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

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

Subject: Submittal of the Completion Report for Regional Aquifer Well R-70

Dear Mr. Cobrain:

Enclosed please find two hard copies with electronic files of the "Completion Report for Regional Aquifer Well R-70."

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-70 (EM2019-0365)

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December 2019
EM2019-0365

Completion Report for Regional Aquifer Well R-70

N3B Los Alamos

EM2019-0365

Completion Report for Regional Aquifer Monitoring Well R-70

December 2019

Responsible program director:

Bruce Robinson		Program Director	Water Program	12/12/19
Printed Name	Signature	Title	Organization	Date

Responsible N3B representative:

Erich Evered		Program Manager	N3B Environmental Remediation Program	12/12/2019
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Responsible DOE EM-LA representative:

Arturo Q. Duran		Compliance and Permitting Manager	Office of Quality and Regulatory Compliance	12/19/19
Printed Name	Signature	Title	Organization	Date

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-70, located in Technical Area 05 at Los Alamos National Laboratory, Los Alamos, New Mexico. The R-70 monitoring well was installed as part of the Chromium Groundwater Project monitoring network. Well R-70 was installed at an angle of 25 degrees from the vertical to a measured distance (MD) down the borehole of 1100 ft, equating to a depth below ground surface (bgs) at the well pad of 997 ft. Well R-70 has two screens in the Puye and pumiceous Puye Formation to provide samples from the regional aquifer. Before drilling and construction of well R-70, there were no monitoring points located within the estimated footprint of the chromium plume east of chromium extraction well CrEX-5 that could be used to monitor the actual plume response to the chromium plume interim measure (IM) actions at chromium extraction well CrEX-5.

Installation of well R-70 fulfills a recommendation made in the “Evaluation of Chromium Plume Control Interim Measure Operational Alternatives for Injection Well CrIN-6,” approved by the New Mexico Environment Department (NMED) letter dated June 6, 2018. The R-70 well will ensure two objectives of the Chromium Groundwater Project are implemented. First, well R-70 will monitor the response of the chromium plume to extraction activities at well CrEX-5 in a timely manner. Second, R-70 will further characterize the lateral and vertical extent of the chromium contamination in the northeastern corner of the plume.

The R-70 monitoring well was drilled using dual-rotary fluid-assisted air-drilling casing-advance methods. Telescoping casing sizes between 20 in. and 14 in. were used to advance the borehole to total depth. Fluid additives used included potable water and foam. Foam-assisted drilling was terminated at 1100 ft MD, within the pumiceous Puye Formation.

The following geologic formations were encountered in R-70: Quaternary alluvium, Tshirege Member of the Bandelier Tuff, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed, upper Puye Formation, Cerros del Rio basalt, mixed basalt and dacite alluvial sediments, Cerros del Rio basalt, dacite- and quartzite-clast-bearing fluvial sediments, Cerros del Rio basalt, Puye Formation, and pumiceous Puye Formation.

Well R-70 was completed as a dual-screen well, allowing evaluation of water quality at two discrete depth intervals in the upper portion of the regional aquifer within the Puye Formation and pumiceous Puye Formation. Well R-70 was completed with a 40-ft upper screen from 963.0 ft to 1004.0 ft MD (872.9 ft to 910.0 ft bgs at the well pad) within the lower part of the Puye Formation and a 20.5-ft lower screen from 1048.0 ft to 1068.5 ft MD (949.9 ft to 968.5 ft bgs at the well pad) in the lower part of the pumiceous Puye Formation. The monitoring well was completed as a dual-screen, dual–access port, single-pump sampling system with the well screens separated by a packer. The final configuration of the well allows future changes to be made to convert the well from a monitoring well to an extraction or injection well, if needed to meet IM objectives. The well was completed in accordance with the NMED-approved well design. Both well screen completion zones were developed with water field parameters of temperature, pH, oxidation/reduction potential, specific conductivity, and dissolved oxygen having stabilized in both screens. However, regarding the regional aquifer groundwater target water-quality parameters, chromium concentration was well above water-quality standards in screen 2.

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Acronyms and Abbreviations

amsl	above mean sea level
APV	access port valve
bgs	below ground surface
cfm	cubic feet per minute
Consent Order	Compliance Order on Consent (NMED)
DO	dissolved oxygen
DOE	Department of Energy (U.S.)
EM-LA	Environmental Management Los Alamos Field Office
gpd	gallons per day
gpm	gallons per minute
HE	high explosives
Holt	Holt Services, Inc.
hp	horsepower
I.D.	inside diameter
IDW	investigation-derived waste
IM	interim measure
LANL	Los Alamos National Laboratory
LIC	liquid inflation chamber
MD	measured distance
N3B	Newport News Nuclear BWXT-Los Alamos, LLC
NAD	North American datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
psi	pounds per square inch
PVC	polyvinyl chloride
SOP	standard operating procedure
TA	technical area
TD	total depth
TOC	total organic carbon
WCSF	waste character strategy form

1.0 INTRODUCTION

This well completion report summarizes borehole drilling, well construction, well development, aquifer testing, and the dedicated sampling system installation for regional aquifer monitoring well R-70. The completion of regional aquifer monitoring well R-70 has two objectives. The first objective is to monitor the chromium plume response to chromium extraction well CrEX-5 in a timely manner in order to guide adaptive management of the chromium plume control interim measure (IM) operational approach in that area, should it be required. The second objective is to further characterize the lateral and vertical extent of the chromium contamination in the northeastern portion of the plume. The location for R-70 was selected to achieve both of these goals and was based on modeling results as well as drilling accessibility. The R-70 location is closest to modeling run P-2 shown on Plate 1 of the "Evaluation of Chromium Plume Control Interim Measure Operational Alternatives for Injection Well CrIN-6" (LANL 2018, 603032, Plate 1).

The R-70 regional aquifer monitoring well was completed with two screens in the upper portion of the regional aquifer. The well was constructed similarly to nearby IM infrastructure wells so as to enable potential repurposing as an extraction or injection well if necessary to meet the IM objective of hydraulic control of the chromium plume. Because of terrain constraints, angled drilling was used to achieve the target location within the aquifer. The well was designed with an 8-in.-diameter casing with two 40-slot screens. Final well design was based on data from lithology logs, water level measurements, video logs, and geophysical logs. Specific well design recommendations were submitted to the New Mexico Environment Department (NMED) for review and approval before the well was constructed.

Secondary objectives included identifying and establishing water levels in perched-intermediate aquifers, collecting samples of drill cuttings for lithologic description, and acquiring borehole geophysical data. The R-70 borehole was drilled to a depth of 1100 ft measured distance (MD) down the borehole (997.0 ft below ground surface [bgs] at the well pad). During drilling, cuttings samples were collected at 5-ft intervals from ground surface to total depth (TD). Well R-70 was installed with a 41-ft screened interval at 963.0 to 1004.0 ft MD (872.9 ft to 910.0 ft bgs at the well pad) and a 20.5-ft screened interval at 1048.0 to 1068.5 ft MD (949.9 ft to 968.5 ft bgs at the well pad) within the lower Puye Formation and upper pumiceous Puye Formation. The depth to water of 948 ft MD (859.3 ft bgs at the well pad) was recorded on March 27, 2019, before 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-70 drilling project.

2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide the activities associated with the drilling, installation, and development of Chromium Groundwater Project monitoring network well R-70:

- "Drilling Work Plan for Chromium Groundwater Project Regional Aquifer Monitoring Well R-70" (N3B 2018, 700107)

- "Evaluation of Chromium Plume Control Interim Measure Operational Alternatives for Injection Well CrIN-6," New Mexico Environment Department letter to D. Hintze (DOE-EM-LA) and J. Legare (N3B) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico (NMED 2018, 700011).
- "Field Implementation Plan for Regional Aquifer Well R-70 and CrIN-6 Well Conversion," February 2019 (N3B 2019, 700683).
- "Waste Characterization Strategy Form (WCSF) for Regional Well R-68," Los Alamos National Laboratory, Los Alamos, New Mexico (LANL 2016, 601994)
- "Amendment #1 to the Waste Characterization Strategy Form (WCSF) for Regional Well R-68," (LANL 2016, 602000)
- "Waste Characterization Strategy Form for Chromium Regional Aquifer Wells Installation 2018–2020" (N3B 2019, 700198)
- "Storm Water Pollution Prevention Plan, Regional Wells (R-Wells) Drilling, Los Alamos National Laboratory, revision 1," (LANL 2014, 601293)
- "Storm Water Pollution Prevention Plan: Chromium Piping and Infrastructure Project Phase 5, R-70 Drilling and Well Installation and CrIN-6 to CrEX-5," N3B-PLN-RGC-0002, R0, November 2018 (N3B 2019, 700684).

3.0 R-70 DRILLING ACTIVITIES

The following are descriptions of the field activities that took place during the drilling of regional aquifer monitoring well R-70 in Technical Area 05 at Los Alamos National Laboratory. The location of monitoring well R-70 is shown in Figure 3.0-1.

3.1 Drilling Approach

The drilling method, equipment, and drill-casing sizes for the R-70 monitoring well were selected to retain the ability to investigate and case or seal off any perched groundwater encountered above the regional aquifer. 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 8.625-in.–outside diameter (O.D.) well screen.

Dual-rotary drilling methods using a Foremost DR-24HD drilling rig reconfigured to drill slant holes were employed to drill the R-70 borehole. The drilling rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, one deck-mounted 950–cubic feet per minute (cfm) air compressor, two Atlas Copco 1350-cfm auxiliary compressors, and general drilling equipment. A 2400-gal. flatwater rig tender, manlift, 4000-gal. water truck, inertial gyro with digital wireline counter, and two forklifts were also used for drilling activities. Light plants were provided for the night shifts.

