November 13 and 20. Using this last response and the composite water-level elevation measured on November 6, estimated static water levels for screens 1 and 2 were 6138.6 and 6130.2 ft amsl, respectively.

It is possible that the original set of head data was erroneous because of the effects of the leaky packer pushing nitrogen into the screen zone. There was evidence from the pumping tests (described below) that the measured head in screen 2 when the packers were first inflated might have been a false high. The dynamic effect of injecting nitrogen gas into the screen zone could result in a pressure somewhat above the true static pressure at screen 2.

The water-level elevations cited above should be considered only approximate because they combine a November 6 water-level tag with head differences observed on November 20. Further, the November 6 measurement came shortly after substantial development pumping, while the November 20 observations followed extensive test pumping. Installation of the permanent sampling system will provide an opportunity to obtain more accurate head data. The well will have had a chance to reach equilibrium conditions, far removed from the antecedent development pumping and test pumping, and the permanent packer should be leak free and not affect levels via leaking nitrogen.

F-1.2 R-69 Testing

Well R-69 was tested from November 6 to 20, 2018. The screen zones were tested in reverse order, with testing of screen 2 from November 6 to 13 followed by screen 1 from November 15 to 20. Testing screen 2 first provided an opportunity to obtain enough preliminary hydraulic yield data to allow selecting a suitable discharge rate for the subsequent screen 1 pumping tests. It was important to make sure that screen 1 was not dewatered during testing in order to avoid air entrainment in the filter pack adjacent to the well screen, and outside the blank pipe above the screen, which could have caused storage-like effects.

This data-gathering effort was accomplished by pumping briefly from both zones simultaneously (packers deflated) before testing screen 2. By comparing the combined yield performance with that of screen 2 producing by itself, it was possible to estimate the expected yield from screen 1 and tailor the discharge rates for the screen 1 tests accordingly.

F-1.2.1 R-69 Screen 2 Testing

Screen 2 was tested from November 6 to 13 initially. Testing consisted of filling the drop pipe, conducting two trial tests, collecting background water-level data, and performing a 72-hr constant-rate test. Because of the nitrogen gas leak that occurred during these tests, a third trial test was performed later, on November 15, when the pumping system was rerun into the well for the screen 1 tests. (The third trial test also afforded the opportunity to resample the screen 2 zone to update the dissolved oxygen measurements, which had been affected by the presence of nitrogen gas during the initial tests.)

When the pump was first installed, it was set with the intake 1 ft above the top of screen 1 to ensure that screen 1 would not be dewatered during startup. When pumping begins with an empty drop pipe, the initial discharge rate is elevated because the pump is operating against little backpressure (pumping lift). If the intake had been set below the top of screen 1, there was a risk that the pumping water level would have been pulled into the screen during the filling of the drop pipe.

Once the drop pipe was filled so that the discharge rate could be constrained, it was safe to set the pump intake deeper. After filling the drop pipe, the pump was lowered to screen 2 and the packers were inflated.

Trial testing of R-69 screen 2 (trial 1) began at 8:00 a.m. on November 7 at a discharge rate of 15.8 gallons per minute (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 15.2 gpm. Following shutdown, recovery/background data were recorded for 2760 min until the start of the 72-hr pumping test.

Once background data collection was complete, the 72-hr pumping test began at 8:00 a.m. on November 9, at a discharge rate of 15.2 gpm. Pumping continued for 4320 min until 8:00 a.m. on November 12. Following shutdown, recovery data were recorded for 1440 min until 8:00 a.m. on November 13 when the packers were deflated. The pump was pulled, the transducer data were retrieved, and the defective packer was replaced to prepare for the screen 1 tests.

When the pump and packers were reinstalled on November 15, the drop pipe was filled again with the pump intake set just above screen 1. Then the pump was lowered to screen 2 temporarily and a third trial test was conducted beginning at 2:00 p.m. and continuing for 90 min. The discharge rate was 15.9 gpm initially but after 40 min it was reduced to 11.6 gpm and maintained there for the balance of trial 3. This was determined to be the approximate safe discharge rate for the screen 1 tests and it was necessary to get the flow control valve in the discharge line set to the proper position in preparation for those tests. Following trial 3, recovery data were recorded for 30 min until 4:00 p.m. Then, the packers were deflated and the pumping system was raised to screen 1 for testing there.

F-1.2.2 R-69 Screen 1 Testing

Trial testing of R-69 screen 1 (trial 1) began at 5:00 p.m. on November 15 at a discharge rate of 11.7 gpm and continued for 60 min. Following shutdown, recovery/background data were recorded for 840 min until the start of the 72-hr pumping test.

The 72-hr pumping test began at 8:00 a.m. on November 16, at a discharge rate of 11.8 gpm. Pumping continued for 4320 min until 8:00 a.m. on November 19. Following shutdown, recovery data were recorded for 1440 min until 8:00 a.m. on November 20 when the packers were deflated and the pump was pulled.

F-2.0 BACKGROUND DATA

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

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

Previous pumping tests on the Plateau have demonstrated a barometric efficiency of between 90% and 100% for most wells. 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 at R-69, have used non-vented transducers, devices that record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated "apparent" hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, when a non-vented transducer is used, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decline). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency, and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from the TA-54 tower site from LANL's Environmental Protection and Compliance Programs (formerly the Waste and Environmental Services Division–Environmental Data and Analysis). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is at 7430.13 ft amsl. The composite static water level in R-69 was 1293.32 ft bgs, making the water-table elevation 6136.81 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-69.

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

$$P_{WT} = P_{TA54}\left[-\frac{g}{3.281R}\left(\frac{E_{R-69}-E_{TA54}}{T_{TA54}}+\frac{E_{Wt}-E_{R-69}}{T_{WELL}}\right)\right] \qquad \textbf{Equation F-1}$$

where, P_{WT} = barometric pressure at the water table inside R-69

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

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

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

E_{R-69} = elevation at R-69 site, in feet (7430.13 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-69, in feet (6136.81 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 33.4 degrees Fahrenheit, or 274.0 degrees Kelvin)

T_{WELL} = air column temperature inside R-69, in degrees Kelvin (assigned a value of 54.8 degrees Fahrenheit, or 285.8 degrees Kelvin)

This formula is an adaptation of an equation Environmental Protection and Compliance Programs 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 to determine whether water-level corrections were 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 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 column pipe, in inches

Q = discharge rate, in gallons per minute

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

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

For wells screened across the water table or wells in which the filter pack can drain during pumping, an additional storage contribution from the filter pack may occur. 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 the left-hand term within the brackets is directly proportional to the annular area [and volume] between the casing and drop pipe, while the right-hand term is proportional to the area [and volume] between the borehole and the casing, corrected for the drainable porosity of the filter pack. Thus, the summed term within the brackets accounts for all of the volume [casing water and drained filter pack water] appropriately.)

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before the test is conducted. This has been the standard approach used in the testing the R-wells.

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. These match-point values are used to compute transmissivity and the storage coefficient 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 (Cooper and Jacob 1946, 098236), a simplification of the Theis equation that is mathematically equivalent to the Theis equation for most pumped well data. The Cooper-Jacob equation describes drawdown around a pumping well as follows:

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

Equation 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

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

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

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

$$T = \frac{264Q}{\Delta s}$$ **Equation 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.

When the earliest recovery data violate the u value assumption inherent in the semilog method, the data can be analyzed using a log-log plot and Theis curve matching.

Recovery data also can be analyzed using the Hantush equation for partial penetration. This approach is generally applied to the early portion of the data set in a plot of recovery versus recovery time. In general, the semilog method for recovery versus time since pumping stopped is not valid for late recovery times.

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 Rothschild (1985, 098234).

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

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

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

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right)$$ **Equation 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-69, the pumping data suggested confined response initially and leaky confined later on. 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-69, b was assigned a value of 150 ft, the approximate saturated thickness of Puye Formation penetrated by the borehole before the well was backfilled and well completed. 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-69 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-69 screen 1 during the test period along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-69 data measurements reflect the sum of the water pressure and barometric pressure that was recorded using a non-vented pressure transducer. The times of the pumping test periods for the R-69 pumping tests are included in the figure for reference.

The figure title incorporates the term “adjusted hydrograph.” This is because the water-level data were collected over two test periods involving separate pump installations for the screen 1 and screen 2 tests. The relative positions of the transducers on the piping string changed from one installation to another and the pipe and pump string length changed somewhat because of the packer replacement that occurred between tests. This resulted in an offset from one hydrograph to the next. Therefore, it was necessary to adjust one of the hydrographs to put it in the correct position relative to the other.

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 the changes in water level were equal to and opposite of changes in barometric pressure. For example, during the background monitoring period from November 7 to 9, the hydrograph showed a steady, gradual rise in aquifer pressure, unaffected by the rapid barometric pressure increase (downward spike on the graph) that occurred during that time.

In addition to the background trend of a gradual water-level rise, the data showed a clear response in screen 1 to pumping screen 2 with a drawdown greater than half a foot.

Figure F-7.0-2 shows an expanded view of the background data from screen 1 for the period from November 7 to 10. A rolling average of the data was used to reduce the amount of scatter. The average water-level rise rate determined from the graph was 0.039 ft/day. This trend was removed from all screen 1 data before analysis. Also, it was possible to discern a slight diurnal wave superimposed on the hydrograph, having an amplitude of just a couple hundredths of a foot – presumably a result of Earth tides.

Although the observed background water level trend of 0.039 ft/day was used in the pumping test drawdown corrections when the data were analyzed, it is possible that it could have changed over time. For example, the observed trend might have been ongoing recovery from the antecedent development pumping on R-69, in which case the rate of groundwater rise would have been expected to diminish slightly over time. Nevertheless, applying the correction was judged to produce more accurate results than omitting it.

Figure F-7.0-3 shows the adjusted hydrograph data from R-69 screen 2. As with screen 1, there was little correlation between the adjusted hydrograph and barometric pressure curve, suggesting a high barometric efficiency. Also, during the background monitoring period from November 7 to 9, there was a steady, gradual rise in the observed water level. Finally, the data recorded during the screen 1 pumping test showed a clear response in screen 2 with a drawdown greater than half a foot.

The most unusual response seen in the hydrograph was the 15-hr-long decline in aquifer pressure that occurred from November 12 to 13, during the screen 2 recovery following the 72-hr pumping test. There was no apparent explanation for this response. It is possible that it could have resulted from the significant nitrogen content in the water associated with the packer leak, although the mechanism involved is not clear. Other R-well tests on the Plateau that have involved large quantities of gas in the pumped water have shown inexplicable water level fluctuations, including such things as feet, or even tens of feet, of “super recovery” in which post-pumping water levels soared above the original static levels. Presumably the presence of gas can contribute to chaotic pressure response as gas bubbles expand and contract and as gas goes into and out of solution. Although not readily explainable, it is clear from other pumping tests on the Plateau that unusual water-level responses can occur when pumping aerated water.

Figure F-7.0-4 shows an expanded view of the background data from screen 2 for the period from November 7 to 10. A rolling average of the data was used to reduce the amount of scatter. The average water-level rise rate determined from the graph was 0.17 ft/day. This trend was removed from all screen 2 data before analysis. The diurnal sinusoidal fluctuations superimposed on the rising water-level trend and having an amplitude of just a few hundredths of a foot were likely attributable to Earth tides.

Water-level data were downloaded from the four nearest R-wells to R-69: R-18, R-47, R-63 and R-68 located at distances of 649, 1170, 1701 and 1195 ft, respectively. Data from these wells were examined to check for responses to pumping R-69.

Figure F-7.0-5 shows a comparison of the hydrograph from R-18 and the barometric pressure at the water table. Note that because the data were recorded using a vented transducer, rather than a non-vented unit, the hydrograph mimicked the barometric pressure curve (on a reversed scale) instead of running independent of it. In this figure, both the hydrograph and barometric pressure curve have been adjusted to obtain a best fit. The barometric pressure data were modified to reflect the barometric efficiency of R-18 so that this parameter could be adjusted while seeking a match. The hydrograph data were adjusted for a background trend to account for possible rise or decline in water levels that might have been occurring naturally. The match shown on Figure F-7.0-5 was obtained using a barometric efficiency of 93 percent and a background water level rise of 0.0055 ft/day.

Figure F-7.0-5 shows a clear response in R-18 (nearly a foot) to pumping R-69 screen 2, including development testing on November 3, trial testing on November 7 and 15, and the 72-hr constant-rate test. The data also showed a response in R-18 to pumping R-69 screen 1 with an apparent drawdown of between 0.1 and 0.2 ft. However, the observed response might have included some lingering effects of screen 2 operation (trial 3) from the day before the screen 1 pumping test.

Figure F-7.0-6 shows an expanded-scale plot of the data around the time that screen 1 was test pumped. During the trial 3 test on screen 2, there was a steep downward spike in the hydrograph showing strong response in R-18 to pumping screen 2. Following pump shutoff, water levels in R-18 did not recover completely before starting the 72-hr test on screen 1. A detailed examination of Figure F-7.0-6 showed that the separation between the hydrograph and barometric pressure curve diminished somewhat before the start of the screen 1 pumping test and increased again during the test, confirming a drawdown response. The increase in the separation between the two curves during the screen 1 test was approximately 0.07 ft. The actual drawdown effect of pumping screen 1 would have been 0.07 ft plus whatever additional recovery from screen 2 pumping had occurred during the 72-hr screen 1 test.

Figure F-7.0-7 shows a comparison of the hydrograph from R-47 and the adjusted barometric pressure at the water table. The match shown on Figure F-7.0-7 was obtained using a barometric efficiency of 93 percent and a background water level decline of 0.0014 ft/day. The R-47 hydrograph showed a response to pumping R-69 screen 2 with a drawdown of approximately 0.11 ft during the 72-hr test. There was no clear response in the data to pumping screen 1.

Figure F-7.0-8 shows a comparison of the hydrograph from R-63 and the barometric pressure at the water table. The match shown was obtained for a barometric efficiency of 90 percent and a background water level decline of 0.0025 ft/day. The data showed no apparent response to pumping either screen in R-69.

Figure F-7.0-9 shows a comparison of the hydrograph from R-68 and the barometric pressure at the water table. The match shown was obtained for a barometric efficiency of 93 percent and no background water-level trend. The data showed no apparent response to pumping either screen in R-69.

F-8.0 WELL R-69 DATA ANALYSIS

This section presents the data obtained from the R-69 pumping tests and the results of the analytical interpretations. Data are presented for R-69 screen 1 trial 1 and the 72-hr test, as well as R-69 screen 2 trials 1, 2 and 3 and the 72-hr test.

F-8.1 Well R-69, Screen 1, Trial 1

Brief trial testing was performed at R-69 screen 1 to obtain “snapshots” of early pumping and recovery response to try to quantify properties of the subsurface materials immediately around the wellbore.

Figure F-8.1-1 shows a semilog plot of the drawdown data collected from trial 1 on R-69 screen 1 at a discharge rate of 11.7 gpm. The transmissivity determined from the earliest line of fit on the graph was 2170 gallons per day per ft (gpd/ft). Based on the well screen length of 20.2 ft, this implied an average hydraulic conductivity value of 107 gpd/ft^2, or 14.4 ft/day.

After just a minute or so, the curve became slightly steeper for several minutes and then re-stabilized near the original slope. The steep portion of the graph likely reflects aquifer heterogeneity, with the cone of depression encountering a zone of somewhat lower conductivity.

The transmissivity determined from the late slope on the graph was 2210 gpd/ft. Based on the well screen length, this implied an average hydraulic conductivity value of 109 gpd/ft^2, or 14.6 ft/day.

It is possible the calculated transmissivity values corresponded to a sediment thickness slightly greater than the well screen length, depending on the vertical growth rate of the cone of depression during the early stages of pumping. This would imply the possibility of a somewhat lower hydraulic conductivity than that calculated based on the screen length. In other words, the computed hydraulic conductivity values may be considered maximum, or upper-bound, values. However, in all cases, the earliest slopes on the drawdown and recovery graphs were based on very early data during which little vertical growth of the cone of depression/impression could have occurred.

The drawdown graph showed significant scatter in the data points, nearly a foot in magnitude. This may have resulted from the percussive effects of running air bubbles through the pump impellers. The transducer was positioned below the pump, which ruled out the possibility that interference from the power cable could have been the cause of the erratic data (a phenomenon seen in other R-well pumping tests in which the transducers were adjacent to the power cables).

Figure F-8.1-2 shows the recovery data obtained from trial 1. The transmissivity values determined from the initial and subsequent lines of fit on the graph were 2200 and 2030 gpd/ft, respectively. This implied upper-bound hydraulic conductivity values of 109 and 100 gpd/ft^2, or 14.6 and 13.4 ft/day, respectively.

The first few data points (right side of graph), corresponding to the first couple of seconds of recovery, showed scatter likely caused by inertial effects when pumping ceased. Other than that, with the pump shut down there was negligible data scatter in the recovery plot. The downward spike in levels shown at the end of the recovery period (left edge of the graph) was caused by deflating and re-inflating the packer system. This was done to release any trapped air that might have accumulated beneath the upper packer during trial 1, which might have affected the ensuing 72-hr test on screen 1.

F-8.2 Well R-69, Screen 1, 72-hr Test

Figure F-8.2-1 shows a semilog plot of the drawdown data collected from the 72-hr test on R-69 screen 1 at a discharge rate of 11.8 gpm. When pumping started, the upper several feet of drop pipe were empty—a precaution taken to prevent water in the drop pipe from freezing overnight. Thus, initially, pumping started against just the head of the water in the pipe with no added backpressure from the flow control valve. After about 5 s, the drop pipe and discharge piping leading to the valve had been filled, backpressure was applied by the valve, and the discharge rate dropped accordingly. The discharge rate of the pump working against just the drop pipe head was determined to be 20 gpm. Once flow reached the valve, the rate dropped to 11.8 gpm.

The early seconds of pumping allowed determining the near-well transmissivity corresponding to the well screen length. After a brief steepening of the data trace, likely caused by aquifer heterogeneity, the slope re-stabilized for an hour or so.

The transmissivity values determined from the lines of fit shown on the graph were 2160 gpd/ft for the initial slope, corresponding to a realistic/upper-bound hydraulic conductivity value of 109 gpd/ft^2, or 14.3 ft/day, and 2190 gpd/ft for the later slope, corresponding to an upper-bound hydraulic conductivity value of 108 gpd/ft^2, or 14.5 ft/day.

Late data on the plot showed continuing flattening of the data trace, a result of ongoing vertical expansion of the cone of depression at late time. It is possible also that delayed yield contributed to the curve flattening.

Figure F-8.2-2 shows recovery data recorded for 1440 min following cessation of the 72-hr pumping test on screen 1. The transmissivity values determined from the lines of fit shown on the graph were 2200 gpd/ft for the initial slope, corresponding to a realistic/upper-bound hydraulic conductivity value of 109 gpd/ft^2, or 14.6 ft/day, and 1980 gpd/ft for the later slope, corresponding to an upper-bound hydraulic conductivity value of 98 gpd/ft^2, or 13.1 ft/day.

The first few data points (right side of graph), corresponding to the first couple of seconds of recovery, showed scatter likely caused by inertial effects when pumping ceased. Late data on the left-hand side of the plot showed continuing flattening of the data trace, corresponding to ongoing vertical expansion of the cone of impression at late time and possible delayed yield effects (or, actually, gradual transition from confined storage coefficient to leaky confined response). Figure F-8.2-3 shows an expanded-scale plot of these data along with the resulting computed transmissivity value of 9030 gpd/ft. This transmissivity corresponded to some greater, unknown thickness of saturated sediments—presumably at least 150 ft.

Figures F-8.2-4 and F-8.2-5 show screen 2 drawdown response to pumping screen 1 along with the Hantush analysis for partially penetrating wells. The figures show calculation results for assumed vertical anisotropy ratios of 0.01 and 0.005, respectively, and an arbitrarily assigned aquifer thickness of 150 ft. Based on the limited array of observation wells for the R-69 pumping tests and the unknown aquifer thickness, it was not possible to solve simultaneously for transmissivity, storage coefficients (confined and leaky confined), anisotropy, and effective aquifer thickness. Therefore, solutions were crafted for reasonable assumed values to see what the resulting transmissivity would be. The steep downward gradient at R-69 (estimated 8.4-ft head difference over a distance of 65 ft between the well screen centers) suggested a severe vertical anisotropy.

As indicated in Figures F-8.2-4 and F-8.2-5, the analysis for the assumed anisotropy values and the 150-ft aquifer thickness implied transmissivity values of 12,400 and 12,100 gpd/ft corresponding to average hydraulic conductivity values for the 150-ft aquifer thickness of 83 and 81 gpd/ft^2, or 11.1 and 10.8 ft/day, respectively.

The plots on Figures F-8.2-4 and F-8.2-5 exhibited a very slight bimodal drawdown distribution, that is, the curves flattened just slightly (after about half a day) and then steepened slightly. This is the characteristic effect seen in delayed yield response although the effect in R-69 screen 2 was subtle. It was possible that this indicated a gradual transition from confined response to leaky confined. It also could have been an artifact of aquifer heterogeneity. This effect made it impossible to fit the Hantush type curves to the entire data set, with the late data falling just beneath the type curve as would be expected if delayed yield had occurred.

For comparison purposes, the analysis shown on Figure F-8.2-5 for an anisotropy of 0.005 was recalculated for an assigned aquifer thickness of 300 ft replacing the 150-ft value. The resulting curve match shown in Figure F-8.2-6 indicated a calculated transmissivity of 17,700 gpd/ft, making the average hydraulic conductivity 59 gpd/ft^2, or 7.9 ft/day.