A Hunke R36 pump hoist Holt Services, Inc. (Holt) rig was mobilized to the site after the well was constructed. This rig was used for well development, installation of temporary pump systems for aquifer testing, and installation of the final Baski sampling system.

3.2 Chronological Drilling Activities for the R-70 Well

The Foremost DR-24HD drilling rig, drilling equipment, and supplies were mobilized to the R-70 drill site on March 7, 2019. The equipment and tooling were decontaminated and inspected before mobilization to the site. Site preparation included installing a spill barrier beneath the drilling rig, welding a shoe to the 20-in.-diameter casing, connecting the centralizer plate to the bottom of the drilling rig, and setting up the discharge line from the drilling rig to the cuttings pit. Complete site setup was attained and the walkdown and acceptance for authorization to proceed inspection was completed on March 8, 2019.

R-70 was drilled as a slant hole 25º from vertical trending northeast. Drilling commenced on March 8, 2019, with advancement of the 20-in.-diameter surface casing to a depth of 57.98 ft MD using a 19-in. shrouded tricone drill bit. The surface casing was advanced through alluvium and cooling unit Qbt 1g of the Tshirege Member of the Bandelier Tuff. From March 10 to March 12, an 18-in.-diameter casing was advanced through Qbt 1g of the Tshirege Member of the Bandelier Tuff, the Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed, the upper Puye Formation, and the Cerros del Rio basalt to 486.19 ft MD.

From March 14 to March 15, 2019, a 16-in.-diameter casing was installed within the 18-in.-diameter casing. Starting on March 15, a 16-in.-diameter casing was advanced using an underreaming hammer bit through the Cerros del Rio basalt, a lens of basaltic and dacitic alluvial sediment, and back into the Cerros del Rio basalt to 640 ft MD. From 640 to 643 ft MD, hard formation overtorqued the bottom hole assembly and drill string, causing the bottom hole assembly to become wedged into the borehole and unable to advance. On March 17, the 16-in.-diameter casing was tripped out and the bottom of the hole was cemented using 150 gal. of water and 30 bags of cement. From March 18 to March 22, the 16-in.-diameter casing and an underreaming hammer bit were tripped in, the cement plug was drilled out, and the 16-in.-diameter casing was again advanced through the lower part of the Cerros del Rio basalt, dacite- and quartzite-bearing fluvial beds, back into the lowest part of the Cerros del Rio basalt, and into the Puye Formation to 805.88 ft MD.

From March 23 to March 24, 2019, one 14-in.-diameter casing was installed within the 16-in.-diameter casing. From March 25 to March 26, the 14-in.-diameter casing was advanced using an underreaming hammer bit through the Puye Formation to TD at 1100 ft MD. After TD was reached, the initial water level was recorded at 948.80 ft MD and the final water level was recorded at 948.58 ft MD on March 26. Table 3.2-1 presents a record of fluid quantities used during drilling and well construction. Table 3.2-2 presents a record of water levels collected on March 27, 2019. No perched water zones were observed during drilling. The 14-in. casing shoe was cut on March 30, 2019, at 1082.26 ft MD.

Gyroscopic surveys of the slant hole were conducted at 364.24 ft MD on March 11, at 495 ft MD on March 13, at 682 ft MD on March 21, and at 1100 ft MD on March 30, 2019. A geophysical survey using gamma and neutron logging tools was conducted on March 27, 2019. Figure 3.2-1 shows the as-built diagram for R-70.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-70. All sampling activities were conducted in accordance with applicable procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-70 monitoring well borehole at 5-ft intervals from ground surface to the TD of 1100 ft MD. At each interval, approximately 500 mL of bulk cuttings was collected by the site geologist from the drilling discharge hose, placed in resealable plastic bags, labeled, and archived in core boxes. Whole rock, +35 sieve-size fractions, 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 high-explosives (HE) spot testing was performed before cuttings were removed from the site per N3B-EP-DIR-SOP-10021, “Characterization and Management of Environmental Program Waste.” All screening measurements were below background values and/or negative for HE. The cuttings were delivered to N3B at the conclusion of drilling activities. The stratigraphy at well R-70 is summarized in section 5.1, and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

4.2.1 Potential Perched Water Samples

No perched groundwater screening samples were collected because no perched water zones were observed during the drilling of R-70.

4.2.2 Well Development Samples

Two groundwater samples were collected during well development and analyzed for total organic carbon (TOC). One sample was collected from screen 2 on May 21, 2019, and one sample was collected from screen 1 on May 21, 2019. Field parameters collected for both samples included temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity.

4.2.3 Aquifer Test Samples

Three groundwater screening samples were collected from each screen during aquifer testing. Samples were collected from screen 1 on May 24, 2019, and from screen 2 on May 27, 2019. Two of the groundwater screening samples from each screen were submitted only for TOC analysis, and the final sample from each screen was submitted for full groundwater characterization as described in section 4.2.4. Results of key constituents in the chromium plume area, including sulfate, chromium, nitrate, tritium, and perchlorate are presented in Table B-1.1-1.

The sample from each screen that was submitted for full groundwater characterization was also analyzed for naphthalene, sulfonic acid and disulfonic acid, rhenium, and TOC. Analytical results are reported in Appendix B, Table B-1.1-1. Field water-quality parameters are presented in Table B-2.2-1.

4.2.4 Groundwater Characterization Samples

Groundwater characterization samples were collected from the completed well at the conclusion of aquifer testing, from screen 1 on May 24, 2019, and from screen 2 on May 27, 2019, in accordance with the 2016 Compliance Order on Consent (Consent Order). For the first year, samples are being analyzed for a full suite of constituents in accordance with the requirements of the “Interim Facility-Wide Groundwater Monitoring Plan for the 2020 Monitoring Year, October 2019–September 2020” (N3B 2019, 700451) following aquifer testing. Analytical results of these samples are in the Intellus New Mexico database and will also be reported in the next periodic monitoring report for the Chromium Investigation monitoring group.

5.0 GEOLOGY AND HYDROGEOLOGY

The geologic and hydrogeologic features encountered at R-70 are summarized below. The N3B geology task leader and project site geologist examined drill 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-70.

5.1 Stratigraphy

Rock units for the R-70 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. Depths are reported in MD since R-70 was drilled as an angled drill hole. Figure 5.1-1 illustrates the borehole stratigraphy of monitoring well R-70. A lithologic log for R-70 is presented in Appendix A.

Alluvium, Qal (0–35 ft MD, 0–31.7 ft bgs at well pad)

Alluvium was encountered from 0 to 35 ft MD. The alluvium consists of moderately sorted and unconsolidated coarse sand. The cuttings consist of subrounded to rounded, grayish to pinkish gray, and devitrified tuff fragments mixed with pumice, quartz, and feldspar grains that are lightly coated with tuffaceous silt. Light- to dark gray angular to subangular porphyritic felsic lava fragments are present. Quartz and feldspar crystals and rounded tuff fragments dominate the fine fraction. Obsidian clasts were noted. Sorting, abundance of silt, and types of rock fragments vary with depth. The basal unit is matrix-supported, poorly sorted, and heavily coated clasts with tuffaceous silt, containing pinkish gray tuff fragments, quartz and feldspar grains, minor pumice, and sparse felsic lava fragments. Minerals are more abundant in the finer fraction (+35). The basal alluvium contains abundant white devitrified tuff in addition to the light pinkish gray tuff fragments, pumices, few grains of quartzite, and abundant quartz and feldspar minerals that are similar to the previous cuttings. The amount of white, crystal-rich, and devitrified tuff fragments similar to Qbt 1v significantly increased while the light pinkish gray tuff fragments decreased with depth. Quartz and feldspar grains lightly coated with white pulverized tuffaceous silt are abundant. Minor pumice and light gray lava fragments are present.

Tshirege Member of the Bandelier Tuff, Qbt 1g (35–60 ft MD, 31.7–54.4 ft bgs at well pad)

Cuttings are matrix-supported, poorly sorted clasts embedded in a pumiceous coarse sand that consists of white devitrified tuff fragments mixed with abundant large (>1 cm) gray pumice clasts and minor felsic lava fragments. Pulverized tuffaceous matrix lightly coats the feldspar and quartz grains. The pumice fragments are mostly gray, inflated, and partially stretched. Minor light pinkish gray clasts are also present. The finer fraction (+35) contains abundant crystals that significantly decreased with depth.

Otowi Member of the Bandelier Tuff, Qbo (60–280 ft MD, 54.5–253.8 ft bgs at well pad)

Volcaniclastic sediments and pumice beds belonging to the Cerro Toledo Formation, which normally underlies the Qbt 1g ash-flow tuff, are absent from the R-70 well. Instead, a poorly sorted crystal-rich gravelly pumiceous sand, containing abundant feldspars and quartz grains in an ashy glassy matrix, underlies the basal Tshirege Member ash-flow tuff (Qbt 1g). Two types of pumice clasts of comparable abundances are present. The light gray fraction is up to 2 cm in size, angular to subangular, and partially inflated, whereas the other type is subrounded and appears reworked and coated by light brown tuffaceous silt. Lithic lava fragments are sparse. Coarser (>4 cm) and less stained pumices were noted. The amount of light gray and medium- to dark gray lava fragments significantly increased, starting at the 80- to 85-ft interval.

There was no recovery of cuttings from the 100–105-ft interval, but the next sequence of cuttings that followed are lithic-rich ash-flow tuff, containing abundant subrounded to rounded medium gray and pale red dacite lava fragments mixed with abundant rounded gray pumices and minor perlite and obsidian fragments. Pumice clasts lightly coated with light brown silt decreased with depth. Rendija Canyon lava fragments are common. In successive cuttings, the amount of lithic lava fragments are more abundant than pumices and crystals, which are generally sparse. Pale red Rendija Canyon dacite clasts appear to be more abundant than the other lava fragments. Sparse perlite fragments also persisted with depth. Occasionally, rusty pumice clasts were noted.

In most cases, pumice clasts are coarser in size than lava fragments, but the amount of pumice continued to vary with depth. In some cases, the cuttings contain more pumice clasts than lava fragments and vice versa. Rendija Canyon lava fragments as well as crystals are sparse, and few perlite grains are present. At the base of the sequence, the pumices are coarser, inflated, relatively stretched, and more abundant than the medium- to dark gray lava fragments.

Guaje Pumice Bed, QBog (280–300 ft MD, 253.8–271.9 ft bgs at well pad)

The Guaje Pumice Bed consists of dense white pumice fragments mixed with abundant medium- to dark gray, subrounded to rounded dacite lava fragments and minor light gray and banded rhyolite. The bulk of the white pumice clasts are less inflated, coarser, and more rounded than the lava fragments. Partially oxidized dacite lava fragments coated with reddish orange stain are common. A few Rendija Canyon lava fragments are present. Crystals are coarse and abundant.

Upper Puye Formation, Tpf (300–323 ft MD, 271.9–292.8 ft bgs at well pad)

Abundant clast-supported, rounded, and indurated light brown silty sandstone mixed with medium to dark dacite lava and pumice fragments are common. The brown sandstone fragments decreased with depth, whereas the amount of light- to medium gray felsic lava fragments significantly increased. Crystals are generally sparse.

Cerros del Rio basalt, Tb4 (323–500 ft MD, 292.8–453.2 ft bgs at well pad)

Dark gray basalts mixed with abundant light brown silty sandstone fragments mark the transition to the Cerros del Rio basalt sequence. The basalt fragments are porphyritic, vesicular, massive, dark gray, and microcrystalline with fractured and partially altered mafic minerals of pyroxene, olivine, and plagioclase. The 375–380-ft depth interval yielded no cuttings. From 380–410-ft depth, comparable amounts of medium- and dark gray weathered and oxidized, porphyritic, and vesicular basalt fragments mixed with equally abundant reddish brown scoriaceous clasts dominate the cuttings. The medium gray and reddish brown oxidized lava fragments persisted with depth. In the 410- to 435-ft interval, the amount of reddish brown oxidized fragments significantly increased, but scoria is rare. The reddish brown lava fragments started to decrease with depth, and medium gray porphyritic and crystalline fragments became dominant. Partially altered dark gray basalt fragments are also present. The amount of dark gray basalt continued to increase with depth, mainly in the 480- to 490-ft interval. Significant amounts of partially altered porphyritic and massive medium gray basalt fragments mixed with minor reddish brown clasts are also common.

Mixed basalt and dacite alluvial sediments (500–520 ft MD, 453.2–471.3 ft bgs at well pad)

The bulk of the cuttings consist of light gray dacite fragments contaminated by medium gray porphyritic and microcrystalline basalt lava clasts. The light- to medium gray basalt is more abundant compared with the dacite clasts that decrease with depth. Other minor rock types include Rendija Canyon dacite, perlite, banded rhyolite, and reddish brown oxidized basalt fragments. Different types of dacite and rhyolite fragments were noted. The dacite fragments are subrounded to rounded, fine-grained, and porphyritic, containing coarse quartz, feldspar, and few mafic minerals.

Cerros del Rio basalt, Tb4 (520–660 ft MD, 471.3–598.2 ft bgs at well pad)

The bulk of the cuttings consists of abundant microcrystalline and porphyritic light- to medium gray, dark gray, and fine-grained reddish brown basalt fragments with no apparent dacite or rhyolite lava clasts. Fractured and altered olivine and pyroxene phenocrysts are common in the grayish and dark gray basalt fragments. The reddish brown oxidized lava fragments are somewhat scoriaceous, partially weathered, and less abundant, whereas the amount of the fairly vesicular and partially weathered dark gray basalts increased with depth. There was no recovery of cuttings from the 580- to 585-ft interval, but successive cuttings contained types and amounts of basaltic clasts similar to the overlying samples.

At the 600- to 605-ft depth interval, different lithic fragments consisting of minor reddish and dark gray scoria fragments and pinkish gray porphyritic lava clasts similar to the Rendija Canyon dacite occur along with the dominant light gray and minor sparsely vesicular and altered dark gray basaltic lava fragments. The pinkish gray clasts mostly persisted within the 600- to 620-ft depth interval. Light- to medium- and dark gray basalt fragments mixed with minor reddish brown fractions and a few grains of light pinkish gray claystone and pinkish gray dacite lava clasts continued to occur within the cuttings. The 645- to 660-ft depth interval contained similar basaltic cuttings plus some medium gray cement fragments used to stabilize the well.

Dacite- and quartzite-clast-bearing fluvial sediments (660–680 ft MD, 598.2–616.4 ft bgs at well pad)

The cuttings from this interval consist of light gray and pale red dacite, quartzite, and sandstone; coarse quartz and feldspar minerals; and minor basaltic fragments. The dacite clasts are mostly subrounded to rounded and larger in size (>0.5 in.) compared with the basalt fragments. The minerals and dacite fragments are partially coated with light brown and white crust. Rendija Canyon dacite fragments are common.

Cerros del Rio basalt, Tb4 (680–734 ft MD, 616.4–665.3 ft bgs at well pad)

Comparable amounts of dark- and light- to medium gray basalt fragments with minor dacite and light pinkish gray claystone fragments compose the cuttings. The 690- to 695-ft depth interval yielded no cuttings. However, successive cuttings consist of basaltic clasts that are similar to previous samples. Some of the basalt fragments are heavily coated with dust from pulverized rocks. The lower part of the basaltic lava sequence is dominated by sparsely vesicular and partially weathered dark gray fragments mixed with subordinate light- to medium gray porphyritic crystalline lava clasts. Few reddish brown oxidized lava fragments are present. Minor light pinkish gray claystone fragments occur in the 725- to 740-ft depth interval. Abundant sparsely vesicular and partially weathered dark gray basaltic cuttings mixed with minor light- to medium gray basalt clasts dominate the basal cuttings.

Puye Formation, Tp (734–1050 ft MD, 665.3–951.7 ft bgs at well pad)

The chip trays from the 740- to 760-ft depth interval contain two types of abundant basaltic lava and minor dacite clasts dominated by Rendija Canyon lava fragments. The 760- to 765-ft depth interval yielded no cuttings, and the first appearance of abundant Puye Formation dacite fragments occurred at the 765- to 770-ft depth interval. However, the gamma log defines the contact between the Cerros del Rio basalts and the Puye Formation at about 734 ft depth. Detailed examination of bulk cuttings simultaneously collected with the chip-tray samples from the 730- to 760-ft interval indicate the first appearance of abundant matrix-supported gravelly sand dominated by dacite lava fragments within the 730- to 740-ft depth interval. This observation is consistent with the stratigraphic contact established by gamma log data at 734 ft MD. Thereafter, the Puye Formation cuttings contain comparable amounts of light- to medium gray and pale red dacite lavas dominated by Rendija Canyon fragments mixed with minor basalt clasts as contaminants. Similar lithologic types continued to occur within the 765- to

780-ft depth interval. There was no recovery of cuttings from the 820- to 830-ft interval, but pale red fragments, which represent the Rendija Canyon dacite, appear to dominate with depth. The bulk cuttings from the base of the Puye Formation consist of pale red and medium gray dacite lava fragments, minor white lava clasts, and sparse quartz and feldspar grains.

Pumiceous Puye Formation, Tp (1050–1100 ft MD, 951.7–997.0 ft bgs at well pad)

The cuttings contain at least two types of abundant lava fragments, minor pumices, and sparse minerals. The lava fragments consist of subrounded to rounded light- to medium gray and pale red porphyritic dacite clasts that are coarser (i.e., up to 0.25 in.) than the pumices. The pale red fragments are more abundant and belong to the Rendija Canyon dacite. White pumice fragments partially covered by light reddish brown silt are common. The amount of pumices significantly increased with depth. Most pumice fragments are lightly covered by light brown silt. Quartz and feldspar grains are generally sparse.

5.2 Groundwater

Drilling at R-70 proceeded without any indications of groundwater until approximately 948 ft MD, based on borehole interrogation at each rod/casing connection. No intermediate perched water was observed in the R-70 borehole. Regional groundwater was first observed at approximately 948 ft MD, near the predicted depth of 900 ft MD, during drilling and advance of the 12-in. casing. The 12-in. casing subsequently was advanced to TD at 1100 ft MD. Table 3.2-2 presents a summary of water levels recorded in R-70 before well development.

6.0 BOREHOLE LOGGING

On March 27, 2019, geophysical logs were run by Jet West Geophysical Services, LLC, after water levels had been recorded. The geophysical logging safety meeting and pre-task discussion occurred at 10:11 a.m., and the downhole tool was configured to run into the hole at 10:26 a.m. From 10:26 to 11:20 a.m., the geophysical tool was run into the bottom of the hole, and the logging run was completed by 12:35 p.m. The log suite that was run included a gamma log and a neutron log.