Although the type curve in Figure F-8.2-6 appeared to be a better fit than that in Figure F-8.2-5 because it encompassed a greater number of data points, it did not necessarily represent a more valid analysis. If delayed yield were present (a gradual transition from confined to leaky conditions), the preferred analysis would be one in which the late data fell below the type curve because the Hantush analysis is based on a constant storage coefficient. Note that the transmissivity values obtained based on the assumption of a 150-ft aquifer thickness (12,400 and 12,100 gpd/ft) were in closer agreement with the late recovery value shown in Figure F-8.2-3 (9030 gpd/ft) than was the value based on a 300-ft thick aquifer (17,700 gpd/ft).

The screen 2 drawdown data were analyzed for a range of assumed aquifer thickness values to examine the effect on the computed hydraulic conductivity. All calculations were performed for the anisotropy value of 0.005. Figure F-8.2-7 shows the results of the analyses via a plot of relative conductivity (compared with that obtained for the 150-ft assumption) versus aquifer thickness.

The results showed that assuming an aquifer thickness greater than 150 ft led to steadily lower conductivity values, leveling off at approximately 30 percent lower than the value obtained for a 150-ft thick aquifer. The best curve matches, considering the likelihood that delayed yield was present, was for aquifer thicknesses around 150 ft or somewhat greater. Reasonable results were obtained for the 300-ft assumption as shown in Figure F-8.2-6. As the assigned aquifer thickness in the analysis increased beyond 300 ft, the quality of the curve matches became progressively worse.

It was not possible to know the actual effective thickness of the hydraulically contiguous sediments responding to the R-69 pumping tests. Subsequent analyses presented below were performed only for the assumption of a 150-ft aquifer. Because using a greater aquifer thickness in the calculations resulted in a lower computed value for hydraulic conductivity, the following partial penetration analyses can be considered to provide upper-bound hydraulic conductivity values.

Figure F-8.2-8 shows the semilog analysis of the late drawdown data response in screen 2 to pumping screen 1. To reduce the scatter prevalent in the plot, a rolling average was computed as shown in Figure F-8.2-9. The transmissivity determined from the late data was 10,300 gpd/ft.

Figures F-8.2-10 and F-8.2-11 show Hantush analysis of the early screen 2 recovery data recorded following shutdown of the 72-hr screen 1 pumping test for anisotropy values of 0.01 and 0.005, respectively. (Recall that this analytical method is valid only for early data.) The transmissivity values obtained from these plots were 8900 and 8300 gpd/ft, making the average hydraulic conductivity values for the 150-ft aquifer thickness 59 and 55 gpd/ft^2, or 7.9 and 7.4 ft/day, respectively. There appeared to be a brief flattening in the data trace about half a day after pumping stopped—possibly consistent with a slight increase in storage coefficient over time.

Figure F-8.2-12 shows a semilog plot of the late recovery data from screen 2. To reduce the data scatter, a rolling average was computed as shown in Figure F-8.2-13. The transmissivity determined from the analysis was 11,200 gpd/ft. The temporary flattening in the recovery curve is evident in Figure F-8.2-13.

F-8.3 Well R-69, Screen 2, Trial 1

Brief trial testing was performed at R-69 screen 2 to obtain snapshots of early pumping and recovery response to try to quantify properties of the subsurface materials immediately around the wellbore. Initially, two trial tests were conducted. However, as discussed above, the early data from these tests were compromised by storage effects due to nitrogen gas leaking into the pumped zone through the upper inflatable packer. Therefore, a third trial test was performed on screen 2 after the packer system was retrofitted and the pump was run back into the well for the screen 1 tests.

Figure F-8.3-1 shows a semilog plot of the drawdown data collected from trial 1 on R-69 screen 2. Several feet of drop pipe had been emptied the day before to prevent freezing overnight. Therefore, when pumping began, the pump operated against only the head imposed by the height of water in the drop pipe. The momentary pumping rate was determined to be 20 gpm until the drop pipe and discharge line had been filled and the inline flow valve applied backpressure—approximately 0.7 min after pumping began. At that time, the discharge rate dropped to 15.8 gpm.

During the second minute of pumping, the discharge rate declined suddenly as evidenced by the abrupt reduction in drawdown. Discharge water had been routed directly to a water truck, rather than to the nearby frac tank, and the entrance valve on the water truck had inadvertently been left closed, blocking flow. The valve was opened quickly and flow was restored.

It appeared that the initial data points on the plot in Figure F-8.3-1 had been storage affected, probably as a result of the nitrogen gas that had been introduced into the screen 2 zone. The transmissivity determined from the subsequent line of fit shown on the graph was 400 gpd/ft. Based on the well screen length of 20.3 ft, this implied an average hydraulic conductivity value of 19.7 gpd/ft^2, or 2.6 ft/day.

The final slope on the drawdown plot supported a transmissivity calculation of 600 gpd/ft. This could indicate an increase in the sediment permeability a short distance from the well or could be representative of a somewhat greater thickness of sediments than just the well screen length (vertical growth of the cone of depression).

Figure F-8.3-2 shows the recovery data from trial 1. The early data were clearly storage affected. The subsequent slope on the plot produced a transmissivity value of 420 gpd/ft, corresponding to a hydraulic conductivity of 20.7 gpd/ft^2, or 2.8 ft/day. After several minutes of recovery, the slope flattened further resulting in a calculated transmissivity of 600 gpd/ft corresponding to more distant sediments or a greater aquifer thickness than the well screen length.

Remarkably, the recovered water level remained 5 ft below the starting level. This was an indication that injection of nitrogen gas when the packers were inflated may have contributed to a false-high starting static water level.

F-8.4 Well R-69, Screen 2, Trial 2

When processing the trial 2 data, all drawdown and recovery values were computed using the static water level observed when the packers were inflated initially (before trial 1). Figure F-8.4-1 shows drawdown data from trial 2 on R-69 screen 2. Following a brief storage event, the transmissivity determined from the early line of fit on the graph was 410 gpd/ft, corresponding to an average hydraulic conductivity value of 20.2 gpd/ft^2, or 2.7 ft/day. The subsequent slope yielded a computed transmissivity of 580 gpd/ft reflecting properties of either more distant sediments and/or a thickness of sediments somewhat greater than the well screen length.

The late data from trial 2 showed unusual and inexplicable response. A little after 20 min of pumping, the curve steepened significantly. This departure from the straight-line slope was distinctly different from what was observed in trial 1 (Figure F-8.3-1) in which the straight-line trend was uninterrupted through the end of the trial (30 min). After exhibiting a steep slope for half an hour, drawdown levels stabilized through the last 10 min of pumping.

It is likely that the presence of nitrogen gas in the pumped zone contributed to the observed effect. If nitrogen gas had previously moved into the aquifer, the pressure reduction associated with the drawdown imposed by pumping may have triggered gas coming out of solution or expansion of existing gas, clogging the pore spaces and increasing the head loss slightly.

Figure F-8.4-2 shows the recovery data from trial 2. The early data were clearly storage affected. The subsequent slope on the plot produced a transmissivity value of 400 gpd/ft, corresponding to a hydraulic conductivity of 19.7 gpd/ft^2, or 2.6 ft/day. After several minutes of recovery, the slope flattened further resulting in a calculated transmissivity of 680 gpd/ft corresponding to more distant sediments and/or a greater aquifer thickness than the well screen length.

Note that the residual drawdown after two days of recovery was still nearly 5 ft. Including both trials 1 and 2, screen 2 had been pumped for 90 min total. So little pumping, followed by two days of recovery, should have resulted in a substantially smaller residual drawdown. This observation supported the idea that the starting static water level may have been erroneously high because of nitrogen gas injection into screen 2.

F-8.5 Well R-69, Screen 2, Trial 3

Figure F-8.5-1 shows drawdown data from trial 3 on R-69 screen 2. Water leakage at the wellhead forced a shutdown immediately after startup. The leak was fixed and the pump was restarted quickly. The initial discharge rate averaged 15.9 gpm. However, the rate varied too much to allow the data to be used to compute aquifer parameters.

After 40 min, the inline valve was adjusted in order to reduce the discharge rate to 11.6 gpm to prepare for collecting recovery data and to set the valve position for the upcoming screen 1 tests.

Figure F-8.5-2 shows the recovery data from trial 3. The retest using a leak-free packer system appeared to be effective at eliminating the storage effects seen in the other tests. The initial slope shown on the graph yielded a transmissivity value of 360 gpd/ft, corresponding to a hydraulic conductivity of 17.7 gpd/ft^2, or 2.4 ft/day. Subsequent data produced a transmissivity value of 780 gpd/ft, presumably reflecting a greater sediment thickness and/or more distant sediments.

The first few data points (right edge of Figure F-8.5-2) fell off the line of fit shown on the plot. This was because the u-value was not yet less than 0.05 and, thus, the semilog method was not valid for the very early data. The data were replotted on the log-log graph shown in Figure F-8.5-3 showing a better match to the early data.

Note on Figure F-8.5-2 that after just 30 min of recovery following 90 min of pumping, the residual drawdown was less than half the amount recorded after trial 2 when recovery had proceeded for 2 days. This was consistent with the inference of a false high static water level at the outset of screen 2 testing.

F-8.6 Well R-69, Screen 2, Trial Test Combined Results

The recovery data for the three trial tests on screen 2 were compared to illustrate the effect that leaking nitrogen gas had had on the test results. Figure F-8.6-1 shows a plot of specific residual drawdown versus t/t' for all three tests. Specific residual drawdown was calculated by dividing the residual drawdown by the discharge rate for each test.

In theory, except for u-value affected data (the first second or two of recovery) the three curves shown on Figure F-8.6-1 should be identical. Clearly the results from trials 1 and 2 are very different from trial 3, confirming that the presence of nitrogen gas affected the initial tests and that the retrofitted packer solved the problem very well.

F-8.7 Well R-69, Screen, 2 72-hr Test

Figure F-8.7-1 shows a semilog plot of the drawdown data collected from the 72-hr test on R-69 screen 2 at a discharge rate of 15.2 gpm. The transmissivity value determined from the line of fit shown on the graph was 460 gpd/ft, corresponding to a realistic/upper-bound hydraulic conductivity value of 22.7 gpd/ft^2, or 3.0 ft/day.

After 10 min of pumping, the drawdown increased rapidly for the next 12 min or so, similar to the effect observed in trial 2. This was presumably caused by permeability reduction due to nitrogen clogging of the formation pore spaces, because the pumping rate remained steady through this period.

Later on, however, variable gas content in the pumped water affected the pump efficiency causing the discharge rate to increase and decrease several times. This accounts for the erratic drawdown trace over the remainder of the 3-day test.

Figure F-8.7-2 shows recovery data recorded for 1440 min following cessation of the 72-hr pumping test on screen 2. The early data showed storage effects and were not usable for computing aquifer coefficients. The transmissivity value determined from the initial line of fit shown on the graph was 450 gpd/ft, corresponding to a realistic/upper-bound hydraulic conductivity value of 22.2 gpd/ft^2, or 3.0 ft/day. The subsequent slope identified on the plot showed a transmissivity of 850 gpd/ft likely reflecting the properties of more distant sediments or a greater thickness than the well screen length.

The late data showed continuing flattening of the recovery curve consistent with vertical expansion of the cone of impression and possible delayed yield. However, water level reversal occurred for a 15-hr period during recovery. Figure F-8.7-3 shows an expanded-scale graph of the late recovery data. As indicated, total aquifer pressure began decreasing approximately 7 hr into recovery and continued for 15 hr, even though atmospheric pressure was increasing during this period. Over the last 2 hr of recovery there was an abrupt rise in water level. There was no obvious explanation for this unusual response. It was likely caused by nitrogen gas in the well and aquifer, but the mechanism is not known.

Despite the anomalous water-level response, it appeared that the residual drawdown was approximately 1 ft following 72 hr of pumping and 24 hr of recovery. Recall that trials 1 and 2 showed an apparent residual drawdown of nearly 5 ft after 90 min of pumping and 2 days of recovery. This provided more evidence that the original static pressure measured in screen 2 on November 6 was erroneously high.

Figures F-8.7-4 and F-8.7-5 show screen 1 drawdown response to pumping screen 2 along with the Hantush analysis for partially penetrating wells. The figures show calculation results for assumed vertical anisotropy ratios of 0.01 and 005, respectively, and the assigned aquifer thickness of 150 ft. As indicated in Figures F-8.2-4 and F-8.2-5, the analysis produced transmissivity values of 13,500 and 13,800 gpd/ft corresponding to average hydraulic conductivity values for the 150-ft aquifer thickness of 90 and 92 gpd/ft^2, or 12.0 and 12.3 ft/day, respectively.

Figures F-8.7-6 and F-8.7-7 show Hantush analysis of the early screen 1 recovery data recorded following shutdown of the 72-hr screen 2 pumping test for anisotropy values of 0.01 and 0.005, respectively. (Recall that this analytical method is valid only for early data.) The transmissivity values obtained from these plots were 11,700 and 10,900 gpd/ft, corresponding to average hydraulic conductivity values for the 150-ft aquifer thickness of 78 and 73 gpd/ft^2, or 10.4 and 9.7 ft/day, respectively.

Data obtained from R-18 during the R-69 screen 2 pumping test were analyzed. Because of the large barometric pressure effect on R-18 water levels, before analysis it was necessary to manually correct the drawdown and recovery data for barometric pressure changes that occurred during the test.

Figure F-8.7-8 shows Hantush analysis of the drawdown data obtained from R-18 during the R-69 screen 2 72-hr test. Only the analysis for an anisotropy of 0.005 is presented. It was not possible to match all of the data using the Hantush method. For more than an hour after startup, R-18 responded to screen 2 as though the two wells were in a limited-thickness zone having a transmissivity value of 2490 gpd/ft. This suggested that rather than functioning hydraulically as a uniformly anisotropic aquifer, the formation is more of a layered system in which R-18 and screen 2 are in a hydraulically continuous horizon that is separated from the rest of the aquifer by low-permeability strata, above and below. The cone of depression expanded rapidly between R-69 screen 2 and R-18, with little leakage from underlying and overlying sediments evident until more than an hour had passed. Clearly, the hydraulic connection between screen 2 and R-18 is excellent.

This response leads to the conclusion that the vertical anisotropy obtained from other analyses is not uniformly distributed but is a composite average of a number of discrete resistive beds—typical of layered geologic systems.

Figure F-8.7-9 shows a semilog analysis of the late drawdown data from R-18. The resulting transmissivity value of 21,200 gpd/ft was not considered valid. The discharge rate varied substantially throughout the test and the late data may have been affected by delayed yield.

Figure F-8.7-10 shows Hantush analysis of the recovery data recorded in R-18 during the R-69 screen 2 test. The results were similar to those from the drawdown data. It was not possible to match more than the first hour or so of recovery data using the Hantush method. A transmissivity value of 2440 was obtained from the match shown in the figure.

Figure F-8.7-11 shows a semilog analysis of the late recovery data from R-18. A transmissivity value (23,200 gpd/ft) was computed but was not considered reliable. The data were erratic in that the water levels appeared to stabilize temporarily and then rose rapidly at the end of the test. There was no apparent explanation for the unusual observed response.

F-8.8 Well R-69 Aquifer Coefficient Summary

Tables F-8.8-1 and F-8.8-2 summarize the transmissivity values obtained from the pumping tests conducted on R-69 screen 1 and screen 2, respectively. For the Hantush analysis, only values based on an assumed aquifer thickness of 150 ft were included.

The screen 1 transmissivity values from Table F-8.8-1 averaged 2140 gpd/ft. Based on the well screen length of 20.2 ft, the average hydraulic conductivity for the screen 1 interval was 106 gpd/ft^2, or 14.2 ft/day.

The screen 2 transmissivity values from Table F-8.8-2 based on early data averaged 410 gpd/ft. Based on the well screen length of 20.3 ft, the average hydraulic conductivity was 20.2 gpd/ft^2, or 2.7 ft/day.

Finally, the composite average of the transmissivity values representing the full 150-ft aquifer thickness (not including the R-18 values) was 11,100 gpd/ft. Based on the assumed saturated thickness of hydraulically contiguous sediments of 150 ft, the average conductivity computes to 74 gpd/ft^2, or 9.9 ft/day. The actual thickness of sediments responding to pumping was not known but was probably at least 150 ft. Analysis showed that the assumption of a greater thickness resulted in a somewhat lower computed conductivity value, but likely not less than approximately 70 percent of the 150-ft based value. Thus, a good estimate of the expected average conductivity of the entire aquifer is in the range of approximately 7 to 9.9 ft/day.

F-8.9 Well R-69 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate lower-bound hydraulic conductivity values for the permeable zones penetrated by R-69 to provide a frame of reference for evaluating the foregoing analyses.

The total saturated thickness of Puye sediments was not known. In applying the specific capacity 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 150 ft—the length of saturated sediments penetrated during drilling of the borehole. The well screen lengths of 20.2 and 20.3 ft were used in the partial penetration calculations for screen 1 and screen 2, respectively. The drawdown values used in the calculations were those observed 24 hr into the pumping tests.

After the first 24 hr of operation during the 72-hr test, R-69 screen 1 produced 11.8 gpm with 7.7 ft of drawdown for a specific capacity of 1.53 gpm/ft. In addition to specific capacity and pumping time, other input values used in the calculations included an assigned storage coefficient value of 0.003 (leaky confined) and a borehole radius of 0.57 ft (inferred from the volume of filter pack required to backfill the screen zone).

Applying the Brons and Marting (1961, 098235) method to these inputs yielded lower-bound hydraulic conductivity estimate of 9.2 ft/day. This result was consistent with the values obtained from test analysis that produced an average hydraulic conductivity value for the screen 1 interval of 14.2 ft/day and suggested a moderate well efficiency.

At the 24-hr mark during testing of R-69 screen 2, the well was producing 15.5 gpm with 35.7 ft of drawdown for a specific capacity at that time of 0.43 gpm/ft. Using the information along with the leaky-confined storage coefficient value of 0.003 and a borehole radius of 0.56 ft (inferred from the volume of filter pack required to backfill the screen zone) the computed lower-bound hydraulic conductivity was 2.6 ft/day. This result was consistent with the values obtained from test analysis that produced an average hydraulic conductivity for the screen 1 interval of 2.7 ft/day and suggested an efficient screen zone.

Note that it could be argued that a more accurate lower-bound hydraulic conductivity for screen 2 might be somewhat less than the 2.6-ft/day estimate based on specific capacity. The hydraulic conductivity of the overlying and underlying sediments appeared to be several times greater than that of the screen 2 zone and probably contributed disproportionately to the screen 2 specific capacity compared to what would have been observed under homogeneous conditions.

F-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-69 screens 1 and 2 to gain an understanding of the hydraulic characteristics of the aquifer. Testing consisted of brief trial pumping and a 72-hr constant rate pumping test on each screen zone. During testing, water levels were recorded in both screen zones as well as nearby wells R-18 (649 ft away), R-47 (1170 ft), R-63 (1701 ft) and R-68 (1195 ft).

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

1. A comparison of barometric pressure and R-69 water-level data showed highly barometrically efficient screen zones. Large changes in barometric pressure caused almost no change in the apparent hydrographs from the well, obtained using non-vented transducers. Also, hydrograph data from R-18, R-47, R-63, and R-68 all showed barometric efficiencies of at least 90 percent.
2. The background data showed Earth tide fluctuations of approximately 0.02 to 0.03 ft in R-69 screens 1 and 2, typical of the response seen in many regional wells on the Plateau.
3. A nitrogen leak from one of the inflatable packers used initially in the testing of screen 2 resulted in variations in the discharge rate as well as storage-like effects. It also may have contributed to an erroneous static water level reading from screen 2 at the outset of testing. After replacing the defective packer, subsequent trial testing at screen 2 successfully produced a data set free of storage effects.
4. There was a strong downward gradient from screen 1 to screen 2 with an estimated head difference of approximately 8 to 10 ft. These estimates were made after pumping had occurred in each of the screen zones and, therefore, might differ slightly from steady state conditions. The substantial vertical head difference implied strongly anisotropic conditions. Installation of the permanent sampling system, after R-69 has remained idle for a time, will allow obtaining more accurate static water level and downward gradient information.
5. Operation of R-69 screen 1 caused a drawdown in R-18 (640 ft away) of approximately a tenth of a foot. There was no discernable response, however, in R-47 (1180 ft), R-63 (1720 ft), or R-68 (1210 ft).
6. Operation of R-69 screen 2 caused a drawdown of nearly 1 ft in R-18 and 0.11 ft in R-47. There was no discernable response, however, in R-63 or R-68. Although R-68 is about the same distance away as R-47, its screen elevation is 70 ft higher and, thus, 70 vertical ft farther removed from screen 2.

7. The drawdown response in R-47 suggested dipping strata, because the top of screen 2 is 20 ft below the bottom of the R-47 screen while the bottom of screen 1 comes within 4 ft of the top of the R-47 screen. Thus, screen 1 is 16 vertical ft closer to R-47 yet did not cause a drawdown response as did screen 2.
8. Numerous tests on screen 1 showed an average hydraulic conductivity of the screened zone of 14.2 ft/day. Specific capacity data were consistent with this, indicating a lower-bound hydraulic conductivity of 9.2 ft/day.
9. Tests on screen 2 showed an average hydraulic conductivity of the screened zone of 2.7 ft/day. Specific capacity data were consistent with this, indicating a lower-bound hydraulic conductivity of 2.6 ft/day.
10. Partial penetration analysis using both screens 1 and 2 suggested an average hydraulic conductivity for the bulk aquifer of 9.9 ft/day, based on an assumed aquifer thickness of 150 ft and reasonable estimates of vertical anisotropy. Assuming greater aquifer thickness led to somewhat lower calculated conductivity but likely no lower than about 7 ft/day.