On March 30 the gyroscopic survey of the borehole was completed. The geophysical logs run are shown in Table 6.0-1. Figure 6.0-1 shows the gamma log overlain on the stratigraphic contacts. The geophysical logs and the gyroscopic survey are in Appendix C, on CD included with this document.

7.0 WELL INSTALLATION R-70 MONITORING WELL

The R-70 dual-screen regional well was installed between April 5 and May 15, 2019.

7.1 Well Design

The R-70 well was designed in accordance with Consent Order guidance, and NMED approved the final well design before the well was installed (Appendix D). The well was designed with two screened intervals, the first between 963.0 ft and 1004.0 ft MD and the second between 1048.0 ft and 1068.5 ft MD, to monitor groundwater quality within two discrete zones of the regional aquifer.

7.2 Well Construction

From April 2 to April 5, 2019, the workover rig, well components, and initial well construction materials were mobilized to the site. Stainless-steel well casing, screens, and tremie pipe were thoroughly cleaned. The stainless-steel well casing and screens of 8-in. diameter were tested for eccentricity, with only one joint of casing being rejected because of conic deviation.

The R-70 monitoring well was constructed of 8-in.–inside diameter (I.D.), 8.625-in.-O.D. schedule 40 pickled and passivated A304 stainless-steel beveled casing fabricated to American Society for Testing and Materials A312 standards. The top screened section used four 10-ft length 8-in. I.D. rod-based 0.040-in. slot wire-wrapped screens to make a 40-ft-long upper screened interval. The bottom screened section used two 10-ft length screens identical to those described above to make a 20-ft-long lower screened interval. The screens were constructed with welded tabs at each end, between all rods and weld ring connections, to increase the rotational strength of the screen. All individual casing and screen sections were welded together using compatible stainless-steel welding rods. The screens were manufactured by Johnson Screens, an Aqseptence Group company. A nominal 2-in. steel tremie pipe was used to deliver backfill and annular fill materials downhole during well construction.

Well screens and well casing were installed in the borehole from April 5 to 10, 2019. Stainless-steel centralizers were welded to the well casing approximately 2.0 ft above and below each screened interval. Figure 3.2-1 presents an as-built schematic showing the construction details for the completed well.

While the 14-in.-diameter casing was rotated on April 12, 2019, it was not possible to raise the casing. From April 13 to 14, 2019, the drill rig was diagnosed for the cause of the difficulty in pulling back the 14-in. casing, and repairs were unsuccessfully attempted. From April 14 to 16, 2019, the drill rig was demobilized from the R-70 site and transferred to Albuquerque for repairs. On April 20, 2019, the repaired DR-24HD drilling rig was mobilized to R-70 in preparation for finishing well completion. The 14-in.-diameter casing pull-back was started on April 26, 2019, during installation of the sand pack for the lower screen. Tripping out the 14-in. casing was completed on May 6, 2019. The 16-in.-diameter casing pull-back was started on May 7, 2019, during installation of the bentonite seal and was completed on May 10, 2019. The 18-in.-diameter casing pull-back was started on May 13, 2019, during installation of the bentonite seal and was completed on May 15. During tripping out of BQ rod, 613.11 ft of BQ rod was lost down the hole on May 9, 2019. After several attempts, 613.11 ft of BQ rod was fished out of the annulus on May 11, 2019.

Annular materials were installed in the borehole from April to May 15, 2019. The top of slough in the bottom of the borehole was tagged at 1080.6 ft MD (979.5 ft bgs at the well pad)on April 21, 2019. Starting on April 22, 2019, bentonite Pel-Plug was installed from 1080.6 ft to 1073.6 ft MD (979.5 ft to 973.1 ft bgs at the well pad), 10/20 filter sand pack was installed from 1073.6 ft to 1043.0 ft MD (973.1 ft to 945.4 ft bgs at the well pad), fine sand collar of 20/40 fine sand from 1043.0 to 1040.4 ft MD (945.4 ft to 943.0 ft bgs at the well pad), the middle bentonite seal was installed from 1040.4 ft to 1009.4 ft MD (943.0 ft to 914.9 ft bgs at the well pad), the upper screen 10/20 sand filter pack was installed from 1009.4 ft to 912.7 ft MD (914.9 ft to 827.3 ft bgs at the well pad), and 20/40 fine sand collar was installed from 912.7 ft to 911.0 ft MD (827.3 ft to 825.7 ft bgs at the well pad). Bentonite seal was installed from 911.0 ft MD to 60.4 ft MD (825.7 ft to 54.7 ft bgs at the well pad) and completed on May 15, 2019. Cement was installed from 60.4 ft to 3 ft MD (54.7 ft to 2.7 ft bgs at the well pad) on May 17, 2019. Figure 3.2-1 presents the as-built diagram of monitoring well R-70, with borehole stratigraphy and technical completion details. Table 7.2-1 presents the annular fills used to build monitoring well R-70.

8.0 POST-INSTALLATION ACTIVITIES

Following well installation at R-70, the well was developed and aquifer pumping tests were conducted. A Baski dual-screen access port valve sampling system was installed, the wellhead and surface pad were constructed, and a geodetic survey was completed. Disposition of the drill cuttings will follow the NMED-approved decision trees for land application of drill cuttings. Disposition of groundwater will follow development/aquifer test decision tree requirements. Table 8.0-1 summarizes groundwater samples collected during well development and aquifer testing of monitoring well R-70.

8.1 Well Development

The well was developed between May 15 and 20, 2019. Bailing was performed in two steps on May 15 and 16. First, sand was bailed from the sump, with 9 to 13 gal. of sand and minor native clay removed. Next, screens 1 and 2 were swabbed and bailed to remove fine sediment in the filter pack and well sump. This activity resulted in 14 bails of 33.5 gal. each of mostly turbid water but no sand. Final well development, performed with a submersible pump, involved lowering and raising the pump intake through the screen interval.

The swabbing tool employed was a 1-in.-thick nylon disc attached to a weighted steel rod. The wireline-conveyed tool was drawn repeatedly across the screened interval, causing a surging action across the screen and filter pack. The bailing tool had a total capacity of approximately 13.5 gal. of water. The bailer was lowered to the bottom of the well 14 times, filled, and withdrawn from the well. Approximately 189 gal. of groundwater was removed during bailing activities.

After swabbing and bailing 435.5 gal. on May 15 and 16, a 30-horsepower (hp) Grundfos submersible pump was deployed into the well. On May 19, both screens were developed without using an intermediate packer by producing 70,241 gal. of water. The upper screen (screen 1) was developed on May 20 with 13,164 gal. pumped, and the lower screen (screen 2) was developed with 10,989 gal. pumped. Both screens were developed by step-pumping at 1- to 2-ft intervals from the top of screen 1 to the bottom of screen 2 (from 962 ft to 1068 ft MD). On May 20, the shroud intake was set at 1011.53 ft MD, the lower screen was tested, and development field parameter data were collected to meet the criteria for completion of well development for screen 2, with 10,989 gal. pumped. From May 20 to 21, the upper screen was tested and development field parameter data were collected to meet the criteria for completion of well development for screen 1, with 24,460 gal. pumped. A water sample was collected from the lower screen at 5:20 p.m. on May 21. Field parameter data are discussed in greater detail in Appendix B, and aquifer test data are discussed in greater detail in Appendix E.

During development, the pumping rate in screen 1 varied from 100.7 to 129.7 gpm. The pumping rate in screen 2 varied from 101.7 to 115.6 gpm. The average pumping rates for screens 1 and 2 were 108.5 and 105.4 gpm, respectively. Approximately 105,690 gal. of groundwater (flow meter reading) was purged with the submersible pump during well development (106,125.5 gal. with the submersible pump and the bailer). Table 8.1-1 shows the volume of water produced during well development.

Total Volumes of Introduced and Purged Water

During drilling approximately 24,375 gal. of potable water was added from 824.94 ft above the top of the regional aquifer to the TD of the borehole at 1100 ft MD. Approximately 27,449.4 gal. was added during construction of the well and installation of the annular fill. In total, approximately 51,824.4 gal. of potable water was introduced to the borehole below 124.49 ft MD during project activities.

Approximately 107,779 gal. of groundwater was purged at R-70 during well development activities. Another 1626 gal. was purged during the setup for the aquifer tests; 130,791 gal. was purged from screen 1; and 129,424 gal. was purged from screen 2 during aquifer testing for a total of 261,841 gal. The total amount of groundwater removed during post-installation activities was 369,620 gal.

8.1.1 Well Development Field Parameters

During the pumping stage of well development, temperature, pH, DO, ORP, and specific conductance in µS/cm were measured. The required TOC and turbidity values for adequate well development are less than 2.0 parts per million and less than 5 nephelometric turbidity units (NTU), respectively.

Final development sample WS 05-19-181466 (WSP-TOC 250 mL) was collected and final field parameters were measured by collecting an aliquot of groundwater from the discharge pipe with the use of a flow-through cell. In screen 1 the final development parameters at the end of development were pH of 8.15, temperature of 21.3ºC, specific conductance of 191.2 µS/cm, DO of 7.88 mg/L, ORP of 223.5 mV, and turbidity of 1.48 NTU. In screen 2 the final parameters at the end of well development were pH of 8.13, temperature of 21.4ºC, specific conductance of 290.4 µS/cm, DO of 6.76 mg/L, ORP of 198.3 mV, and turbidity of 0.72 NTU. Table 8.1-2 shows field parameters measured during well development.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-70 between May 20 and 28, 2019. Several short-duration tests with short-duration recovery periods were performed on the first day of testing for each of the two screened intervals. These short-duration tests produced 1626 gal. of water on May 22. A 24-hr test followed by a 24-hr recovery period completed the testing of each screened interval. From May 23 to 24, 130,791 gal. of groundwater was produced from screen 1. From May 26 to 27, 129,424 gal. of groundwater was produced from screen 2. Table 8.2-1 shows the volume of water produced during aquifer testing.

A 10-hp pump was used for the aquifer tests. Approximately 261,841 gal. of groundwater was purged during the aquifer testing. The R-70 aquifer test results and analysis are presented in Appendix E.

8.3 Dedicated Sampling System Installation

The Hunke R36 Holt rig was mobilized to the R-70 well site and the dedicated sampling system was delivered and inspected at the site from September 24 through September 27, 2019. The inspection revealed reasons to return parts of the sampling system to the manufacturer. The dedicated sampling system for R-70 was returned to the site on October 12 and the temporary packer was removed from the well (the packer had been set on May 28, 2019). From October 12 through 15, the sampling system was unsuccessfully installed because it got stuck in a tight spot within the upper screen. On October 16 and 17, the sampling system was pulled out of the well. A video camera was lowered into the well on October 18 to inspect the well screen for tight spots and damage, showing no damage, and a temporary packer was set at 1033 ft MD on October 19, 2019. The Baski sampling system was successfully installed from October 28 through 31, with the electrical control panel installed and tested on November 2 and 4, 2019. When the temporary packer was out of the well, groundwater communication potentially occurred between screens 1 and 2. The temporary packer was out of the well for 152.67 hr between October 12 and October 18, 2019, and for 78.15 hr between October 28 and October 31, 2019. An estimated minimum of 6000 gal. of water needs to be purged in order to counteract the effects of this cross-flow between screens 1 and 2.

The sampling system is a Baski, Inc.-manufactured system that uses 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 was 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 screened intervals. Pump riser pipes consist of threaded and coupled non-annealed (pickled), passivated1-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-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. Two In-Situ Inc. Level Troll 500 transducers were installed in the PVC tubes to monitor water levels in each screened interval.

Installation and construction details for the monitoring well R-70 sampling system are presented in Figure 8.3-1a. Technical notes for the installation and construction of the R-70 sampling system are presented in Figure 8.3-1b. The performance curve of the submersible pump is presented in Figure 8.3-1c. Appendix F is the R-70 sampling system report.

8.4 Wellhead Completion

A 16-in.-O.D. steel protective casing with a locking lid was installed around the stainless-steel riser on July 17 to a depth of 3 ft MD. A reinforced concrete surface pad, 10 ft × 10 ft × 10 in. thick, was installed at the R-70 wellhead from July 16 to 22, 2019. 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 on July 22. 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.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on November 1, 2019. 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-70 monitoring well. Survey coordinates are shown in Table 8.5-1.

8.6 Waste Management and Site Restoration

Waste generated from the R-70 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, development, and sample system installation at the R-70 well is presented in Table 8.6-1.

All investigation-derived waste (IDW) generated during well reconfiguration activities will be managed in accordance with applicable standard operating procedures (SOPs). These SOPs incorporate the requirements of all applicable U.S. Environmental Protection Agency and NMED regulations, U.S. Department of Energy orders, and N3B requirements. The SOP applicable to the characterization and management of IDW is N3B-EP-DIR-SOP-10021, “Characterization and Management of Environmental Program Waste.”

All waste streams produced during drilling and development activities will be sampled and characterized in accordance with the ”Waste Characterization Strategy Form for Chromium Regional Aquifer Wells Installation 2018-2020 (N3B 2019, 700198), which was approved per requirements of N3B-EP-DIR-SOP-10021, “Characterization and Management of Environmental Programs Waste.” This WCSF provides detailed information on IDW characterization methods, management, containerization, and potential volumes. R-70 construction materials (primarily PVC and stainless steel); fluids (purge and decontamination waters); contact waste (gloves, paper towels, plastic and/or glass sample bottles); and cement chase water will be the primary waste streams generated during the well development and drilling activities. The fluids produced will be sampled and analyzed for the suite of constituents listed in the WCSF and disposed of as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-70 were performed as specified in the NMED-approved “Drilling Work Plan for Chromium Groundwater Project Regional Aquifer Monitoring Well R-70,” (N3B 2018, 700107) with the exception of the following deviation.

- From 640 to 643 ft MD, hard formation overtorqued the bottom hole assembly and drill string. As a result, the 16-in.-diameter casing was tripped out and the bottom of the hole was cemented on March 17, 2019. From March 18 to March 22, the 16-in.-diameter casing and an underreaming hammer bit were tripped in and the cement plug was drilled out. Advancing the 16-in. casing from this point onward was continued as planned, through the lower part of the Cerros del Rio basalt, the dacite- and quartzite-bearing fluvial beds, the bottom of the Cerros del Rio basalt, and the Puye Formation.

10.0 ACKNOWLEDGEMENTS

Holt Services, Inc., drilled and installed R-70 monitoring well.

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

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

The following reference list 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, Safety, and Health (IDs 600000 through 699999); and EMIDs are assigned by N3B (IDs 700000 and above). IDs are used to located documents in N3B's Records Management System and Master Reference Set. The NMED Hazardous Waste Bureau and N3B maintain copies of the Master Reference Set. The set ensures that NMED has 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), 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), April 2018. "Evaluation of Chromium Plume Control Interim Measure Operational Alternatives for Injection Well CrIN-6," Los Alamos National Laboratory document LA-UR-18-23385, Los Alamos, New Mexico. (LANL 2018, 603032)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), October 2018. "Drilling Work Plan for Chromium Groundwater Project Regional Aquifer Monitoring Well R-70," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2018-0068, Los Alamos, New Mexico. (N3B 2018, 700107)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), January 16, 2019. "Waste Characterization Strategy Form for Chromium Regional Aquifer Wells Installation 2018-2020," Los Alamos National Laboratory, Los Alamos, New Mexico. (N3B 2019, 700198)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), February 2019. "Field Implementation Plan for Regional Aquifer Well R-70 and CrIN-6 Well Conversion," Newport News Nuclear BWXT-Los Alamos, LLC, document, Los Alamos, New Mexico. (N3B 2019, 700683)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), May 2019. "Interim Facility-Wide Groundwater Monitoring Plan for the 2020 Monitoring Year, October 2019–September 2020," Newport News Nuclear BWXT-Los Alamos, LLC, document EM2019-0156, Los Alamos, New Mexico. (N3B 2019, 700451)

N3B (Newport News Nuclear BWXT-Los Alamos, LLC), October 8, 2019. "Storm Water Pollution Prevention Plan, Chromium Piping and Infrastructure, Project Phase 5, R-70 Drilling and Well Installation and CrIN-6 to CrEX-5," Newport News Nuclear BWXT-Los Alamos, LLC, document N3B-PLN-RGC-0002, R0, Los Alamos, New Mexico. (N3B 2019, 700684)

NMED (New Mexico Environment Department), June 6, 2018. “Evaluation of Chromium Plume Control Interim Measure Operational Alternatives,” New Mexico Environment Department letter to D. Hintze (DOE-EM-LA) and J. Legare (N3B) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2018, 700011)

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.

Pave 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.