F-10.0 REFERENCES

The following reference list includes documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ERID, ESHID, or EMID. This information is also included in text citations. ERIDs were assigned by the Laboratory's Associate Directorate for Environmental Management (IDs through 599999); ESHIDs were assigned by the Laboratory's Associate Directorate for Environment, Safety, and Health (IDs 600000 through 699999); and EMIDs are assigned by Newport News Nuclear BWXT-Los Alamos, LLC (N3B) (IDs 700000 and above). IDs are used to locate documents in N3B's Records Management System and in the Master Reference Set. The NMED Hazardous Waste Bureau and N3B maintain copies of the Master Reference Set. The set ensures that NMED has the references to review documents. The set is updated when new references are cited in documents.

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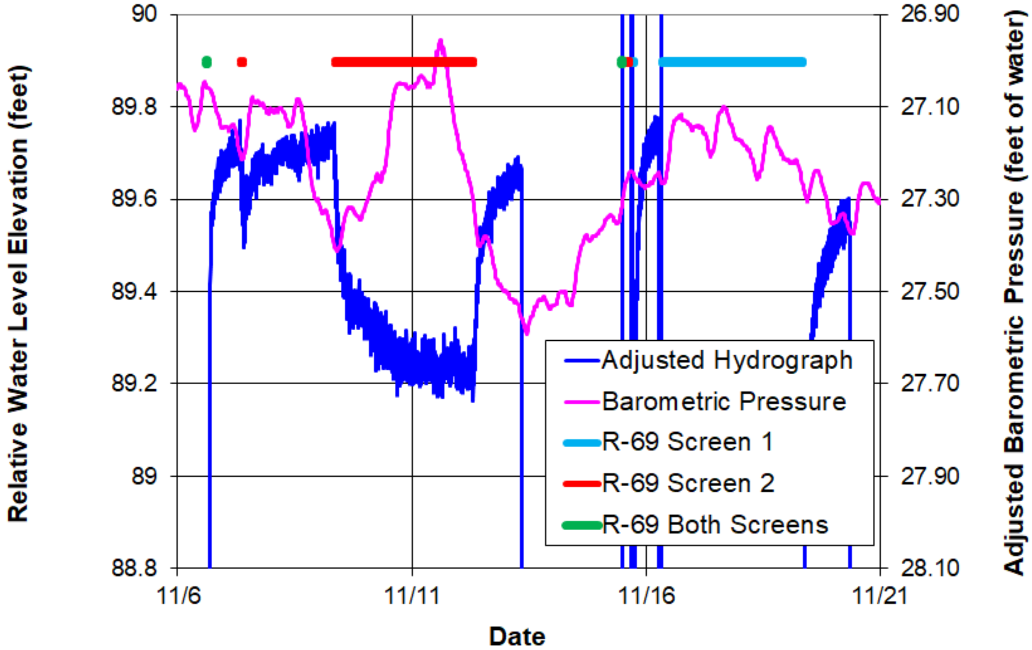

Figure F-7.0-1 Well R-69 screen 1 adjusted hydrograph

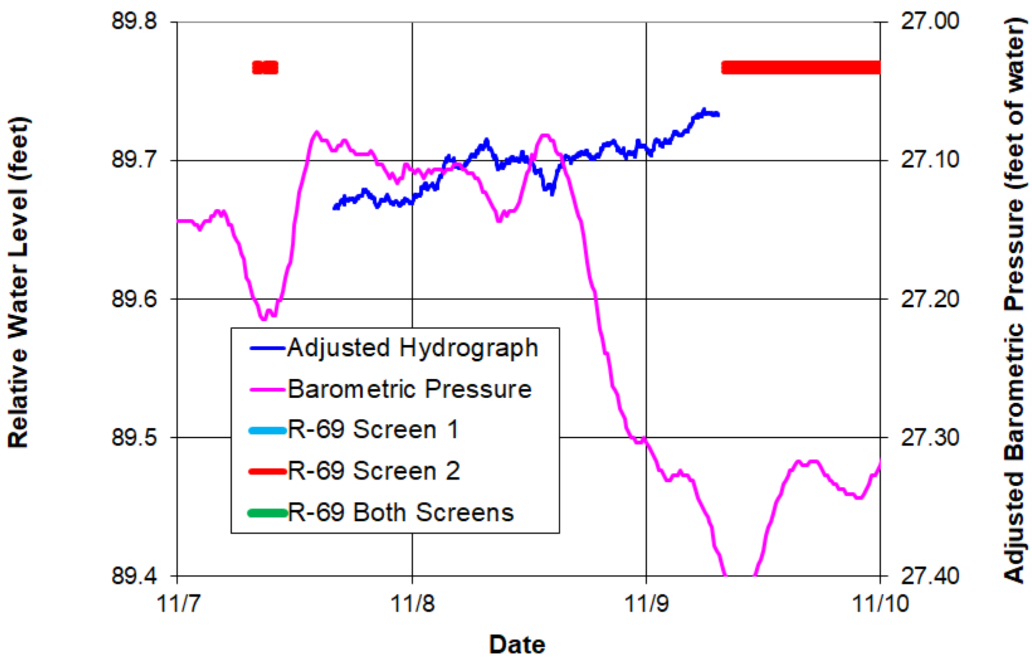

Figure F-7.0-2 Well R-69 screen 1 rolling average background

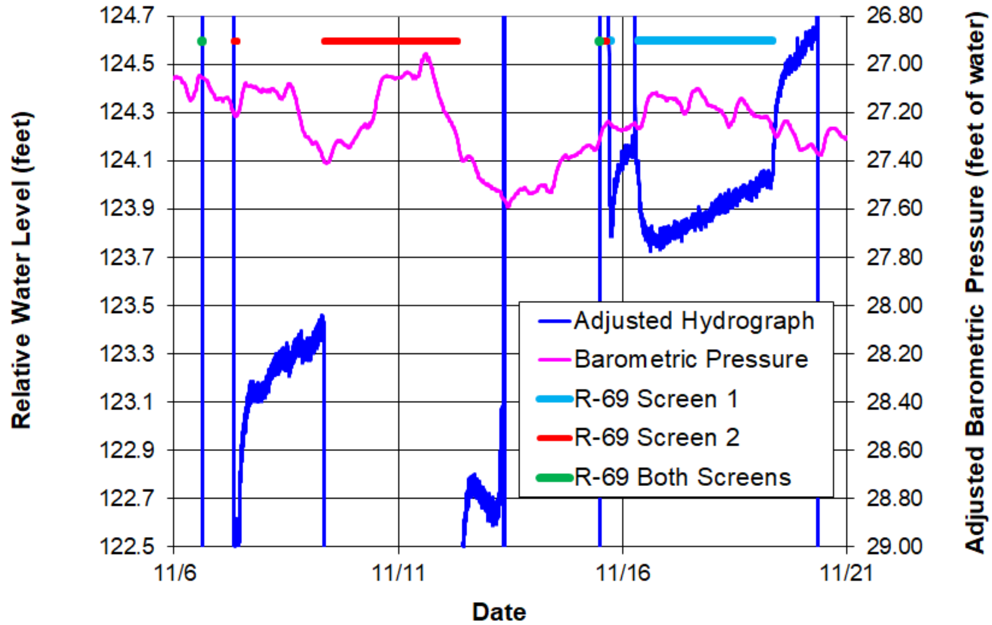

Figure F-7.0-3 Well R-69 screen 2 adjusted hydrograph

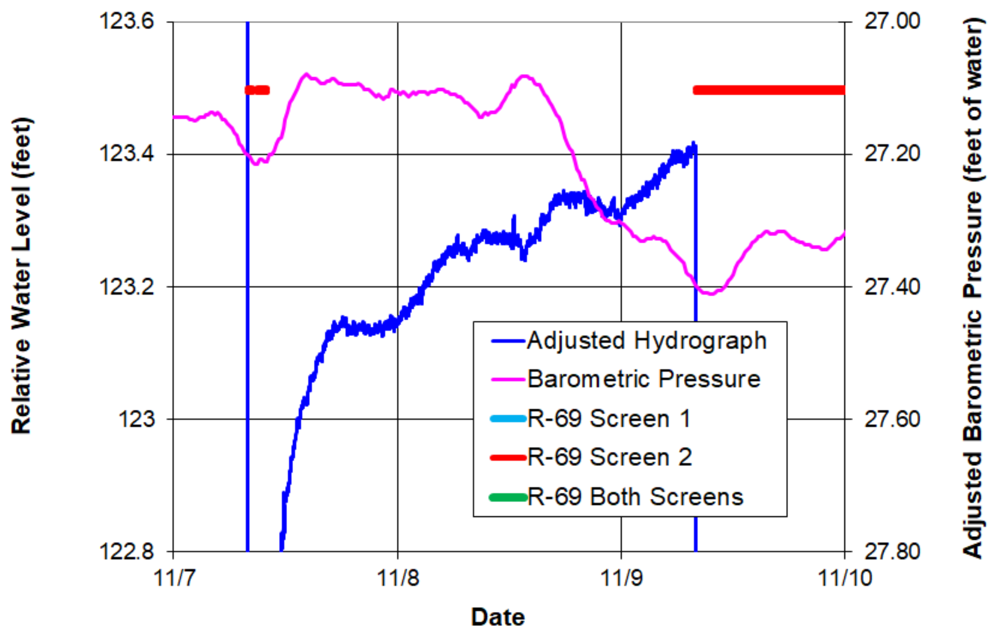

Figure F-7.0-4 Well R-69 screen 2 rolling average background

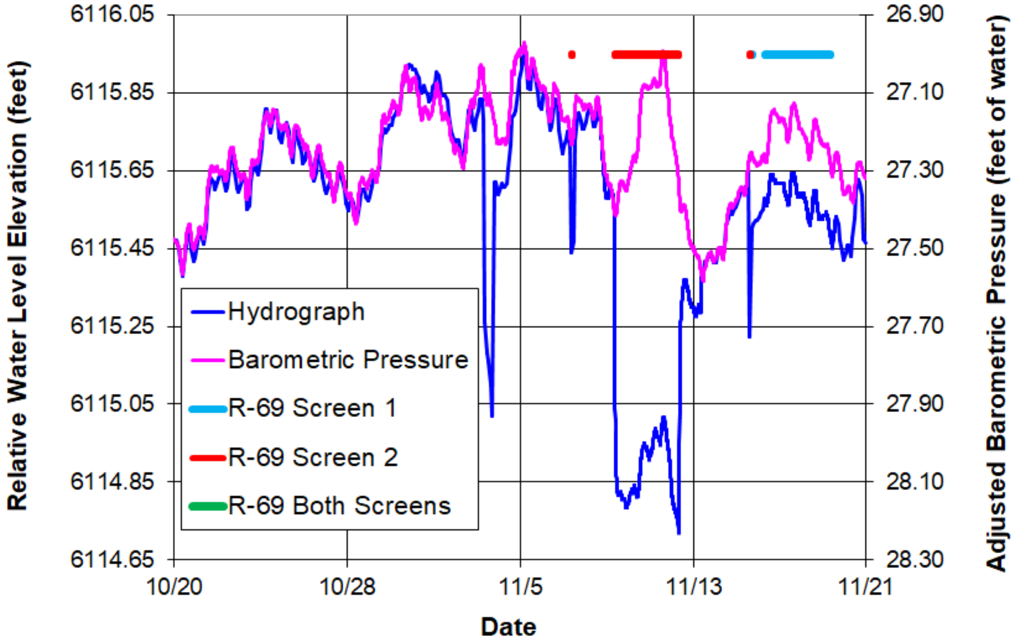

Figure F-7.0-5 Well R-18 adjusted hydrograph for 93% barometric efficiency and 0.0055 ft/day water-level rise

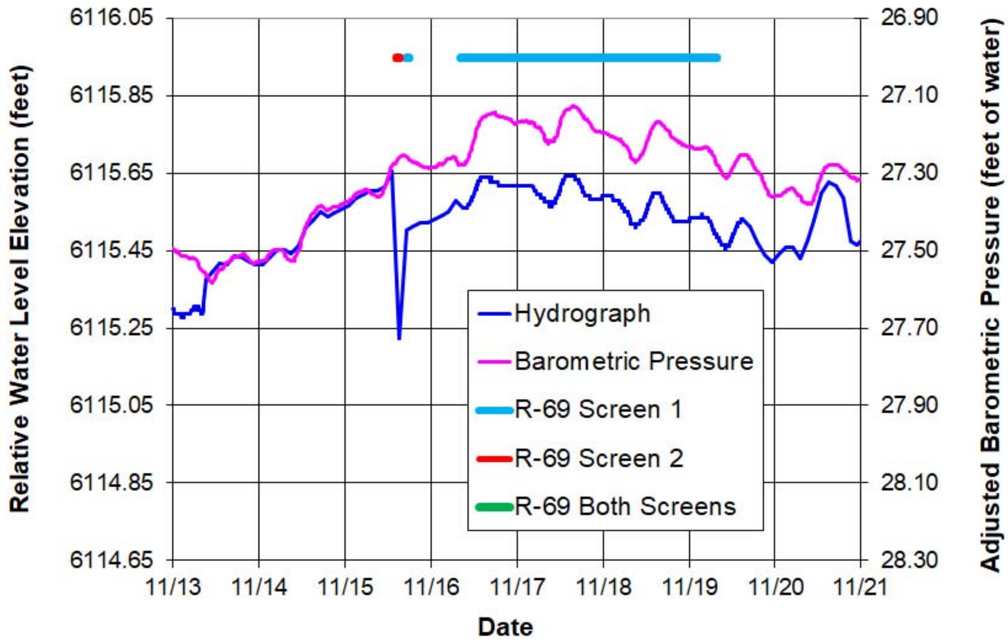

Figure F-7.0-6 Well R-18 hydrograph – expanded view

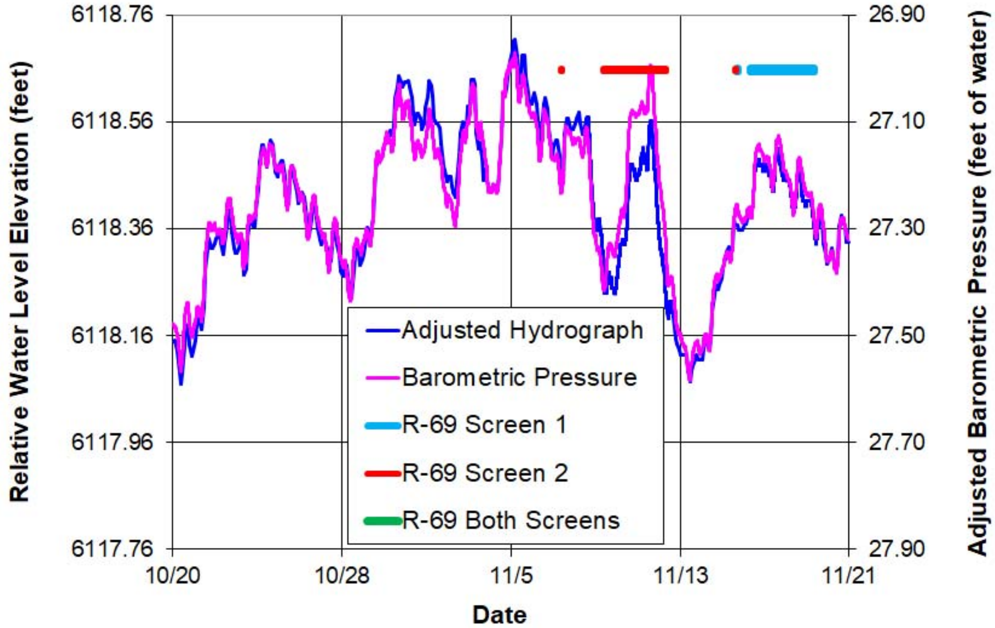

Figure F-7.0-7 Well R-47 adjusted hydrograph for 93% barometric efficiency and 0.0014 ft/day water-level decline

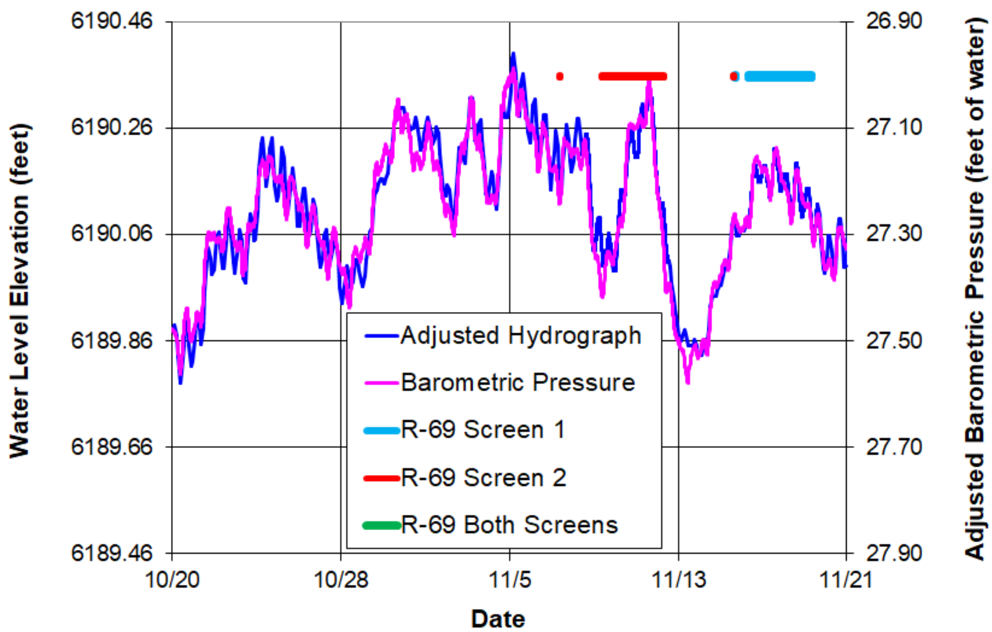

Figure F-7.0-8 Well R-63 adjusted hydrograph for 90% barometric efficiency and 0.0025 ft/day water-level decline

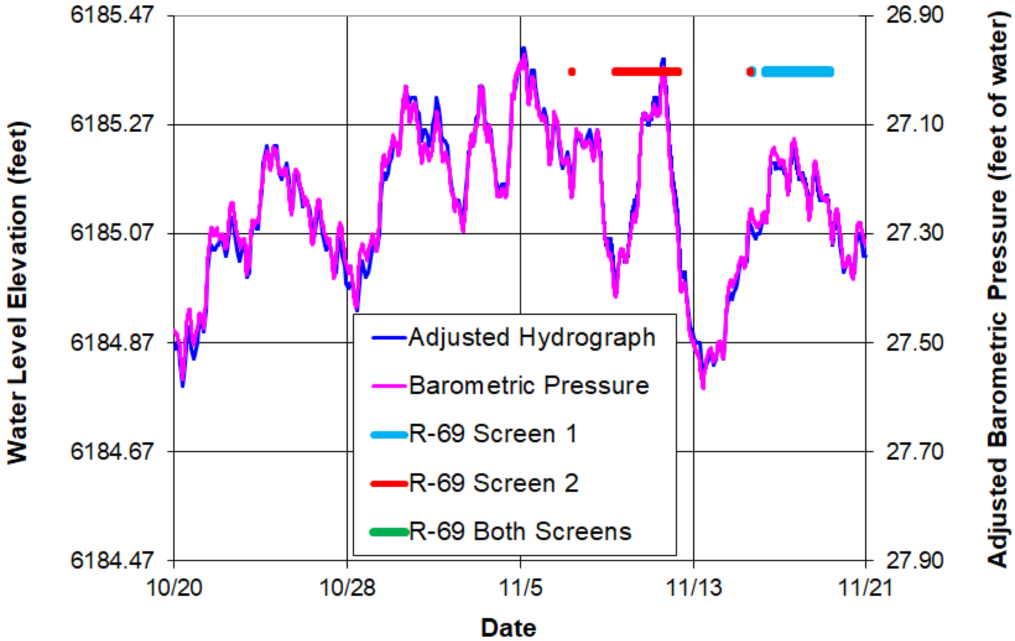

Figure F-7.0-9 **Well R-68 adjusted hydrograph for 93% barometric efficiency and no water-level trend**

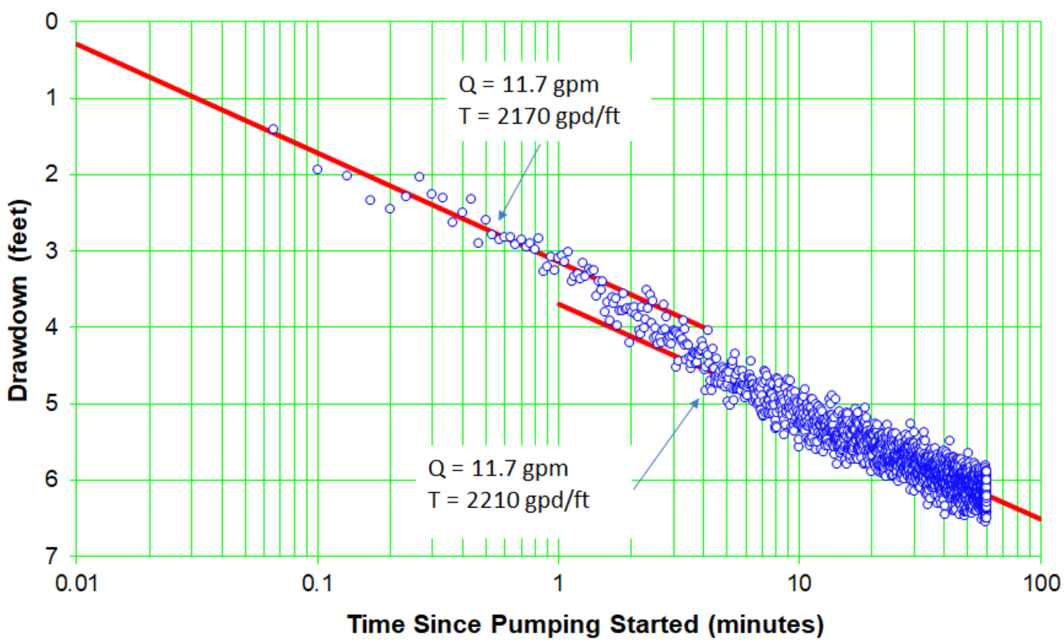

Figure F-8.1-1 **Well R-69 screen 1 trial 1 drawdown**

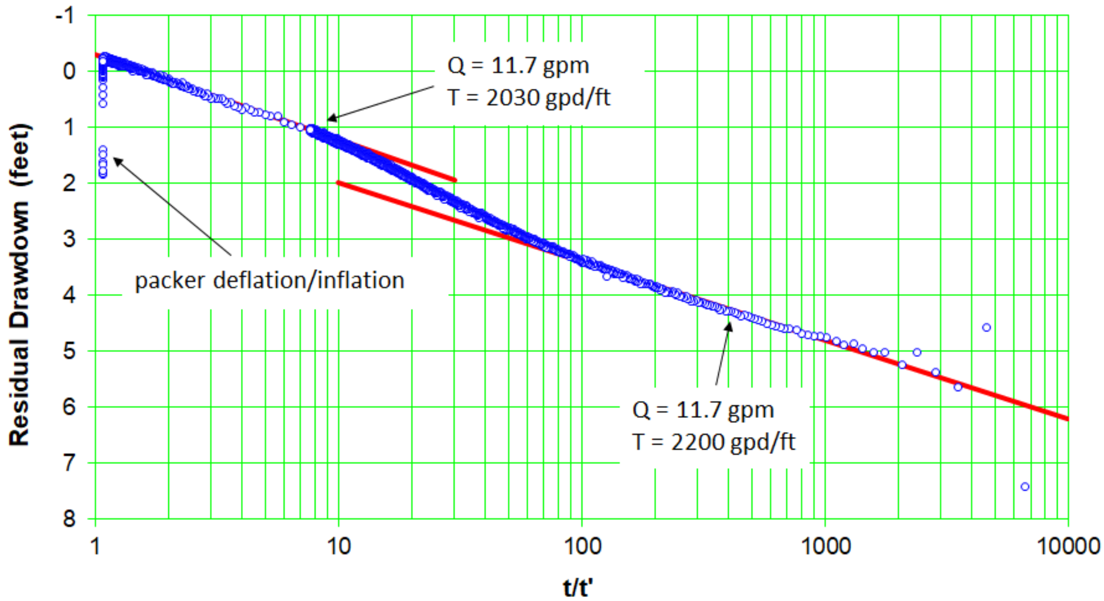

Figure F-8.1-2 Well R-69 screen 1 trial 1 recovery

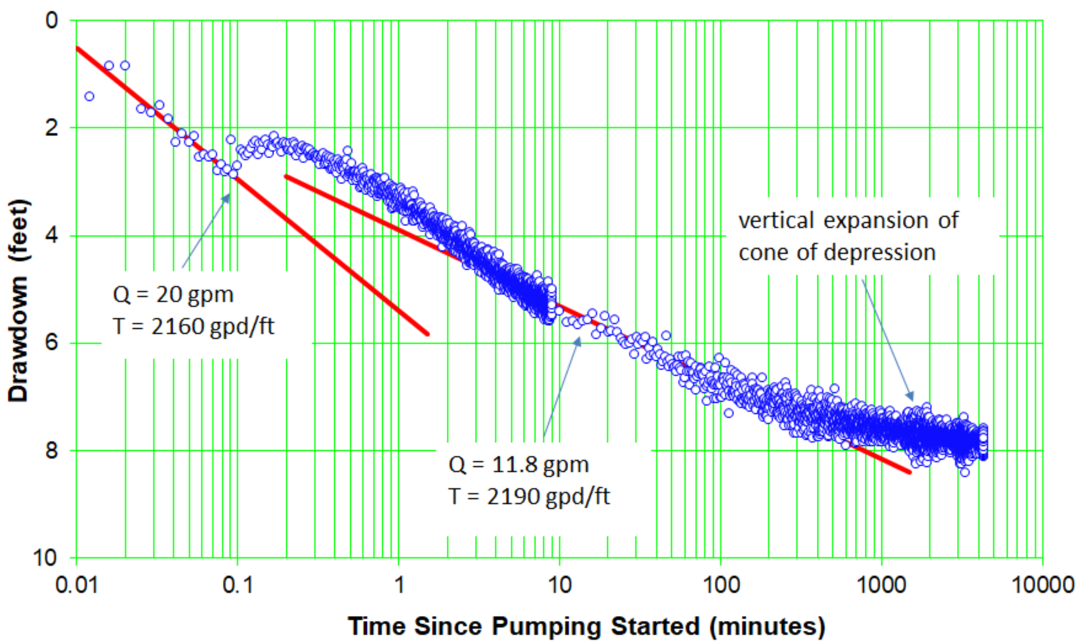

Figure F-8.2-1 Well R-69 screen 1 drawdown

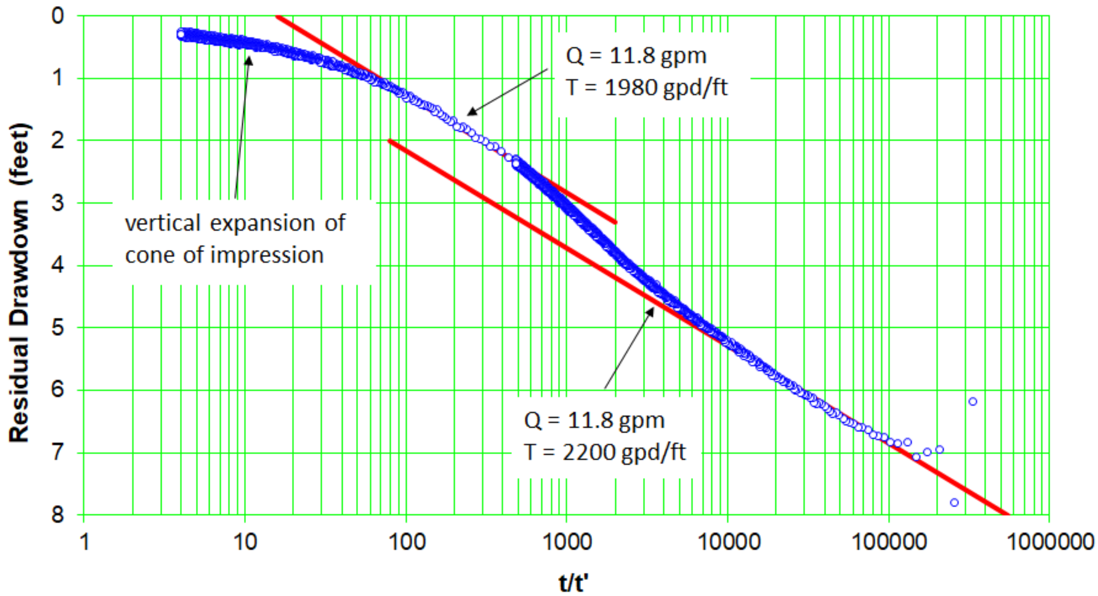

Figure F-8.2-2 Well R-69 screen 1 recovery

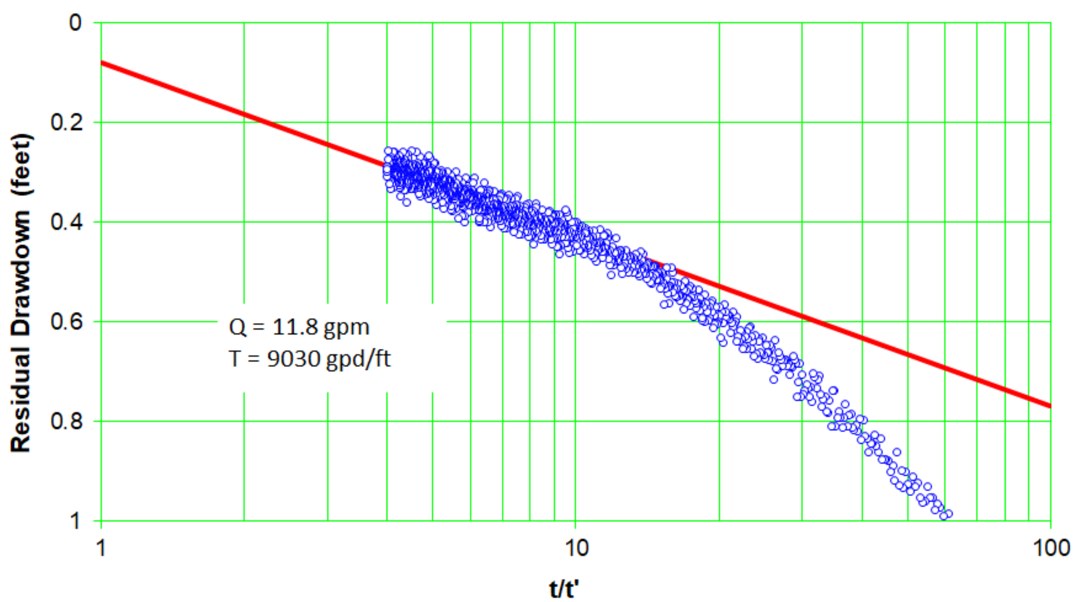

Figure F-8.2-3 Well R-69 screen 1 late-time recovery

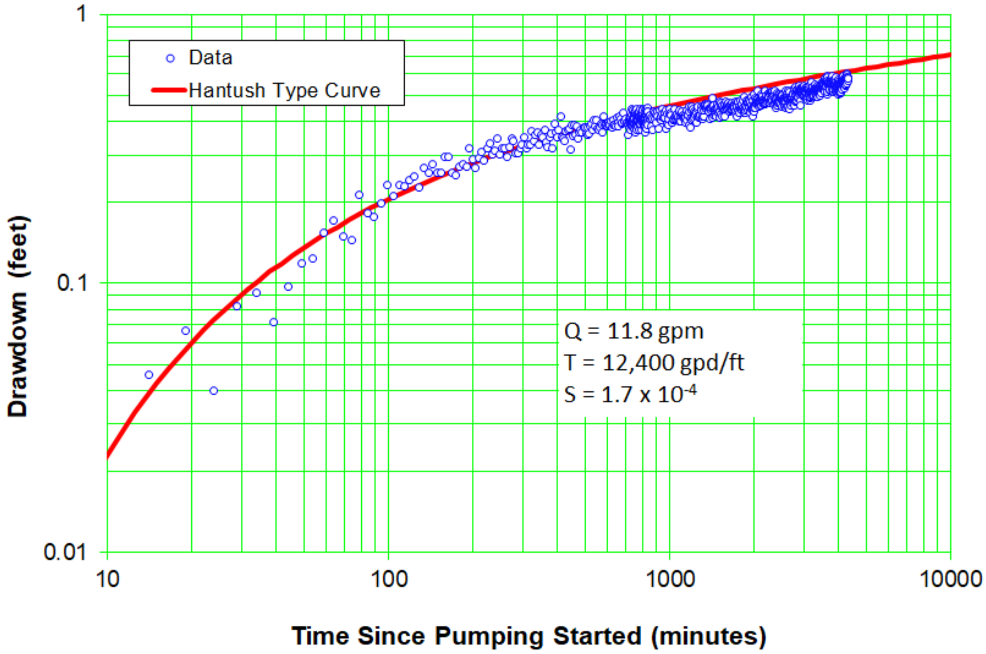

Figure F-8.2-4 Screen 2 response to screen 1 pumping for A = 0.01 and b = 150 ft

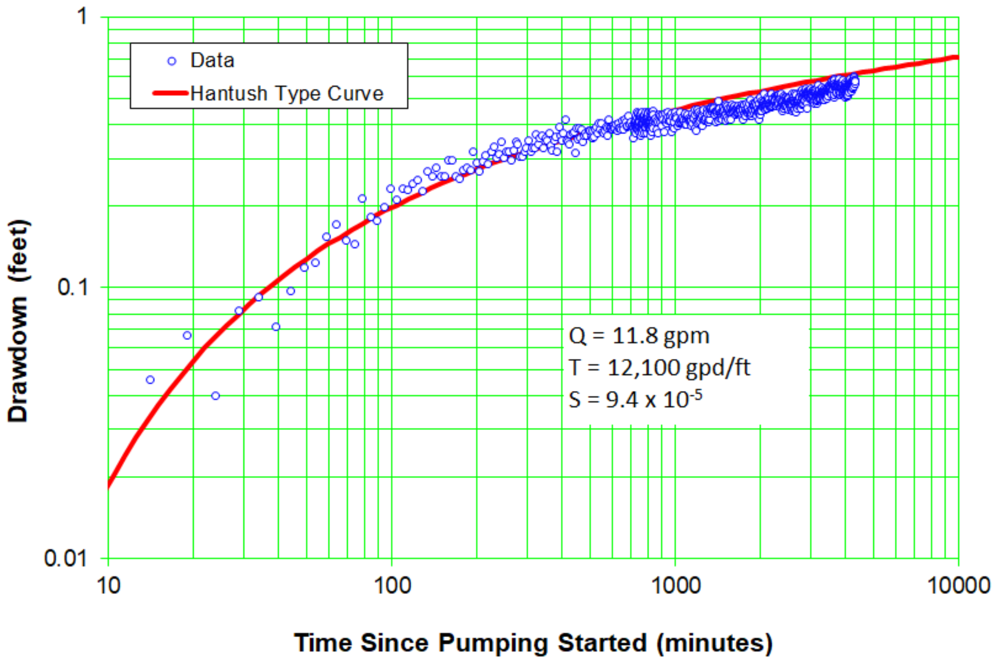

Figure F-8.2-5 Screen 2 response to screen 1 pumping for A = 0.005 and b = 150 ft

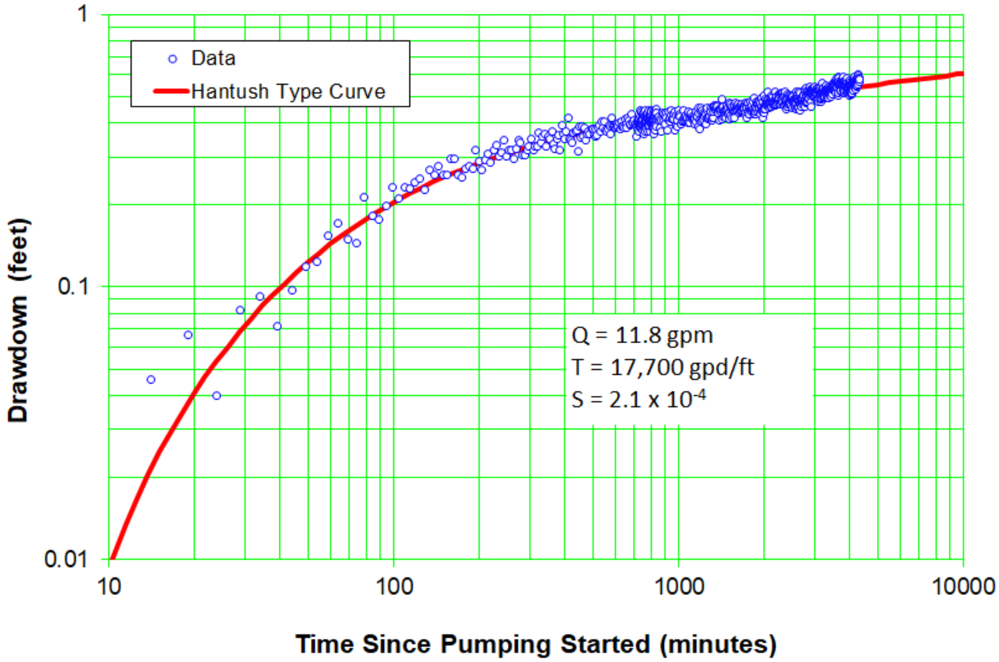

Figure F-8.2-6 Screen 2 response to screen 1 pumping for A = 0.005 and b = 300 ft