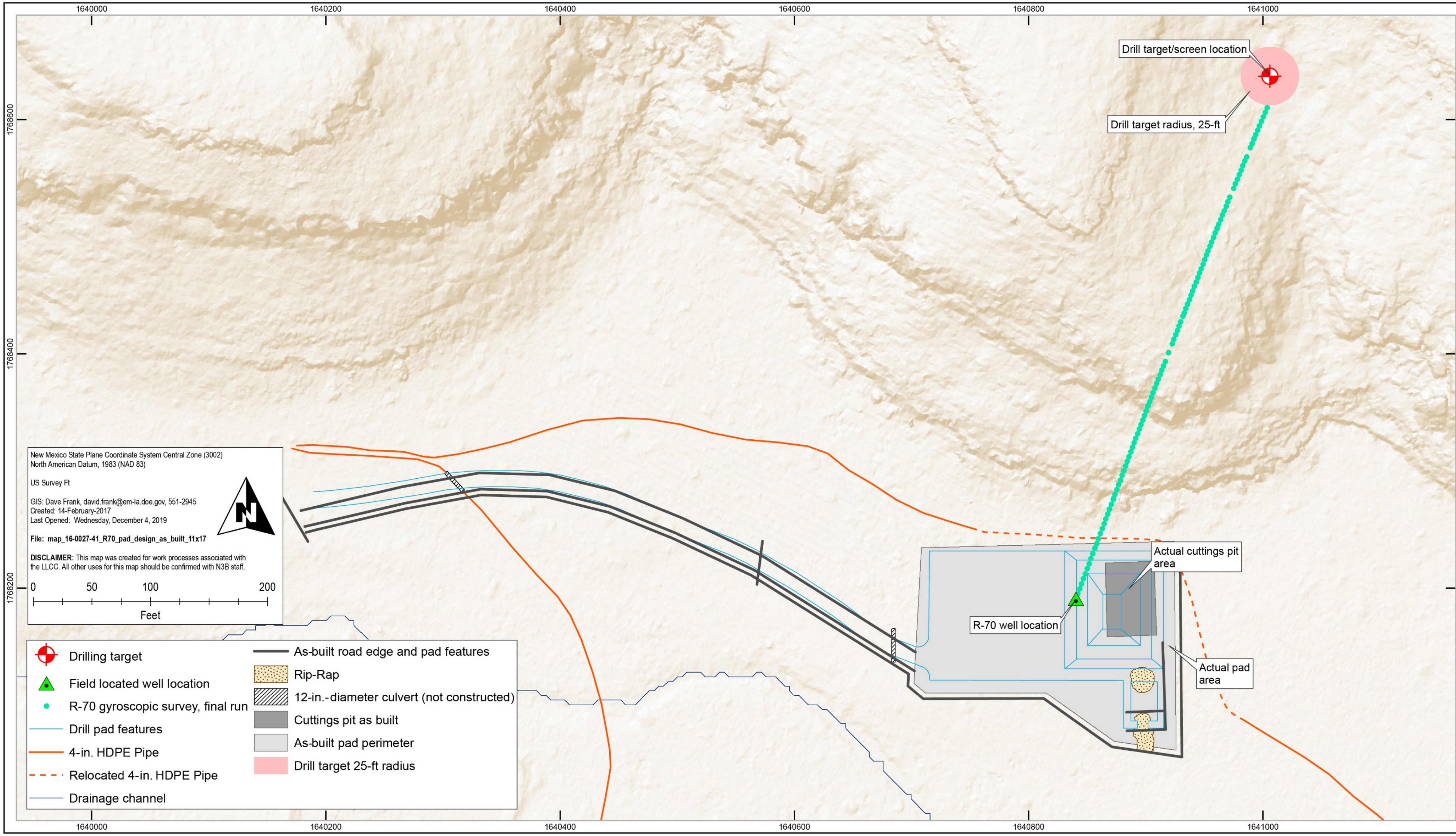


Figure 3.0-1 Location of regional monitoring well R-70

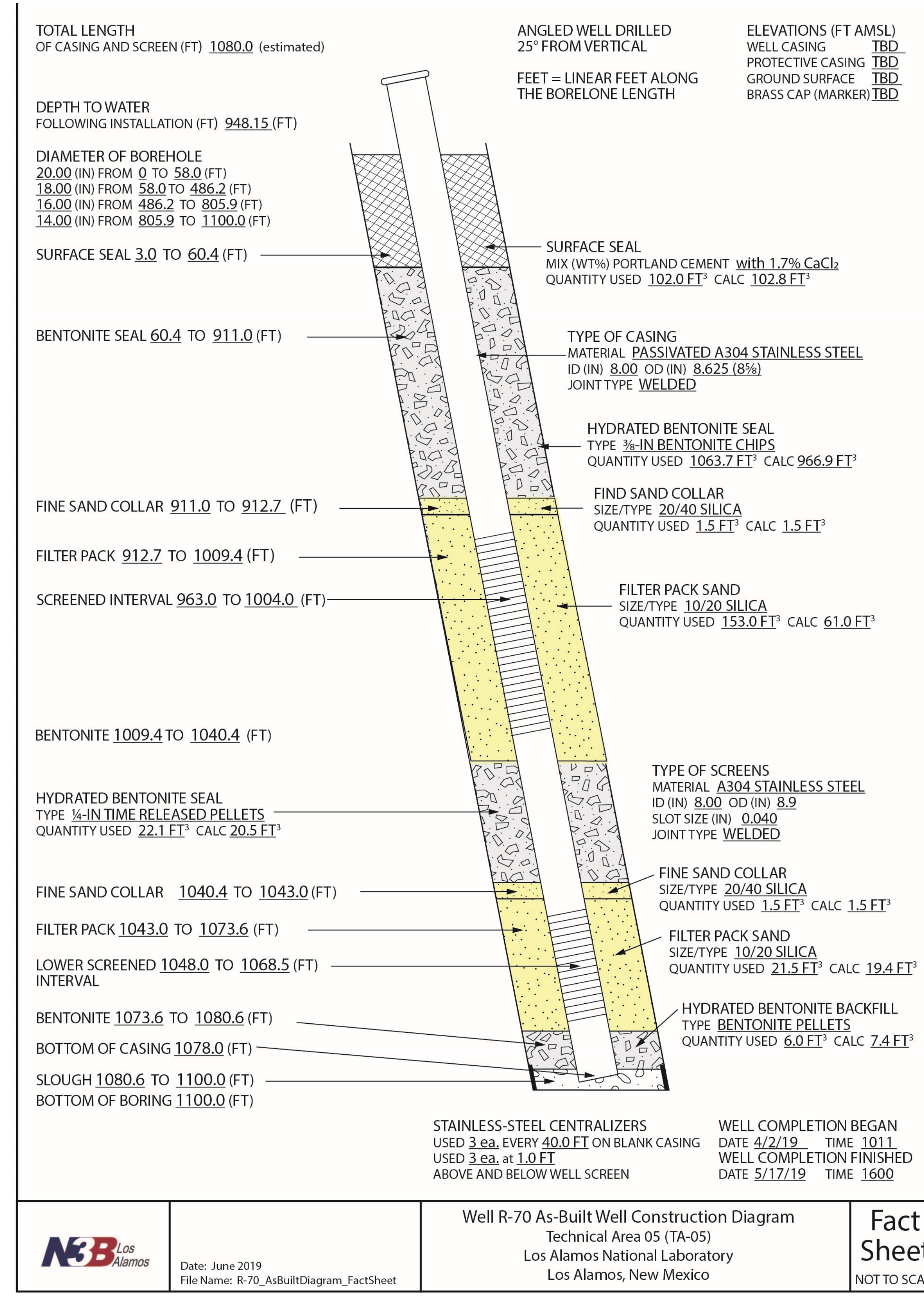


Figure 3.2-1 Monitoring well R-70 as-built construction diagram and technical well completion details

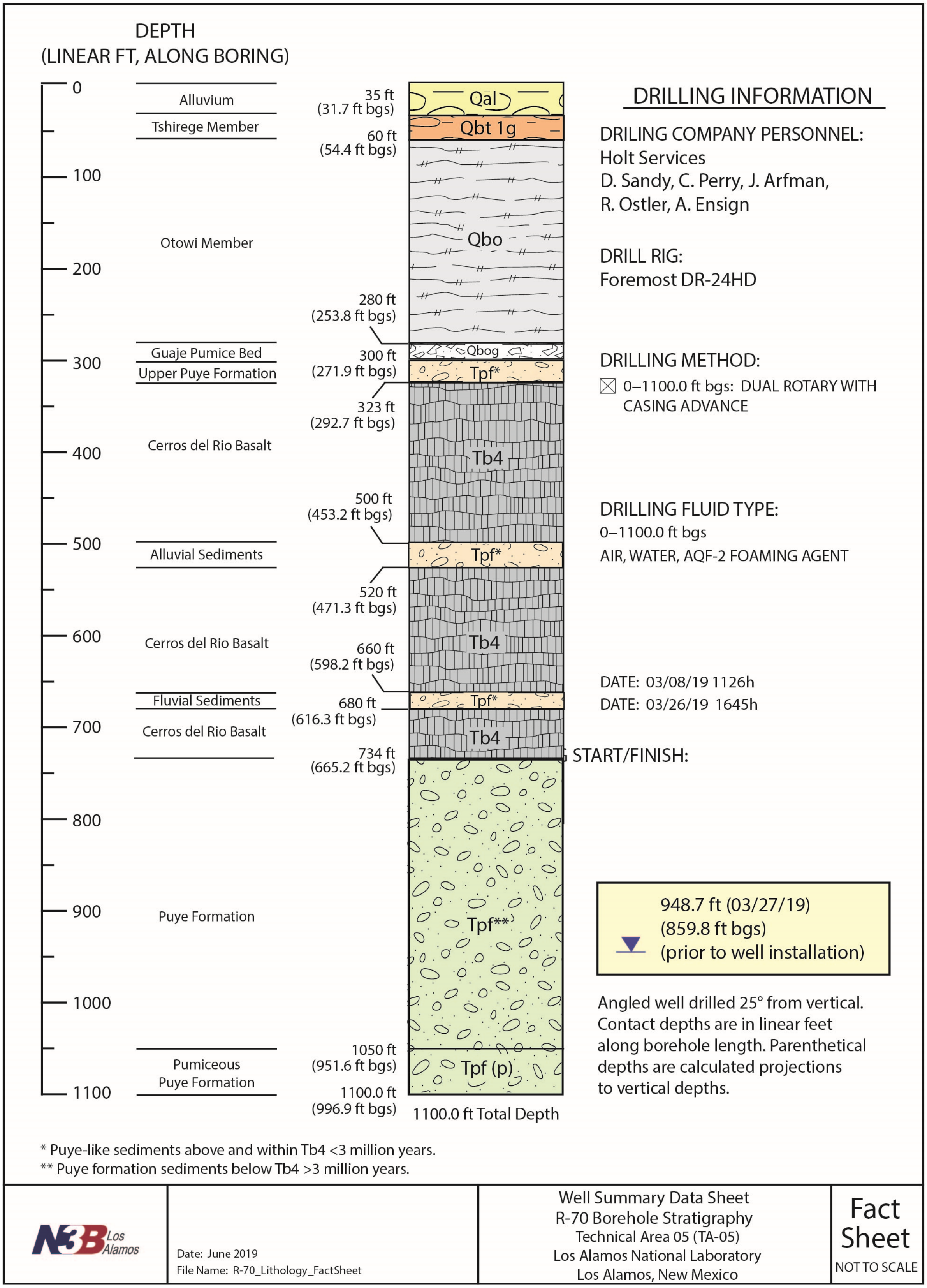
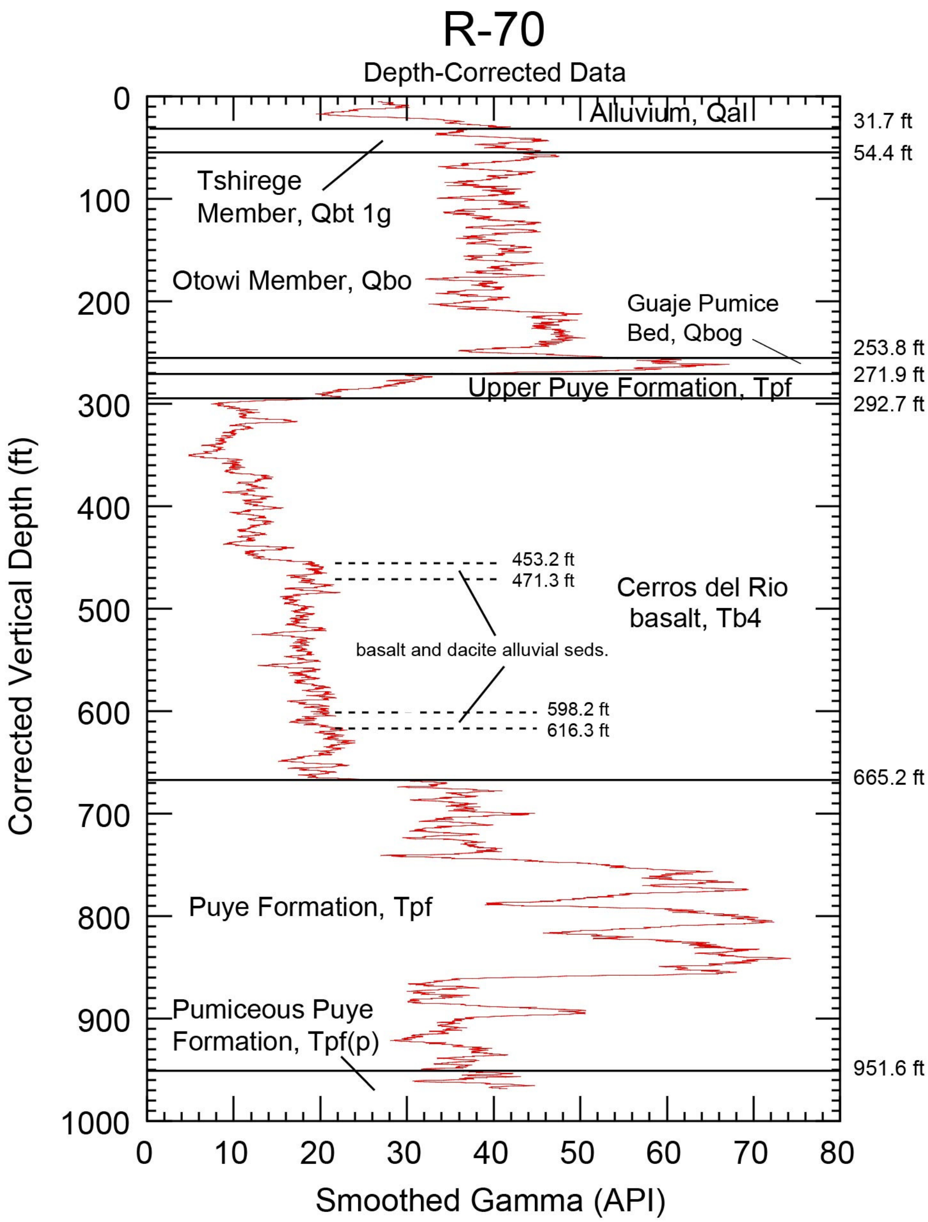


Figure 5.1-1 Monitoring well R-70 borehole stratigraphy



Note: The Guaje Pumice Bed shows the strongest log signature of all, although both the upper and lower contacts of the Cerros del Rio Basalt are also quite noticeable.

Figure 6.0-1 Gamma log compared with borehole stratigraphy

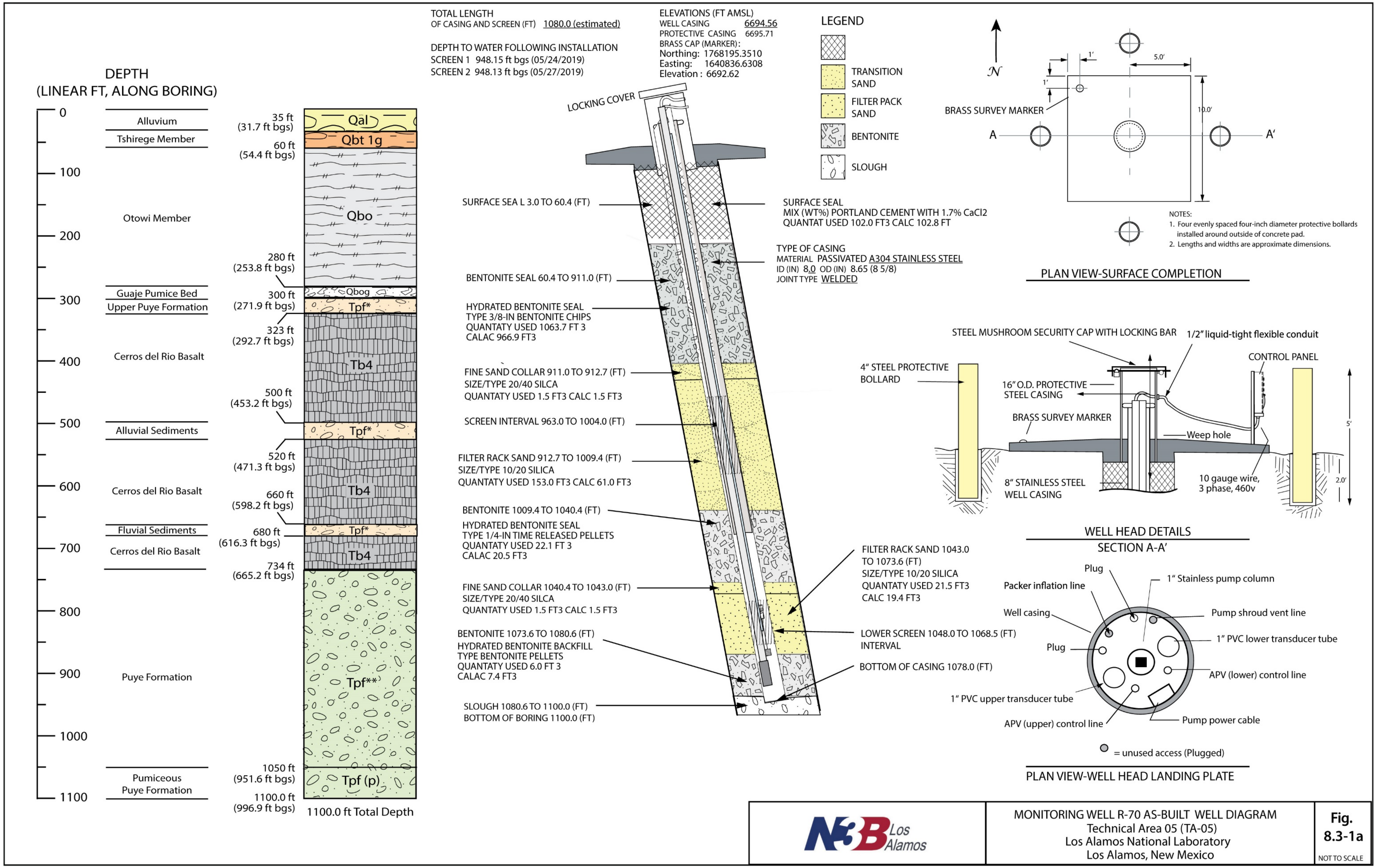


Figure 8.3-1a Installation and construction details for the R-70 sampling system

R-70 SAMPLING SYSTEM DESIGN PACKAGE TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker
Northing: 1768195.3510
Easting: 1640836.6308
Elevation: 6692.62

Well Casing
Northing: 1768186.6876
Easting: 1640838.0377
Elevation: 6694.56

SAMPLING SYSTEM MATERIALS AND PRODUCT LIST
Pump: Grundfos OK-10550-930-70
Pump motor: Franklin 23432786020
Motor cable: 460v, 3ph

Discharge column: 2" SS
Check valve: 1" SS
Couplings: 2.375 NUE/Nitronic 60
Gauge tubes: 1" PVC
Banding: SS
Thread Compound: V-2
Sampling tree: A304 schd. 40 stainless steel
1-in nipples, elbows, bushings, and hose barbs

AQUIFER TESTING
Constant Draw Down Test (screen #1)
Specific Capacity: 13.47 gpm/ft
Performed on: 05/23-24/2019

Constant Draw Down Test (screen #2)
Specific Capacity: 7.5 gpm/ft
Performed on: 05/26-27/2019

DEDICATED SAMPLING SYSTEM

Pump (shroud)
Make: Grundfos
Model: OK-10550-930-70
S/N: P11832 1001
Base of shroud: 1017.69' linear ft below ground surface (not bgs due to slant)

Motor
Make: Franklin
Model: 2343278602G
S//N: 19A14-18-00699C

Pump Shroud
SS; 1009.58'-1017.69' bgs

Pump Column
2" Stainless Steel

Transducer Tubes
Upper = 1" PVC pipe banded to SS drop pipe (1007.30' bgs)
Lower = 1" PVC pipe banded to SS drop pipe (1007.30' bgs)

Transducer
Upper:
InSitu LT500 (30 psi)
S/N: 694581 (Manufactured 2019-10)
Screen: 987.26' - 1007.17'