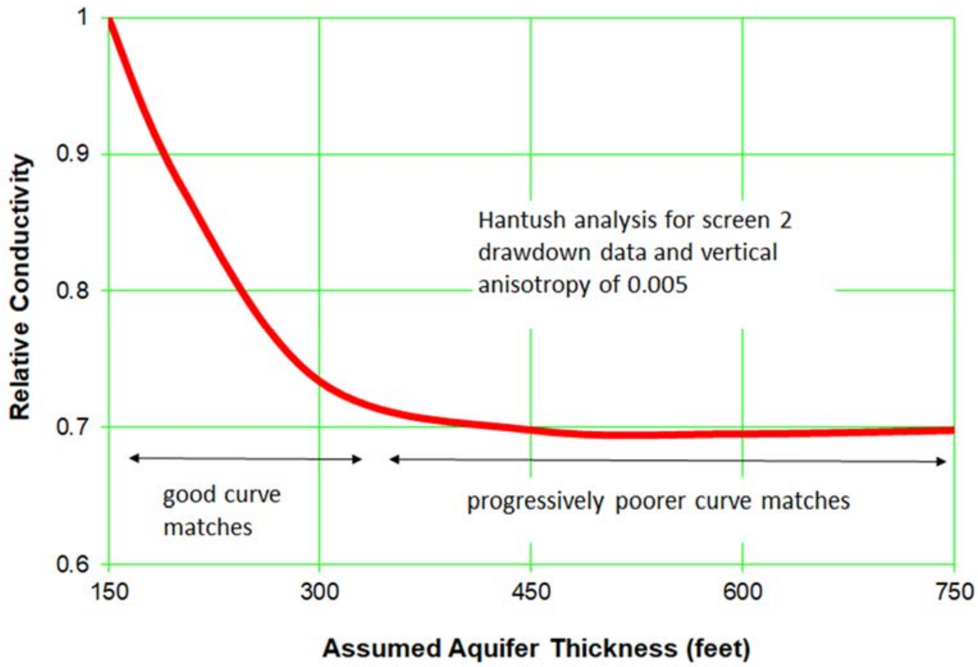

Figure F-8.2-7 Effect of aquifer thickness on computed hydraulic conductivity

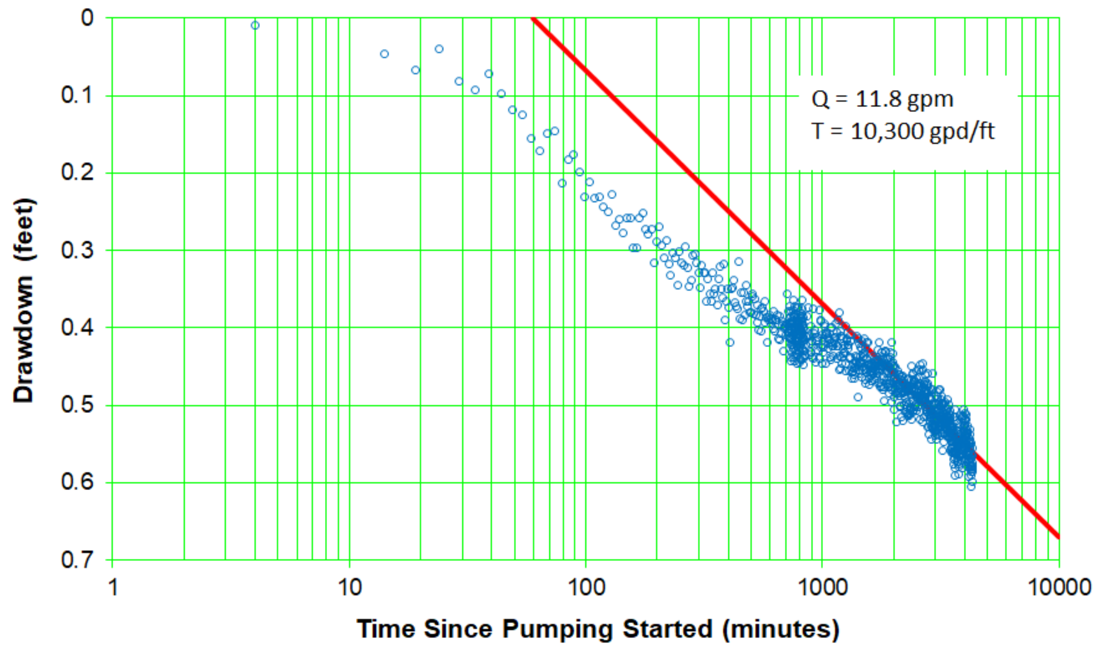

Figure F-8.2-8 Late screen 2 response to screen 1 pumping

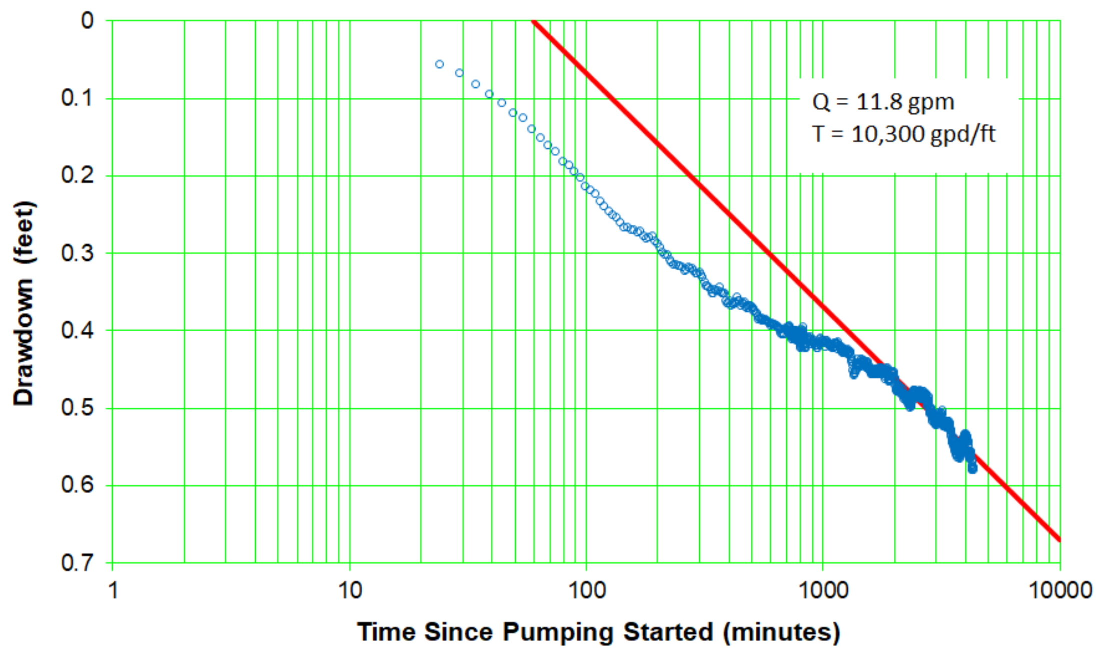

Figure F-8.2-9 Late screen 2 response – rolling average

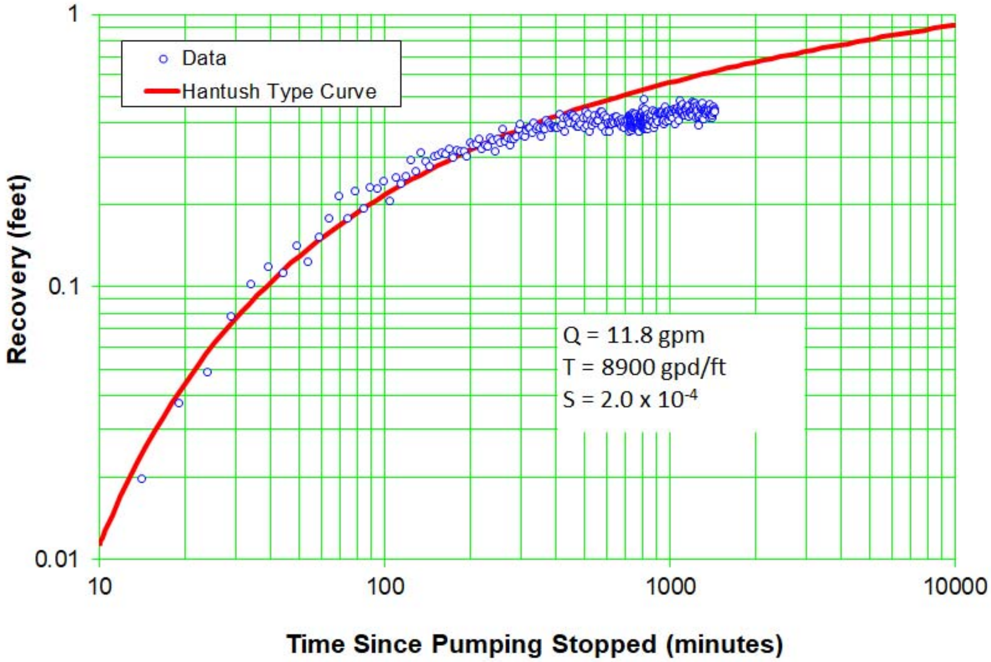

Figure F-8.2-10 Early screen 2 recovery response to screen 1 pumping for A = 0.01

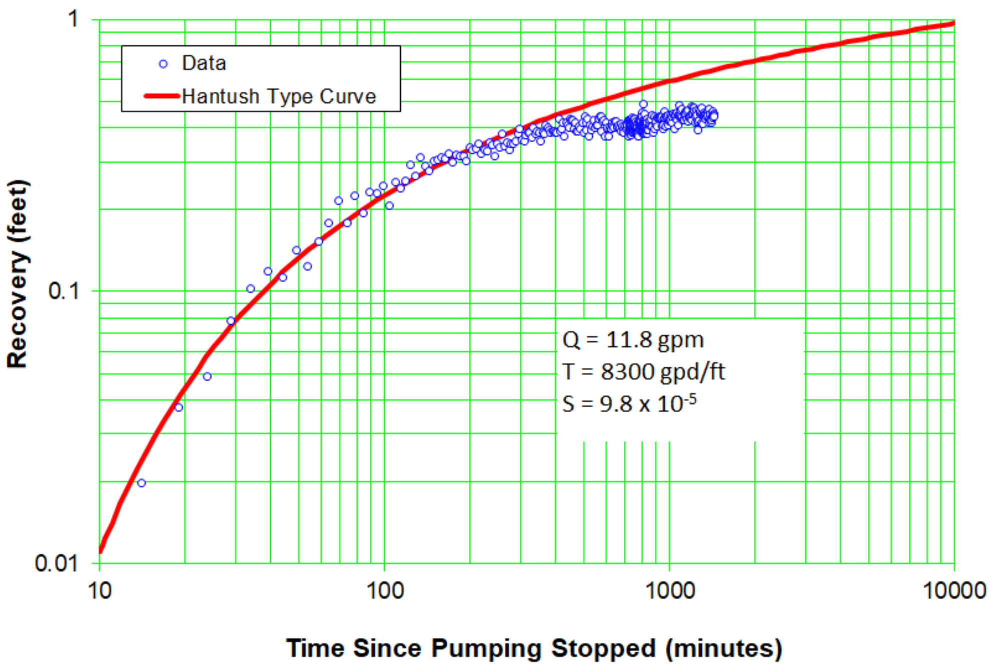

Figure F-8.2-11 Early screen 2 recovery response to screen 1 pumping for A = 0.005

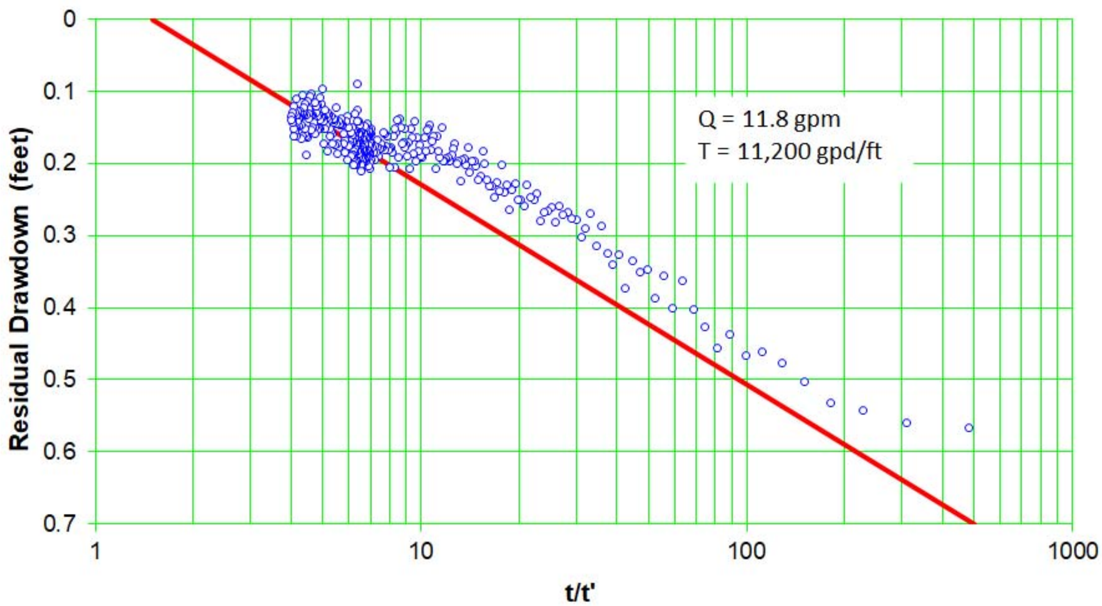

Figure F-8.2-12 Late screen 2 recovery response to screen 1 pumping

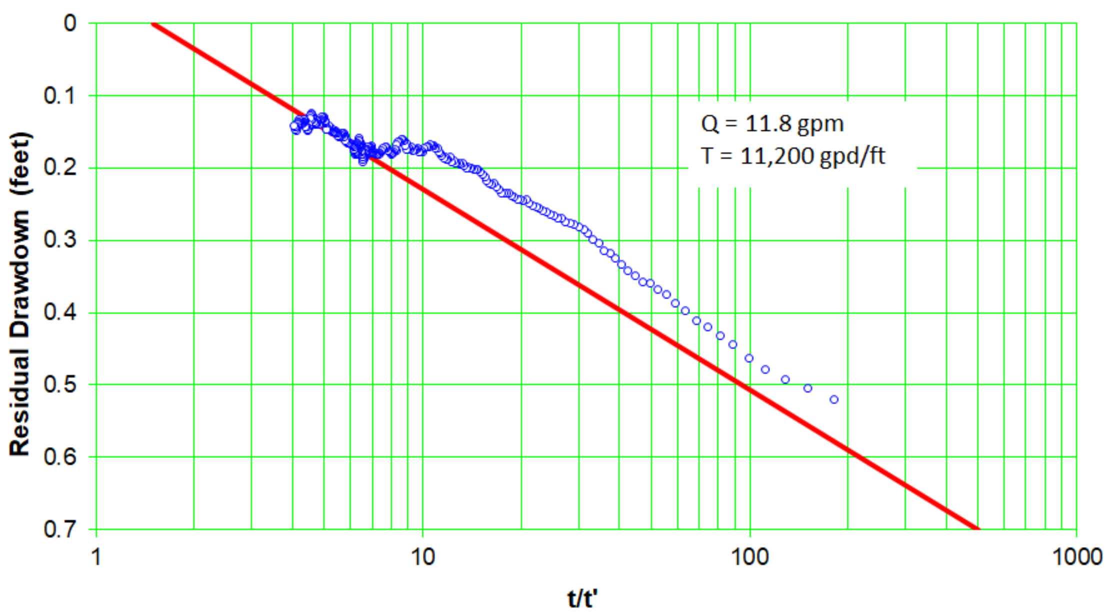

Figure F-8.2-13 Late screen 2 recovery response to screen 1 pumping – rolling average

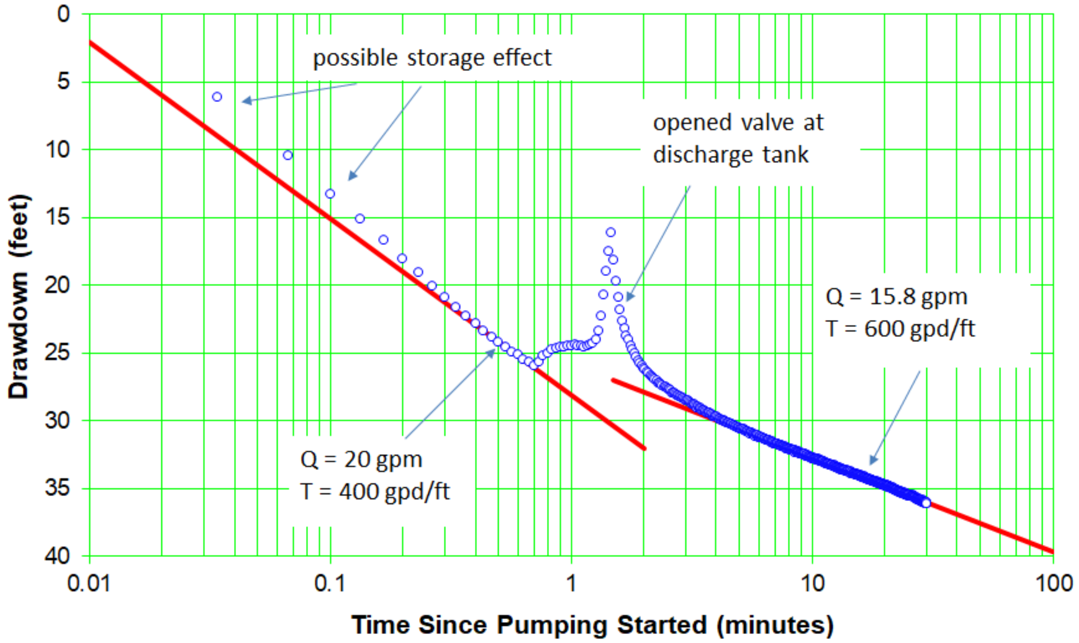

Figure F-8.3-1 Well R-69 screen 2 trial 1 drawdown

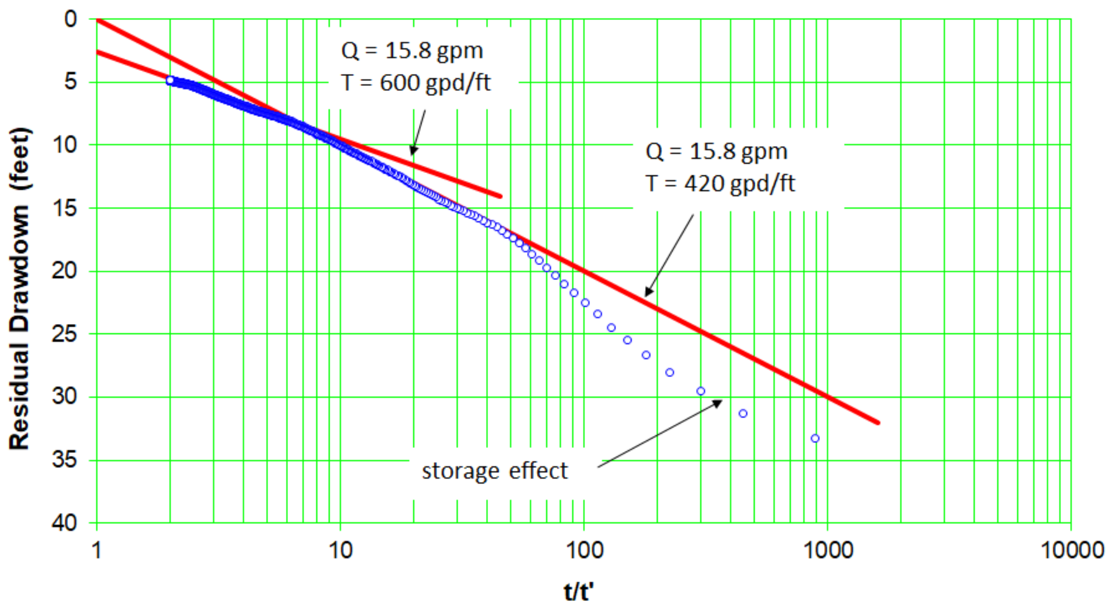

Figure F-8.3-2 Well R-69 screen 2 trial 1 recovery

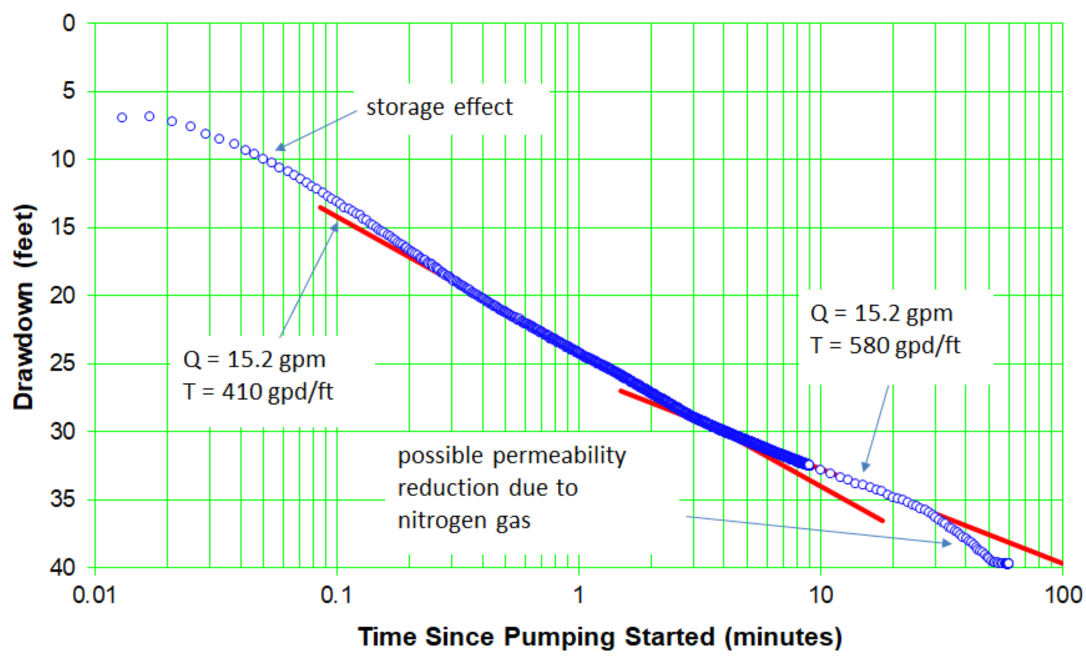

Figure F-8.4-1 Well R-69 screen 2 trial 2 drawdown

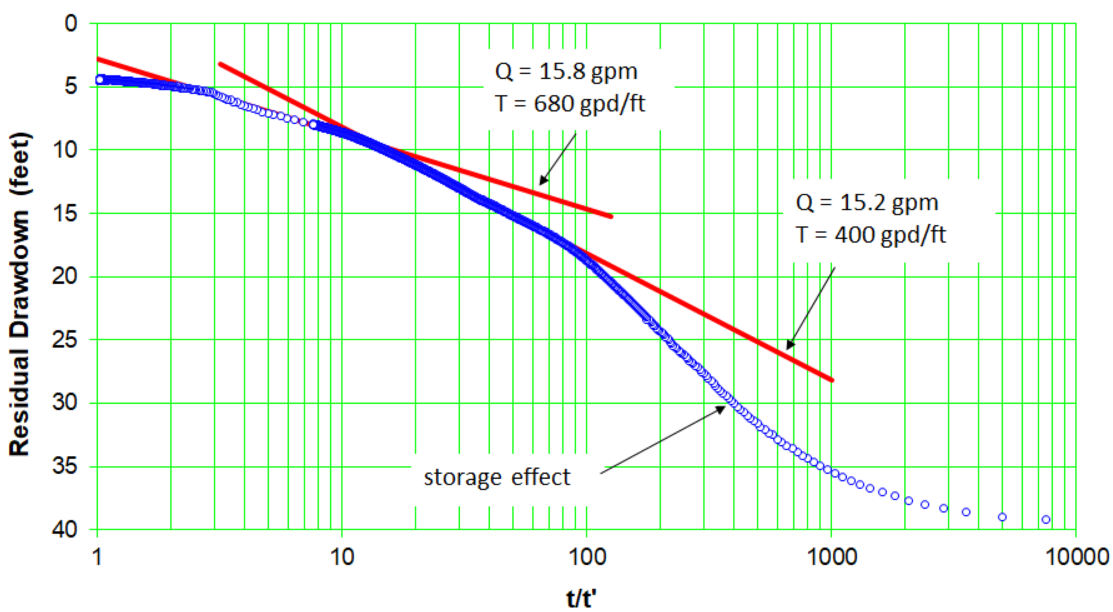

Figure F-8.4-2 Well R-69 screen 2 trial 2 recovery

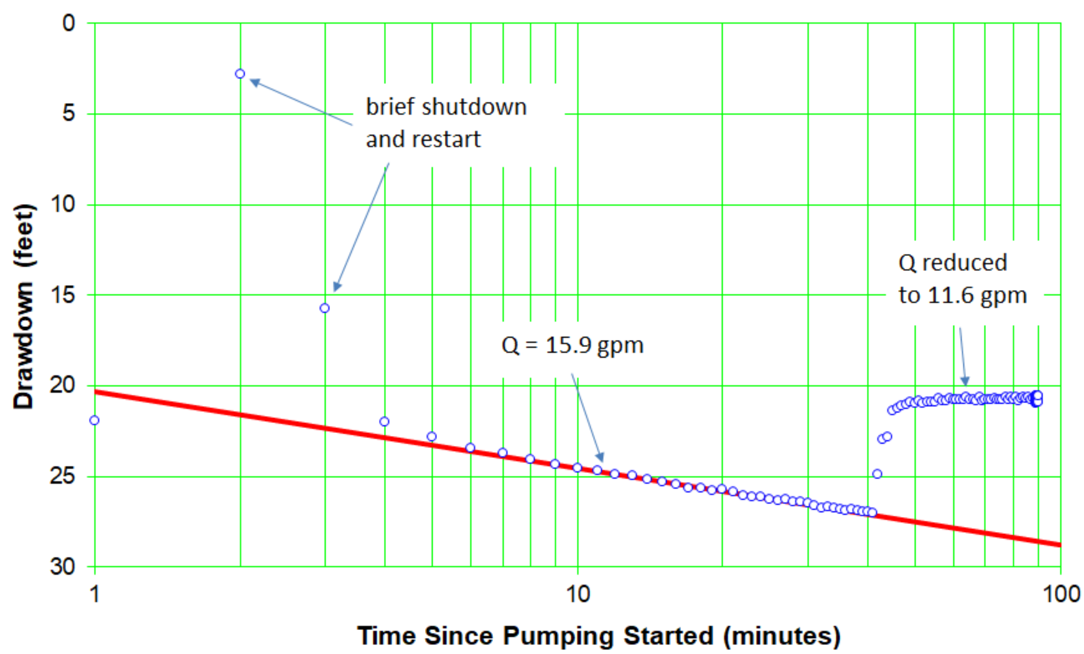

Figure F-8.5-1 Well R-69 screen 2 trial 3 drawdown

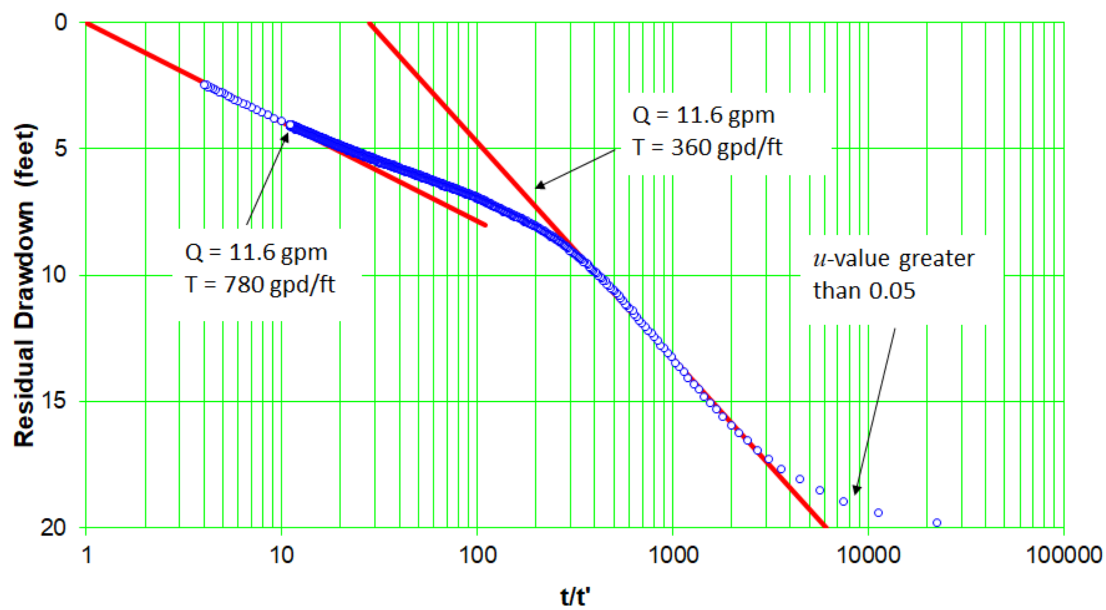

Figure F-8.5-2 Well R-69 screen 2 trial 3 recovery

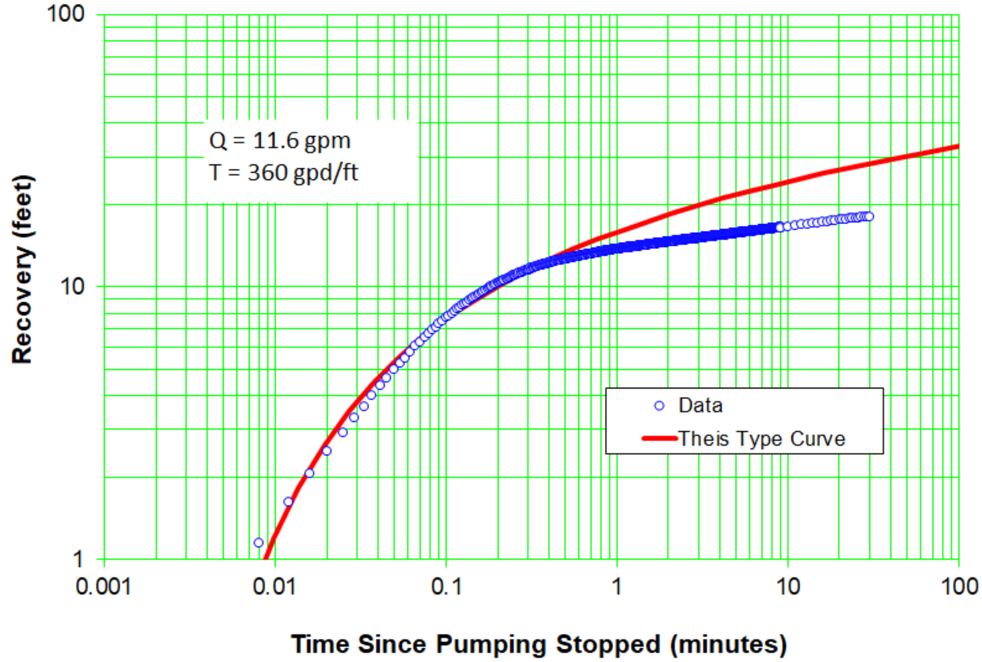

Figure F-8.5-3 Log-log analysis of well R-69 screen 2 trial 3 early recovery

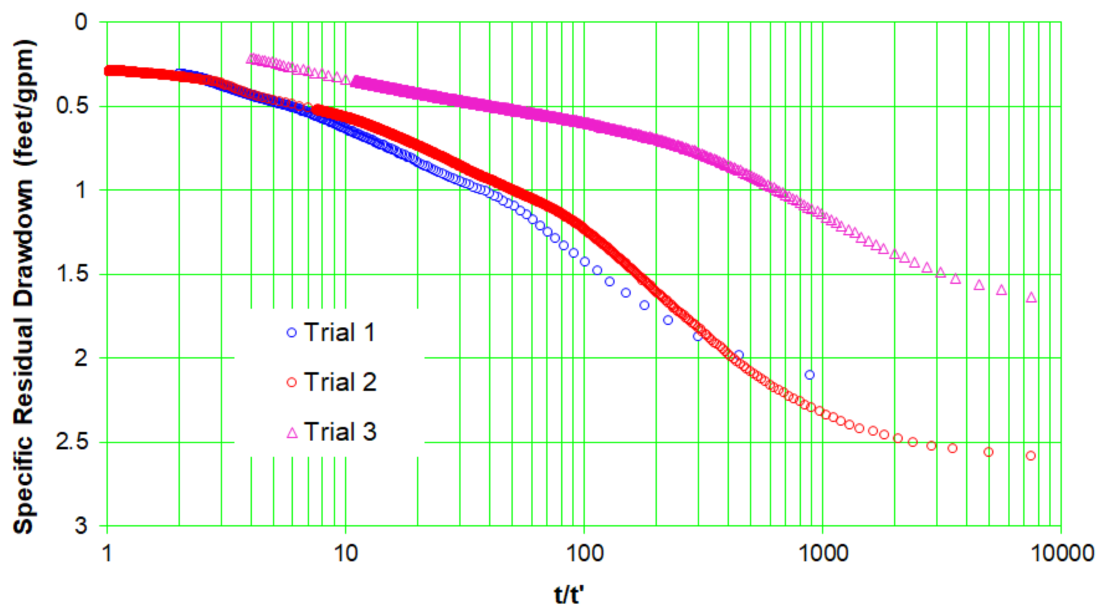

Figure F-8.6-1 Specific residual drawdown comparison for screen 2 trial tests

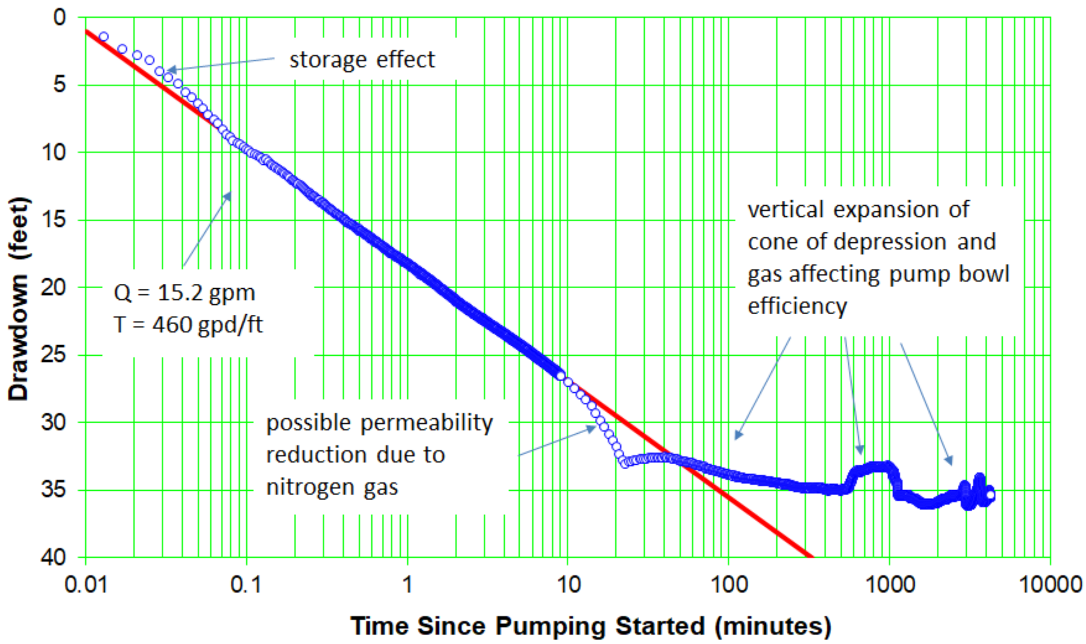

Figure F-8.7-1 Well R-69 screen 2 drawdown

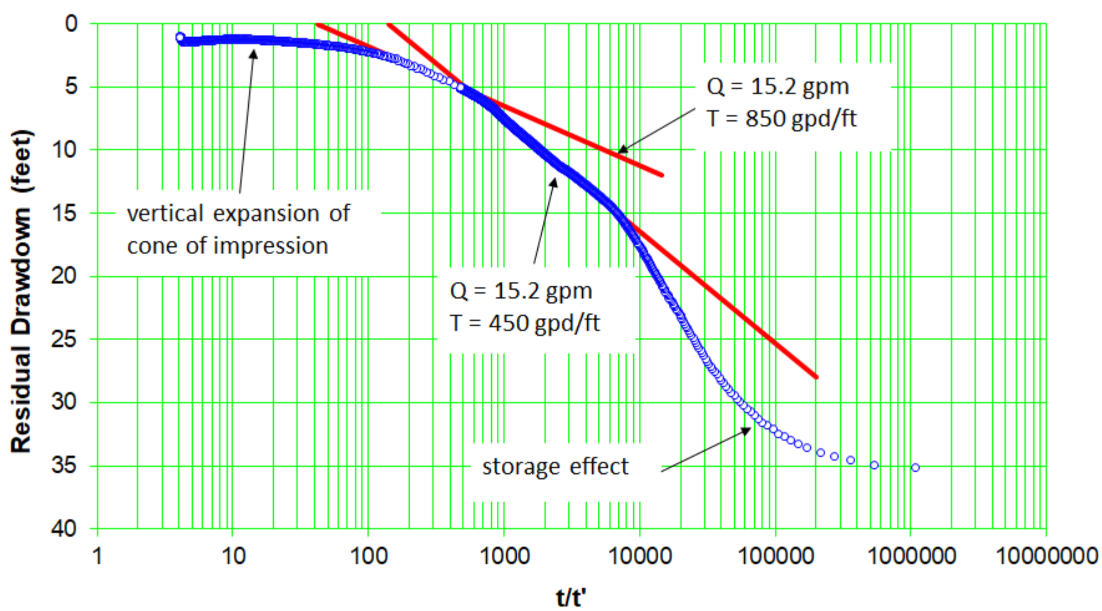

Figure F-8.7-2 Well R-69 screen 2 recovery

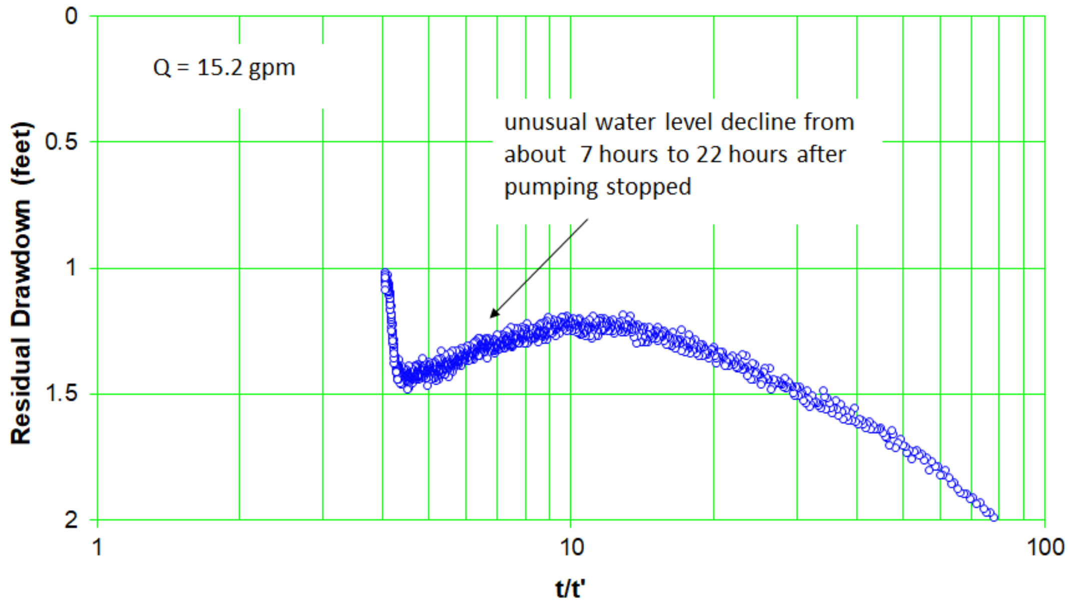

Figure F-8.7-3 Well R-69 screen 2 late time recovery

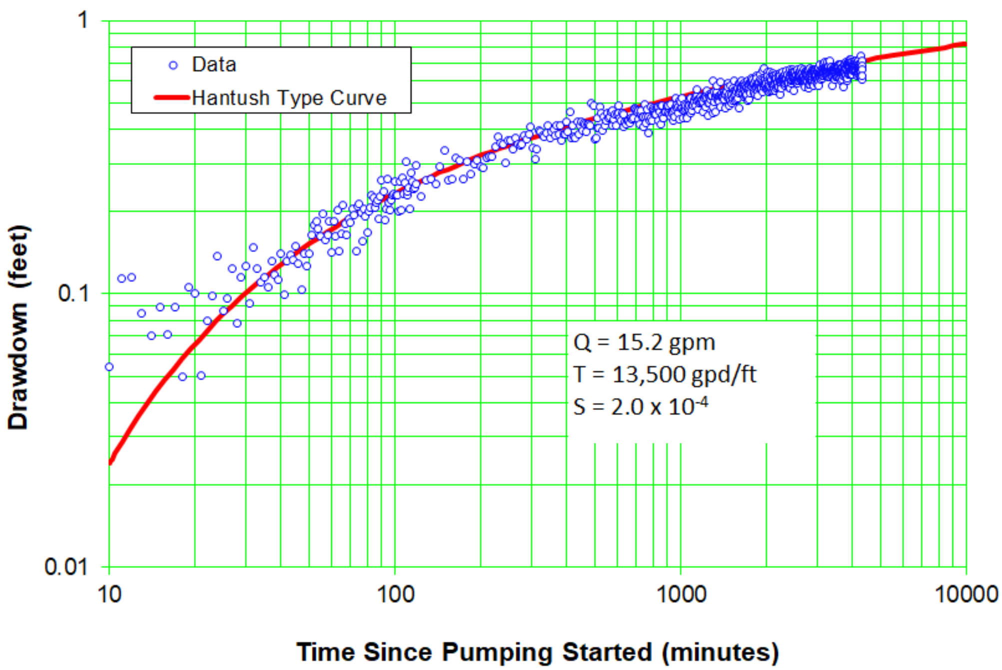

Figure F-8.7-4 Screen 1 response to screen 2 pumping for A = 0.01

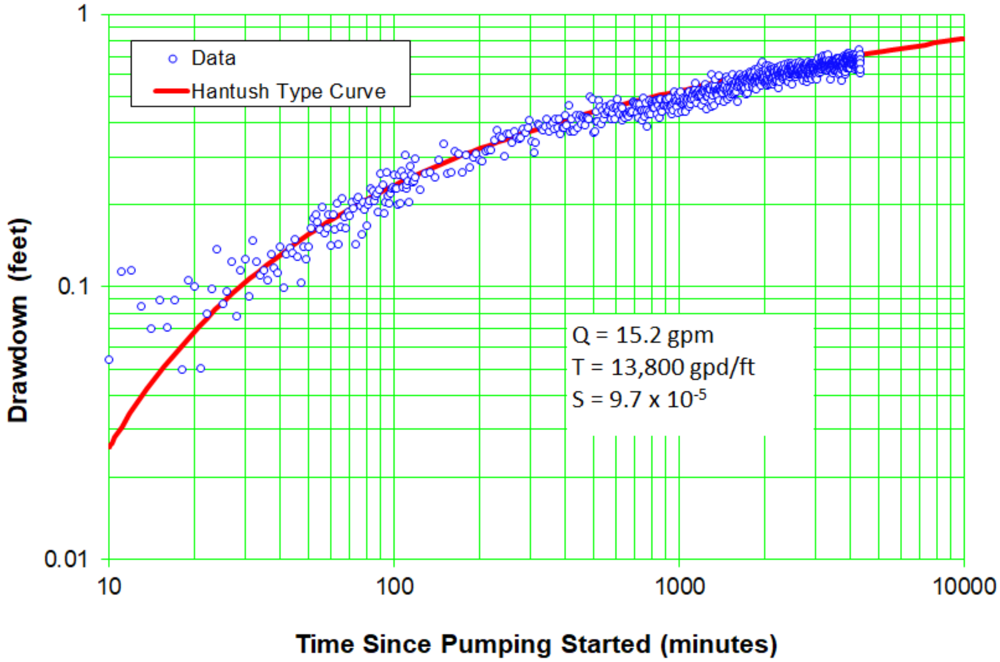

Figure F-8.7-5 **Screen 1 response to screen 2 pumping for A = 0.005**

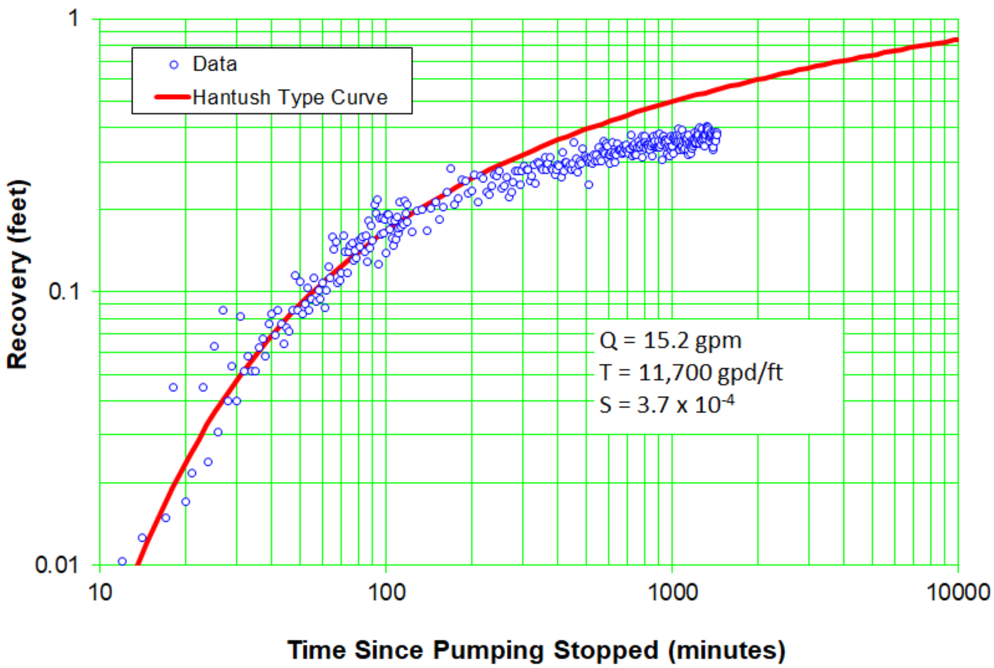

Figure F-8.7-6 **Early screen 1 recovery response to screen 2 pumping for A = 0.01**

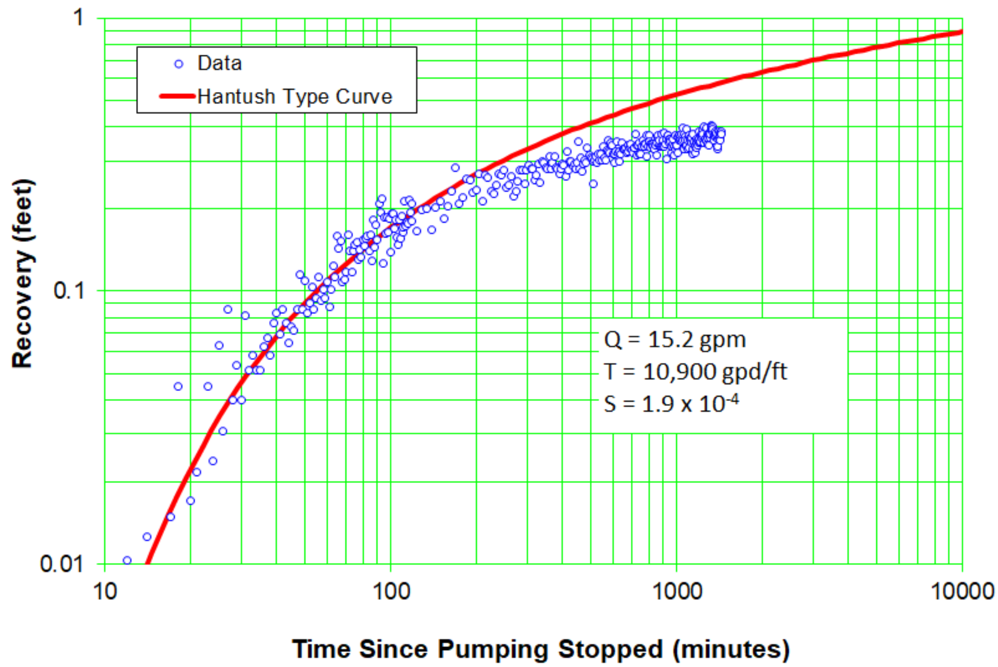

Figure F-8.7-7 Early screen 1 recovery response to screen 2 pumping for A = 0.005

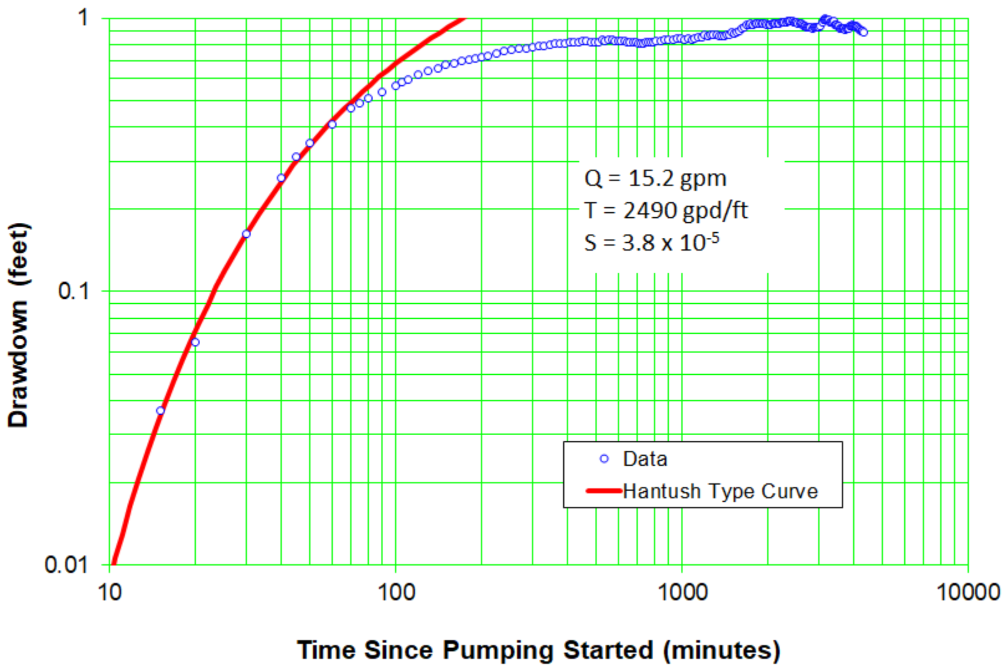

Figure F-8.7-8 Well R-18 response to screen 2 pumping for A = 0.005

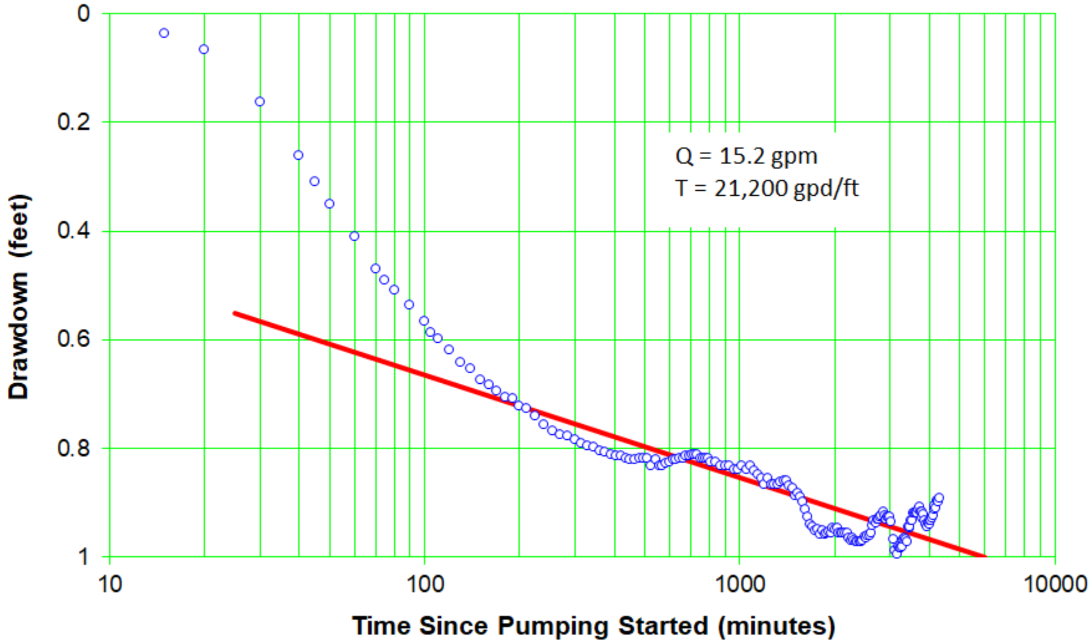

Figure F-8.7-9 Well R-18 late response to screen 2 pumping

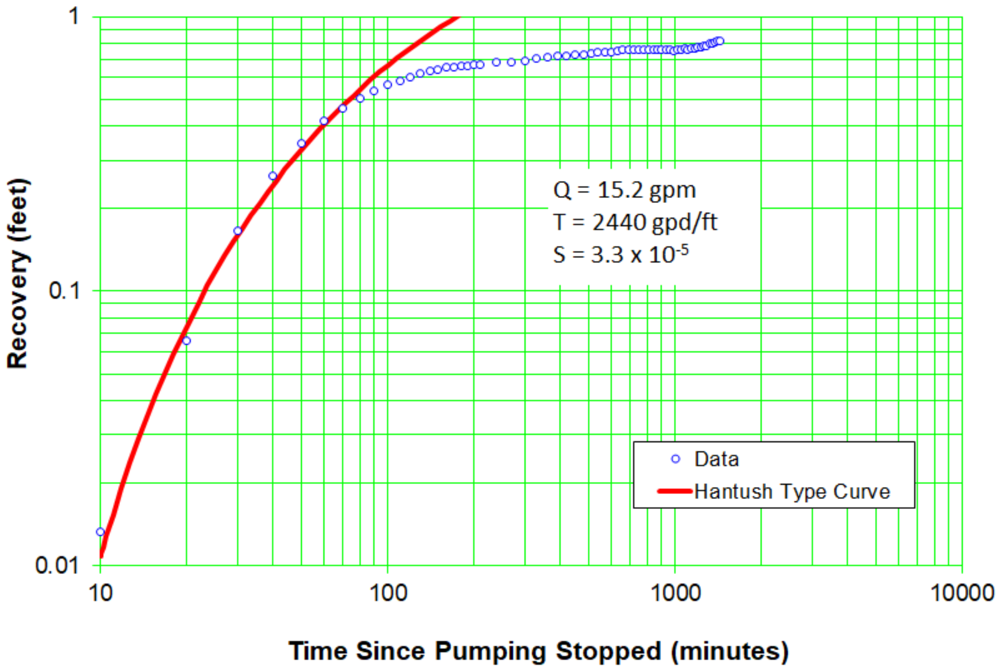

Figure F-8.7-10 Well R-18 recovery response to screen 2 pumping for A = 0.005

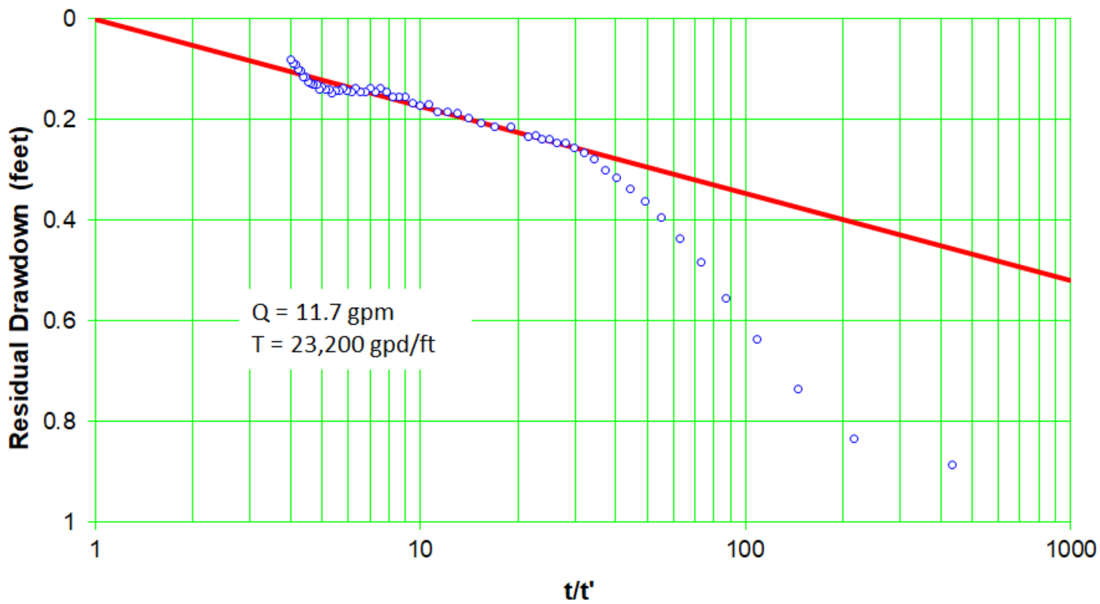

Figure F-8.7-11 Well R-18 late recovery response to screen 2 pumping

Table F-8.8-1
Aquifer Parameter Values From R-69 Screen 1 Pumping Tests

Test	Source	Data Used	Method	T (gpd/ft)
Trial 1	Screen 1	Drawdown (early)	Semilog	2170
Trial 1	Screen 1	Drawdown (middle)	Semilog	2210
Trial 1	Screen 1	Recovery (early)	Semilog	2030
Trial 1	Screen 1	Recovery (middle)	Semilog	2200
72-hour	Screen 1	Drawdown (early)	Semilog	2160
72-hour	Screen 1	Drawdown (middle)	Semilog	2190
72-hour	Screen 1	Recovery (early)	Semilog	1980
72-hour	Screen 1	Recovery (middle)	Semilog	2200
72-hour	Screen 1	Recovery (late)	Semilog	9030
72-hour	Screen 2	Drawdown (early/middle)	Hantush, A = 0.01	12,400
72-hour	Screen 2	Drawdown (early/middle)	Hantush, A = 0.005	12,100
72-hour	Screen 2	Drawdown (late)	Semilog	10,300
72-hour	Screen 2	Recovery (early/middle)	Hantush, A = 0.01	8900
72-hour	Screen 2	Recovery (early/middle)	Hantush, A = 0.005	8300
72-hour	Screen 2	Recovery (late)	Semilog	11,200

Table F-8.8-2
Aquifer Parameter Values From R-69 Screen 2 Pumping Tests

Test	Source	Data Used	Method	T (gpd/ft)
Trial 1	Screen 2	Drawdown (early)	Semilog	400
Trial 1	Screen 2	Drawdown (middle)	Semilog	600
Trial 1	Screen 2	Recovery (early)	Semilog	420
Trial 1	Screen 2	Recovery (middle)	Semilog	600
Trial 2	Screen 2	Drawdown (early)	Semilog	410
Trial 2	Screen 2	Drawdown (middle)	Semilog	580
Trial 2	Screen 2	Recovery (early)	Semilog	400
Trial 2	Screen 2	Recovery (middle)	Semilog	680
Trial 3	Screen 2	Recovery (early)	Semilog	360
Trial 3	Screen 2	Recovery (middle)	Semilog	780
72-hour	Screen 2	Drawdown (early)	Semilog	460
72-hour	Screen 2	Recovery (early)	Semilog	450
72-hour	Screen 2	Recovery (middle)	Semilog	850
72-hour	Screen 1	Drawdown (all)	Hantush, A = 0.01	13,500
72-hour	Screen 1	Drawdown (all)	Hantush, A = 0.005	13,800
72-hour	Screen 1	Recovery (early)	Hantush, A = 0.01	11,700
72-hour	Screen 1	Recovery (early)	Hantush, A = 0.005	10,900
72-hour	R-18	Drawdown	Hantush, A = 0.005	2100
72-hour	R-18	Recovery	Hantush, A = 0.005	2450

Attachment F-1

R-69 Aquifer Test Data
(on CD included with this document)

Appendix G

Sampling System Test Report for Well R-69

G-1.0 INTRODUCTION

The R-69 Baski dual valve submersible pump sampling system installation was completed on January 16, 2019, and testing of the sampling system and performance of the groundwater level gauge tubes took place on January 17, 2019.

Table G-1.0-1 shows the details of the R-69 well and sampling system components. The system is installed with the pump shroud brass cap several feet beneath screen 1, from 1334.7 to 1342.9 ft below ground surface (bgs), and a weep valve about 7.75 ft bgs. After the sampling system was installed, the packer was inflated to a pressure of 225 psi on January 16, 2019. After installation on January 16, a temporary electrical panel was wired to the pump, the lower access port valve (APV) was opened, and the lower screen was pumped to ascertain that the pump wiring was correct and to fill the drop pipe.

G-2.0 PACKER INFORMATION

The packer in R-69 is located from 1358.7 to 1361.2 ft bgs, which is 28.5 ft below screen 1 and 14.3 ft above screen 2. The packer inflation tubing uses 1/4-in. stainless-steel tubing from surface to the packer and to the closed side of the APVs. The APV control tubing is also 1/4-in. stainless-steel tubing.

The packer was initially inflated on January 16, 2019, at 11:10 Mountain Standard Time (MST) to a pressure of 225 psi. The shut-in packer pressure on the morning of January 17, 2019, before testing was 225 psi, indicating that the packer and associated tubing appeared to be holding pressure. The packer had been inflated for more than 25 hr before system testing began, so any initial packer pressure fluctuations associated with expansion and seating of the packer should have been complete. After initial packer inflation on January 16, 2019, the APVs were operated to ascertain that there were no leaks in the control lines.

During system testing on January 17, 2019, the packer pressure responded to APV opening and closing operations and appeared to hold pressure during the duration of testing. Table G-2.0-1 lists the packer pressure requirements and APV actuation pressure requirements for R-69. The minimum pressure that should be applied to the R-69 packer is 129 psi, and the maximum pressure that should be applied is 320 psi. The table shows the APV actuation pressures needed for the different packer pressures.

The formula used to determine the minimum packer inflation pressure required for proper system operation is as follows:

$$R_{\min} = 50 + M(50, 0.2h) + \frac{d_p - d_{hswl}}{2.31}$$

Equation G-1

where, Rmin = minimum packer inflation pressure required, in psi

M(a,b) = the maximum of a or b

h = head difference above and below packer, in feet

dp = depth to packer, in feet

dhswl = depth to the higher static water level of the two zones above and below the packer (usually that of the upper zone), in feet

The formula used to estimate the maximum safe packer pressure is as follows:

$$R_{\max} = 300 + \frac{M\left(-27, d_p - d_{lpwl}\right)}{2.31} \qquad \textbf{Equation G-2}$$

where, $R_{\max}$ = maximum allowable packer inflation pressure, in psi

$M(a,b)$ = the maximum of a or b

d_p = depth to packer, in feet

d_{lpwl} = depth to the lower pumping water level of the two zones, in feet

The access port valves are opened by overcoming frictional forces and the packer pressure that is keeping the valves closed. The following formula can be used to estimate the pressure required:

$$R_{APV} = f + \frac{1}{2.2}\left[3.2P - \frac{M\left(0, d_{APV} - d_{cv} - 27\right)}{2.31}\right] \qquad \textbf{Equation G-3}$$

where, R_{APV} = minimum required APV pressure, in psi

f = estimated APV sliding friction pressure requirement, in psi

P = packer pressure, in psi

$M(a,b)$ = the maximum of a or b

d_{APV} = depth to APV in feet

d_{cv} = depth to check valve, in feet

All of the terms in Equation G-3 are known exactly except the friction factor, *f*. This parameter varies from one APV to another, but 60 psi is considered a reasonable, conservative estimate.

These equations were used in conjunction with the well and sampling system geometry to estimate pressure guidelines for operating the inflatable packers and APVs as summarized in Table G-2.0-1.

For packer pressures different from those listed in Table G-2.0-1, adjust the APV pressure requirements by 1.455 psi per psi change in packer pressure.

G-3.0 GROUNDWATER-LEVEL MEASUREMENTS

Groundwater-level measurements for each screen are accessed via two 1-in.-diameter polyvinyl chloride (PVC) gauging tubes. The gauge tubes were installed at a depth of 1332.6 ft bgs. During transducer installation, the bottom of the screen 1 gauge tube was tagged and measured to be 1333.3 ft bgs, just over 1/2 ft different than expected. This difference is likely due to the limits of the measurement accuracy when running a flexible tape through more than 1300 ft of 1-in. pipe (which might tend to spiral around the drop pipe to some extent), as well as a cumulation of tiny pipe measurement inaccuracies that inevitably result during system installation.

The screen 2 gauge tube connects to 1/4-in.-diameter tubing that extends downward for about 30 ft through the pump shroud and packer to provide measurement of the groundwater level at screen 2. Two mesh filters, each 0.25-in. diameter and approximately 10 in. length, connect to the ends of the tube, one beneath the packer and one up inside the PVC gauge tube. The screen 2 gauge tube depth was not tagged so as to avoid risking damage to the filter at the bottom of the tube.

The groundwater level in each gauge tube was manually measured before transducers were installed in each gauge tube. Table G-3.0-1 summarizes the results of the manual measurements obtained on January 17, 2019. The packer had been inflated for approximately 23 hr before the manual measurements were obtained and, thus, the water levels measured were the approximate static groundwater level at each screen. The screen 1 groundwater elevation was 6135.92 ft, and the screen 2 groundwater elevation was 6126.45 ft, for a head separation of 9.47 ft between screens at the time of the manual measurements, with the upper screen having the higher head. The screens are 65.5 ft apart, center to center, for an apparent downward vertical head gradient of about 0.145 ft/ft in the interval spanned by the screens.

Note that the measured water levels in R-69 were several feet deeper than determined during the aquifer test conducted in November 2018–particularly surprising in that the November readings were taken following extensive pumping, both development and test pumping. This may be an indication that the electric water-level tape used during the November test pumping was inaccurate–possibly stretched out somewhat from its original length.

Transducers were installed in both R-69 gauge tubes on January 17, 2019, to prepare for system testing and subsequent long-term monitoring of groundwater levels.

G-4.0 R-69 SYSTEM TESTING ON JANUARY 17, 2019

Before testing, the transducers were programmed to record water levels at 5-s intervals. Figure G-4.0-1 shows the groundwater-level responses in the gauge tubes during system testing on January 17, 2019. The pumping periods for both screens are indicated on the graph for reference.

During the testing, both transducers responded well to water-level changes. The screen 2 water-level response was fairly rapid, considering the need to drain and fill the 1-in. PVC gauge tube through the 1/4-in. transfer tubing. Water-level rise and fall rates of nearly 5 ft per min were observed in the 1-in. PVC gauge tube during pumping and recovery at screen 2.

The most unusual response noted during testing was a low amplitude sinusoidal fluctuation in the screen 1 water levels. Figure G-4.0-2 shows an expanded view of the water levels recorded during the first 2 hr of testing. When data recording at screen 1 began, the water level there was declining somewhat. Within a couple minutes the trend reversed and water levels rose for about 20 min, and then declined for about 20 min. Over the next 40 min or so this cycle was repeated. However, the second water-level peak was attenuated somewhat by pumping from screen 2, because the interference drawdown effect of pumping screen 2 cancelled out some of the water-level rise at screen 1.

There was no explanation for the observed cyclical water-level fluctuations. The observed pattern is what would be expected if there were cyclic pumping occurring in another water well in the area.

G-5.0 ACCESS PORT VALVE OPERATION

With the packer inflated, each APV valve was opened for a few minutes and the pressure response at each screen gauge tube was monitored. The control tubing for the APVs in R-69 is stainless-steel tubing. The pressure applied to open the APVs was in excess of 400 psi. When the APVs were actuated, the packer pressure increased about 5 psi in response to the movement of the valve, indicating that the valve had opened. The APVs typically opened about 46 s after the nitrogen gas was applied and closed about 17 s after the gas pressure was released. However, pressure in the control lines continued to be released for an additional minute or so after the valves closed; this pressure must be entirely dissipated before disconnecting the APV control fill line quick-connect at the well head to ensure complete closure of the valves and that the valves are appropriately held closed by the packer pressure.

The lower APV was pressurized initially at 12:20 p.m. After 46 s, the packer pressure gauge showed a 5-psi increase in pressure, confirming that the lower APV had opened. As shown in Figure G-4.0-2, when the valve opened, the water level at screen 2 rose a few tenths of a foot. This indicated that water was flowing from the well into the screen 2 zone. After 5 min, the water level declined somewhat, still above the static level, indicating that the flux rate into screen 2 had lessened. At 12:36 p.m. the lower APV was depressurized and, after a 20-s delay, the valve closed, indicated by a 5-psi drop in packer pressure. At that time, flow into the aquifer at screen 2 ceased and the water level returned to static.

One theoretical explanation for a water-level rise at screen 2 when opening the lower APV is a leak in the pump shroud. If a leak existed, screen 1 water would enter the shroud through the leak and move downward into screen 2. However, if this occurred there would be a corresponding drawdown response in screen 1. As indicated in Figure G-4.0-2, this was not observed. This meant that the drop pipe was the source of water entering screen 2 and suggested a leaky check valve. Indeed, as described below, when pumping first began there was a delay in water reaching the surface, indicating that a portion of the 1-in. stainless-steel drop pipe was empty before starting the pump.

The upper APV was pressurized at 12:41 p.m. After a 48-s delay, the packer pressure gauge showed a 5-psi increase in pressure, confirming that the upper APV had opened. When the valve opened, there was a brief, transient spike in the screen 1 water level. The water level quickly returned to static and remained there during the time when the valve was closed (12:51 p.m.). When the valve was closed, there was no discernable change in head, suggesting that the check valve was holding or the leakage rate was greatly reduced.

In preparation for pumping screen 2, the lower APV was pressurized at 12:56 p.m. After 46 s, the packer pressure gauge showed a 5-psi increase in pressure, confirming that the lower APV had opened. As shown in Figure G-4.0-2, when the valve opened, the water level at screen 2 rose again, indicating the downward flow of water into screen 2. However, when the lower APV was closed following screen 2 pumping (Figure G-4.0-1), there was no discernable effect on the recovery water-level trend, suggesting that the check valve was holding or the leakage rate was miniscule. (Note that the broad scale of Figure G-4.0-1 could mask subtle water-level perturbations. However, zooming in to the critical portion of the data trace [not illustrated] confirmed that there was no visible effect on water levels when the APV was closed.)

In preparation for pumping screen 1, the upper APV was pressurized at 1:46 p.m. After 42 s, the packer pressure gauge showed a 5-psi increase in pressure, confirming that the upper APV had opened. As shown in Figure G-4.0-2, when the valve opened, the water level at screen 1 rose again, just slightly, indicating the downward flow of a tiny amount of water into screen 1. However, when the lower APV was closed following screen 1 pumping (Figure G-4.0-1), there was no discernable effect on the recovery water-level trend, suggesting that the check valve was holding or the leakage rate was greatly reduced.

(As before, despite the broad scale of Figure G-4.0-1, zooming in to the critical portion of the data trace confirmed that there was no visible effect on water levels when the APV was closed.)

G-6.0 PUMPING SCREEN 2

After actuating the lower APV at 12:56 p.m., pumping at screen 2 began at 1:00 p.m. An open sampling valve at the well head was observed closely to watch for water in order to confirm that water had reached the surface. After 20 s, however, no water was seen emerging from the valve so the pump was shut off temporarily to investigate the cause. The valve was suspected to possibly being frozen shut. But when the pump was restarted at 1:02 p.m., water emerged from the valve a few seconds later confirming that the valve was open to flow. It appeared that the delay in water reaching the valve was caused by antecedent drainage of a portion of the drop pipe. This was consistent with the idea of a leaky check valve. The delay of 25 to 30 s for water to reach the surface indicated that approximately 80 ft of drop pipe had drained before pumping.

Pumping continued at screen 2 until 1:30 p.m., long enough to simulate a sampling event. The discharge rate measured during pumping was 6.7 gallons per minute (gpm). After 28-plus min of pumping, the drawdown at screen 2 was 9.91 ft (Figure G-4.0-1) making the screen 2 specific capacity 6.7/9.91 = 0.68 gpm/ft.

At 1:35 p.m. the lower APV was depressurized and, after a 16-s delay, the valve closed, indicated by a 5-psi drop in packer pressure.

G-7.0 PUMPING SCREEN 1

After actuating the upper APV at 1:46 p.m., pumping at screen 1 began at 1:50 p.m. Pumping continued at screen 1 for 40 min until 2:30 p.m., long enough to simulate a sampling event for screen 1. The discharge rate measured during pumping was 7.0 gpm. After 40 min of pumping, the drawdown at screen 1 was 3.19 ft (Figure G-4.0-1) making the screen 1 specific capacity 7.0/3.19 = 2.19 gpm/ft.

At 2:35 p.m. the upper APV was depressurized and, after a 17-s delay, the valve closed, indicated by a 5-psi drop in packer pressure.

G-8.0 CASING AND PURGE VOLUMES

Casing and drop-pipe volumes were calculated to determine purging requirements for screens 1 and 2 at R-69. In computing the criteria, the unit volumes used for the 5-in. casing and 1-in. minimum-wall drop pipe were 1.04 gal./ft and 0.039 gal./ft, respectively. Table G-8.0-1 lists the parameters associated with calculation of the casing and purge volumes at each screen.

For screen 1, the casing purge length was taken as the distance from the static water level (1294.2 ft bgs) to the top of the packer (1358.7 ft bgs), or 64.5 ft. This corresponded to a water volume (CV) of 67.1 gal. The drop-pipe length was taken as the distance from the static water level (1294.2 ft bgs) to the top of the drop pipe at 2.5 ft above ground surface, for a total distance of 1296.7 ft. The corresponding volume was 50.6 gal. Thus, the purge volume for a single CV plus drop pipe is 67.1 + 50.6 = 117.7 gal. The purge volume for 3 CVs plus drop pipe is 3 × 67.1 + 50.6 = 251.9 gal. At a pumping rate of 7.0 gpm, the time to purge 3 CVs plus drop pipe is 36.0 min.

For screen 2, the casing purge length was taken as the distance from the bottom of the packer (1361.2 ft bgs) to the bottom of the well (1406.2 ft bgs), or 45.0 ft. This corresponded to a water volume (CV) of 46.8 gal. The drop-pipe length was taken as the distance from the bottom of the packer (1361.2 ft bgs) to the top of the drop pipe at 2.5 ft above ground surface, for a total distance of 1363.7. The corresponding volume was 53.2 gal. Thus, the purge volume for a single CV plus drop pipe is 46.8 + 53.2 = 100.0 gal. The purge volume for 3 CVs plus drop pipe is 3 × 46.8 + 53.2 = 193.6 gal. At a pumping rate of 6.7 gpm, the time to purge 3 CVs plus drop pipe is 28.9 min.

G-9.0 POSSIBLE CHECK VALVE LEAK

Operation of the sampling system showed symptoms of a leaky check valve, with the magnitude of the leak changing over time. If debris is stuck in the valve, it is possible that the check valve performance could improve over time as debris is flushed away by pumping.

In theory, there are several possible sources of leakage in a Baski sampling system: (1) check valve, (2) coupling joints, (3) APVs, (4) pump shroud, and (5) packer. However, because a water-level rise is seen in each zone when the respective APV is opened, and because the rise in level at screen 2 is not accompanied by a corresponding decline in level at screen 1, the check valve or associated threaded connection just above the check valve and inside the pump shroud would appear to be the source of the leak.

The water level in the 1-in. drop pipe declined to a level beneath the weep valve on more than one occasion:

- The delay in getting water to the surface when pumping screen 2 on January 17 implied antecedent drainage of about 80 ft of drop pipe since well operation on January 16.
- After the well sat idle for 9 days, from January 17 to 26, the water level in the drop pipe was tagged and found to be about 22 ft bgs.
- After sitting idle overnight, on the morning of January 27 the level in the drop pipe was about 28 ft bgs.
- After sitting idle overnight, on the morning of January 28 the level in the drop pipe was about 27 ft bgs.

Whenever pumping stops, water leaking through the check valve (or fitting immediately above the valve, inside the pump shroud) is free to flow into the zone that was pumped. This occurs until the APV is closed. Once the APV closes, additional leakage is directed up the vent tube. As water rises in the vent tube, the driving head forcing water through the valve diminishes and, presumably, so does the leakage rate. This may account for the fact that the amounts of 1-in. drop pipe that had drained by January 26, 27, and 28 were similar (22, 28, and 27 ft, respectively) even though the first episode was 9 days long while the other two were less than 1 day in duration.

Based on the relative diameters, the water draining from 20 ft of 1-in. drop pipe is sufficient to fill approximately 600 ft of 1/4-in. nylon vent tube. After equilibrium occurs, the next time an APV is opened, the water in the vent tube can drain suddenly into the well causing measurable water level rises such as those observed in Figure G-4.0-2.

If water in the vent tube rises to the same level as that in the 1-in. drop pipe, the internal pressure within the nylon tube could reach approximately 540 psi. This is below the safe working pressure of the nylon tube of 625 psi (an empirical guideline determined by Baski, Inc.) Thus, there should be no deleterious effects on the tubing caused by the leakage. Further, once the APV has been closed, no more than about 40 ft of 1-in. drop pipe would be expected to drain into the well before pressures in the drop pipe and 1/4-in. tube would equalize causing leakage to cease.

G-10.0 CROSSFLOW FROM SCREEN 1 TO SCREEN 2

There have been several episodes of crossflow of screen 1 water into screen 2 since completion of the November pumping tests:

- 640 min from 8:00 a.m. to 6:40 p.m. on November 20, 2018, when the test pump was removed and a temporary packer was installed.
- 57 min from 10:30 a.m. to 11:27 a.m. on December 4, 2018, during brief work at the wellhead.
- 6190 min from 9:53 a.m. on January 11, 2019, to 5:03 p.m. on January 15, 2019, during the Baski system installation.
- 178 min from 8:12 a.m. to 11:10 a.m. on January 16, 2019, during final hookup and pressurization of the Baski system.

It was necessary to estimate the volume of the crossflow so that suitable purging of screen 2 could be performed to remove the crossflow.

The crossflow rate, Q, can be computed using the following formula:

$$Q = h\frac{c_1 c_2}{c_1 + c_2}$$ **Equation G-4**

where, Q = cross flow rate, in gpm

c1 = specific capacity of screen 1, in gpm/ft

c2 = specific capacity of screen 2, in gpm/ft

h = head difference between screens 1 and 2, in ft

The total cross flow volume over a time, t, can then be computed as the product Qt. Expressing t in minutes yields the crossflow volume in gallons.

In assessing the crossflow, using the 24-hr specific capacity to calculate the estimate was judged appropriate. At shorter times, the specific capacity is greater and over longer periods, it declines slightly. The capacity after 24 hr of pumping serves as a reasonable representation of average conditions.

During system testing, screen 1 produced 7.0 gpm with a drawdown of 3.19 ft after 40 min of pumping. Using information from the extended pumping test conducted in November, the increase in drawdown that would have occurred had the well been pumped for 24 hr was estimated to be 0.84 ft, making the extrapolated 24-hr drawdown 4.03 ft and the 24-hr specific capacity 7.0/4.03 = 1.74 gpm/ft.

Screen 2 produced 6.7 gpm with a drawdown of 9.91 ft after 29 min of pumping. The estimated incremental drawdown after 24 hr of pumping was 0.72 ft, making the extrapolated 24-hr drawdown 10.63 ft and the 24-hr specific capacity 6.7/10.63 = 0.63 gpm/ft.

These specific capacities are greater than those observed during the November test pumping, especially for screen 2 (14 percent for screen 1 and 47 percent for screen 2). During those tests, there was a great deal of nitrogen gas and air in formation, particularly in screen 2, reducing the hydraulic conductivity, transmissivity, and discharge rates. Over time, the gas has dissipated, dissolved, and moved downgradient. Also, screen 1 water moving into screen 2 would have reduced the gas content there substantially by pushing the gas away from the well bore.

The groundwater elevations in screen 1 and 2 were measured at 6135.92 and 6126.45 ft above mean sea level (amsl), respectively, making the head difference between the two zones 9.47 ft.

Using the 24-hr specific capacities and the head difference between the screen zones, the calculated crossflow rate was computed as 4.38 gpm. Thus, the total crossflow duration was 7065 min. This makes the crossflow volume estimate 4.38 × 7065 = 30,940 gal.

G-11.0 SUMMARY

Testing of the Baski sampling system on January 17, 2019, provided the following information:

- The groundwater elevations in screens 1 and 2 were 6135.92 and 6126.45 ft amsl, for a difference of 9.47 ft and a downward gradient of 0.145 ft/ft.
- The packer was set to the midrange pressure level of 225 psi at 11:10 a.m. on January 16. (The pressure has not changed since a week and a half after that time.)
- The packer, pump, pump shroud and APVs appeared to function normally during testing.
- There appeared to be a minor leak in the check valve, which could allow up to about 40 ft of 1-in. drop pipe to drain following each sampling event. This minor leak will not affect sample results.
- The 1/4-in. stainless-steel screen 2 transfer tube appeared to be functioning well, allowing rapid water-level response in the 1-in. PVC screen 2 gauge tube.
- The pumping rate at screen 1 was 7.0 gpm with a drawdown of 3.19 ft for a specific capacity of 2.19 gpm/ft.
- The pumping rate at screen 2 was 6.7 gpm with a drawdown of 9.91 ft for a specific capacity of 0.68 gpm/ft.
- The screen 1 casing volume and drop pipe volume are 67.1 and 50.6 gal., respectively. The volume of 3 CVs plus drop pipe is 251.9 gal. At a discharge rate of 7.0 gpm, the purge time is 36.0 min.
- The screen 2 casing volume and drop pipe volume are 46.8 and 53.2 gal., respectively. The volume of 3 CVs plus drop pipe is 193.6 gal. At a discharge rate of 6.7 gpm, the purge time is 28.9 min.

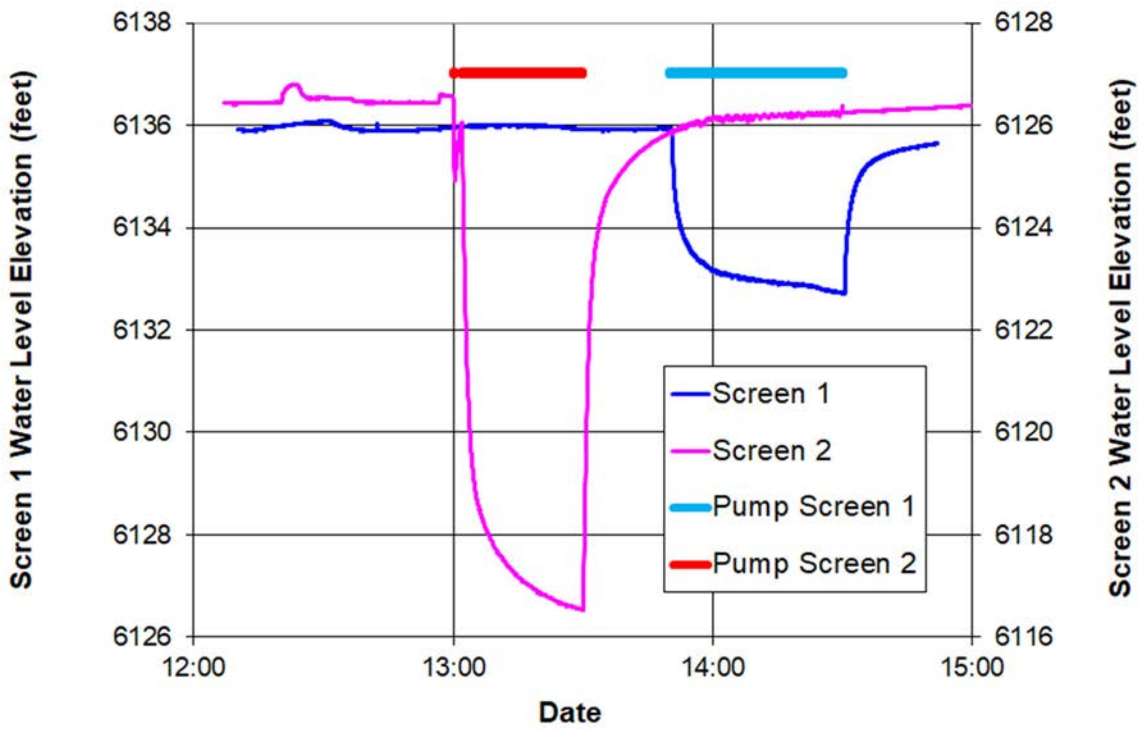

Figure G-4.0-1 Well R-69 response to pumping on January 17, 2019

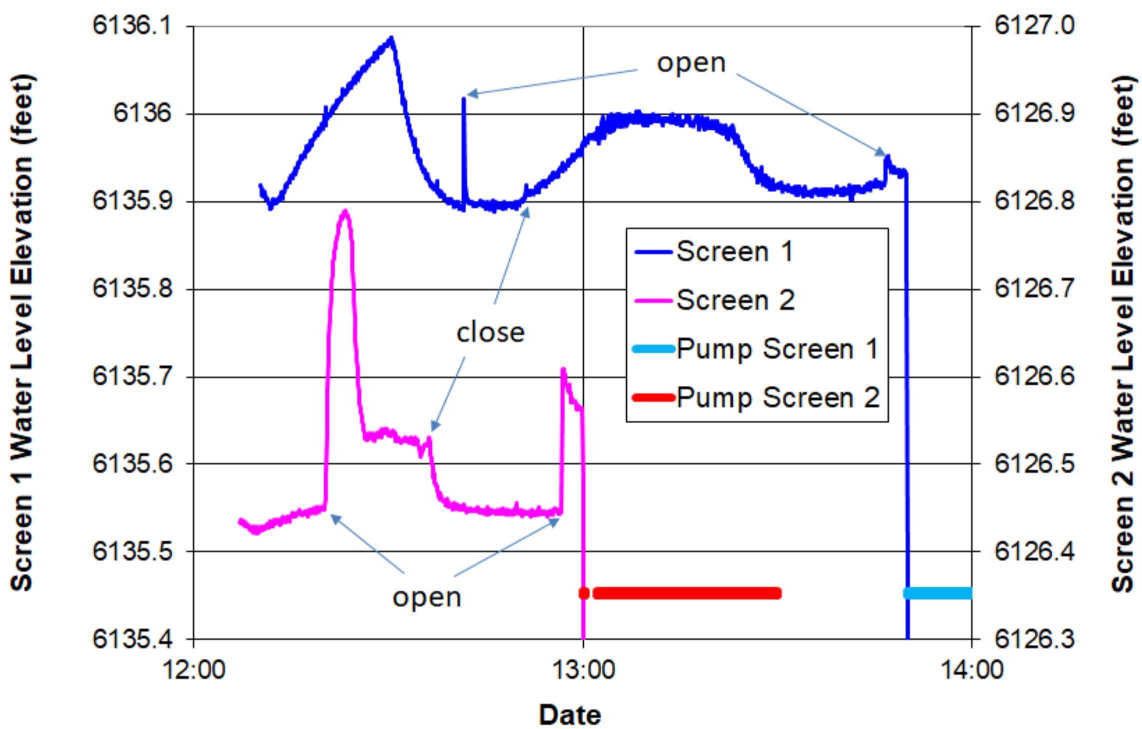

Figure G-4.0-2 Well R-69 APV operation

Table G-1.0-1
R-69 Completion Details

System Component	Depth (ft bgs)	Elevation (ft)
Screen 1 top	1310.0	6120.1
Screen 1 bottom	1330.2	6099.9
Screen 2 top	1375.5	6054.6
Screen 2 bottom	1395.8	6034.3
Upper APV intake center	1347.0	6083.1
Lower APV intake center	1374.2	6055.9
Packer top	1358.7	6071.4
Packer bottom	1361.2	6068.9
Upper transducer screen top	1323.0	6107.1
Upper transducer screen bottom	1332.3	6097.8
Lower transducer screen top	1363.2	6066.9
Lower transducer screen bottom	1363.9	6066.2
Pump shroud top	1334.7	6095.4
Pump shroud bottom	1342.9	6087.2
LIC* top	1348.7	6081.4
LIC bottom	1353.4	6076.7
Casing bottom	1406.2	6023.9

* LIC = Liquid inflation chamber.

Table G-2.0-1
Pressure Requirements for Operating the Baski System at R-69

System Component	Minimum Packer Pressure Required (psi)	Action Packer Pressure (psi)	Target Packer Pressure (psi)	Maximum Packer Pressure Allowable (psi)
Packer	129	177	225	320
Upper APV	247	317	387	525
Lower APV	245	315	385	523

Table G-3.0-1
Manual Water-Level Measurements on January 17 2019

Well	Time (MST)	Gauge Tube	Outer Casing Height (ft)	Water Level from TOC (ft)	Water Level from Brass Cap (ft bgs)	Water Elevation (ft)
R-69	9:52 AM	1	3.56	1307.24	1303.68	6135.92
R-69	10:23 AM	2	3.56	1297.77	1294.21	6126.45

Table G-8.0-1
Purge Volumes

System Item	Dimension
Screen 1 water level	1294.2 ft bgs
Top of packer	1358.7 ft bgs
Screen 1 saturated casing length	64.5 ft
Screen 1 casing purge volume	67.1 gal.
1-in. drop-pipe length above water level	1296.7 ft
Screen 1 1-in. drop-pipe purge volume	50.6 gal.
Screen 1 purge volume for 3 CVs plus drop pipe	251.9 gal.
Screen 1 purge time at 7.0 gpm	36.0 min
Bottom of packer	1361.2
Bottom of casing	1406.2
Screen 2 saturated casing length	45.0 ft
Screen 2 casing purge volume	46.8 gal.
1-in. drop-pipe length above bottom of packer	1363.7 ft
Screen 2 1-in. drop pipe purge volume	53.2 gal.
Screen 2 purge volume for 3 CVs plus drop pipe	193.6 gal.
Screen 2 purge time at 6.7 gpm	28.9 min