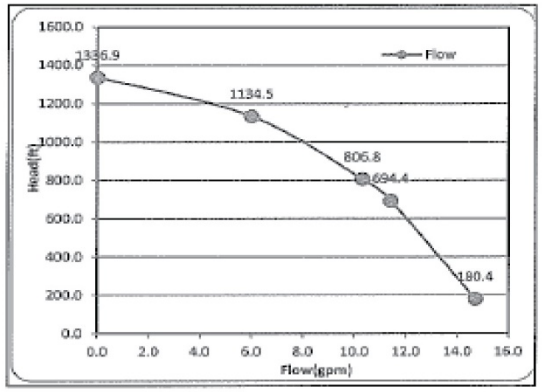
Lower:
InSitu LT500 (30 psi)
S/N: 694573 (Manufactured 2019-10)
Screen: 1038.59' - 1039.58'

N3B Los Alamos		R-70 SAMPLING SYSTEM DESIGN PACKAGE TECHNICAL NOTES Technical Area 05 (TA-05) Los Alamos National Laboratory Los Alamos, New Mexico	Fig. 8.3-1b NOT TO SCALE
Drafted By: N3B Project Number: 86306	Date: October 10, 2019 Filename: --		

Figure 8.3-1b Technical notes for the installation and construction of the R-70 sampling system

VERIFIED PERFORMANCE TEST SHEET

DATE: 07/24/2019
CUST: uerque Pipe & S
WO #:
TEST#: 1



PUMP
MFR: GRUNDFOS
MN: 10s50-930
SN: P11832 1001

MOTOR
MFR: FRANKLIN
MN:
SN: 9A14-18-00699

HP:
VOLTS:
AMPS:

HZ:
PHASE:
SFA:

TEST POINT	FLOW GPM	HEAD FT	HEAD PSI	AMPS L1	AMPS L2	AMPS L3
1	14.7	180.4	78.1	6.0	6.9	6.9
2	11.4	694.4	300.6	6.4	7.3	7.2
3	10.3	806.8	349.3	6.3	7.3	7.2
4	6.0	1134.5	491.1	5.8	6.7	6.6
5	0.0	1336.9	578.7	4.4	5.4	5.2
6						
7						
8						
9						
10						

Tested By: jw

N3B Los Alamos

Drafted By: N3B
Project Number: 86306

Date: October 10, 2019
Filename: --

R-70 SAMPLING SYSTEM
DEDICATED PUMP PERFORMNCE CURVE
Technical Arera 05 (TA-05) Los Alamos National Laboratory
Los Alamos, New Mexico

Fig. 8.3-1c
NOT TO SCALE

Figure 8.3-1c Performance curve for the submersible pump

Table 3.2-1
Fluid Quantities Used During R-70 Drilling and Well Construction

Date	Depth Interval (ft MD)	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling					
3/9/2019	123.49	975	975	17	17
3/10/2019	363.55	1925	2900	44	61
3/11/2019	403.52	1100	4000	26	87
3/12/2019	495.7	4695	8695	124	211
3/14/2019	503.59	350	9045	0	211
3/16/2019	639	2625	11,670	84	295
3/17/2019	643	675	12,345	19	314
3/20/2019	639.04	965	13,310	15	329
3/21/2019	738.79	2180	15,490	207	536
3/22/2019	809.7	1770	17,260	140	676
3/24/2019	823.8	255	17,515	10	686
3/25/2019	978	3160	20,675	118	804
3/26/2019	1082.6	2450	23,125	80	884
3/27/2019	1100	250	23,375	0	884
Well Construction					
4/22/2019	1077.63	342	342	n/a*	n/a
4/23/2019	1061.88	2218	2560	n/a	n/a
4/24/2019	1046.37	1,431	3991	n/a	n/a
4/25/2019	1031.16	811.5	4802.5	n/a	n/a
4/26/2019	1010.86	1079.5	5882	n/a	n/a
4/27/2019	980.42	3640.8	9522.8	n/a	n/a
4/28/2019	979.1	988.7	10,511.5	n/a	n/a
4/29/2019	970.77	1635.9	12,147.4	n/a	n/a
4/30/2019	960.98	1207	13,354.4	n/a	n/a
5/1/2019	955.5	595	13,949.4	n/a	n/a
5/2/2019	923.09	1847	15,796.4	n/a	n/a
5/3/2019	911.04	792	16,588.4	n/a	n/a
5/4/2019	844.53	322	16,910.4	n/a	n/a
5/5/2019	809.74	217	17,127.4	n/a	n/a
5/7/2019	755.7	388	17,515.4	n/a	n/a
5/8/2019	697.26	245	17,760.4	n/a	n/a
5/9/2019	646.41	102	17,862.4	n/a	n/a
5/11/2019	613.11	48.2	17,910.6	n/a	n/a
5/12/2019	600.58	805.2	18,715.8	n/a	n/a
5/13/2019	422.07	1703.6	20,419.4	n/a	n/a
5/14/2019	215.98	2100	22,519.4	n/a	n/a

Table 3.2-1 (continued)

Date	Depth Interval (ft MD)	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
5/15/2019	60.13	1200	23,719.4	n/a	n/a
5/17/2019	3	510	24,229.4	n/a	n/a
5/18/2019	3	3220	27,449.4	n/a	n/a
Total Water Volume (gal.)					
R-70	51,824.4				

* n/a = Not applicable.

Table 3.2-2
Water Levels Recorded Before, During, and After Induction Test

Date	Time	Level (ft MD)
3/27/2019	01:48	948.80
3/27/2019	02:15	948.80
3/27/2019	02:45	948.72
3/27/2019	03:15	948.70
3/27/2019	03:45	948.68
3/27/2019	04:45	948.65
3/27/2019	05:45	948.63
3/27/2019	06:45	948.80
3/27/2019	07:45	948.60
3/27/2019	08:45	948.53
3/27/2019	09:45	948.58
3/27/2019	17:17	948.3
3/27/2019	18:17	948.55
3/27/2019	19:17	948.44
3/27/2019	20:17	948.43
3/27/2019	20:30	921.16[a, b]
3/27/2019	20:35	924.15[b]
3/27/2019	20:40	926.35[b]
3/27/2019	20:45	928.60[b]
3/27/2019	20:52	931.35[b]
3/27/2019	20:55	932.25[b]
3/27/2019	21:00	933.65[b]
3/27/2019	21:16	937.65[b]
3/27/2019	21:40	941.75[b]
3/27/2019	22:10	944.89[b]
3/27/2019	22:40	946.65[b]

Table 3.2-2 (continued)

Date	Time	Level (ft MD)
3/27/2019	23:10	947.59[b]
3/27/2019	23:40	948.05[b]
3/28/2019	14:40–17:33	945.75

[a] Added 200 gal. water at 20:27 for induction test.

[b] Induction test conducted.

Table 6.0-1
R-70 Geophysical Logging Runs

Date	Logging Interval (ft MD)	Description
3/27/2019	0–1050	Gamma log
3/27/2019	0–1050	Neutron log

Table 7.2-1
R-70 Monitoring Well Annular Fill Materials

Material	Calculated Volume (ft^3)	Actual Volume (ft^3)
Upper surface seal: cement slurry	102.8	102
Upper bentonite seal: chips/pellets	966.9	1063.7
Upper fine sand collar: 20/40 silica sand	1.5	1.5
Upper filter sand pack: 10/20 silica sand	61	153
Middle bentonite seal: chips/pellets	20.5	22.1
Lower fine sand collar: 20/40 silica sand	1.5	1.5
Lower filter sand pack: 10/20 silica sand	19.4	21.5
Lower bentonite seal: chips/pellets	7.4	5.99

Table 8.0-1
Summary of Groundwater Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-70

Location ID	Sample ID	Date Collected	Collection Depth (ft MD)	Sample Type	Analysis
Well Development					
R-70	WST05-19-181466	5/20/2019	1048–1068	Groundwater	TOC
R-70	WST05-19-181465	5/21/2019	963–1004	Groundwater	TOC
Aquifer Test					
R-70	WST05-19-181522	5/24/2019	963–1004	Groundwater	TOC
R-70	WST05-19-181523	5/24/2019	963–1004	Groundwater	TOC
R-70	WST05-19-181554	5/24/2019	963–1004	Groundwater	TOC
R-70	WST05-19-181526	5/27/2019	1048–1068	Groundwater	TOC
R-70	WST05-19-181527	5/27/2019	1048–1068	Groundwater	TOC
R-70	WST05-19-181555	5/27/2019	1048–1068	Groundwater	TOC

Table 8.1-1
Water Produced During R-70 Well Development

Date	Screen	Start Reading	End Reading	Volume (gal.)	Cumulative Volume (gal.)
05/16/2019	Bailing	n/a*	n/a	435.5	435.5
05/19/2019	Both, no packer	2046	72,287	70,241	70,676.5
05/20/2019	Upper	72,330	85,494	13,164	83,840.5
05/20/2019	Lower	85,494	96,483	10,989	94,829.5
05/21/2019	Upper	96,483	107,779	11,296	106,125.5

* n/a = Not applicable.

Table 8.1-2
Field Parameters Measured During Well Development at R-70

Date	Time	Screen	Temp. (°C)	DO (mg/L)	Spec. Cond. (µS/cm)	pH	ORP (mV)
5/20/2019	9:34:30	Screen 2	14.256	7.78	5	8.36	179.3
5/20/2019	9:43:21	Screen 2	14.302	7.77	4.7	8.35	179.7
5/20/2019	10:13:21	Screen 2	14.297	7.77	5	8.51	180.5
5/20/2019	10:43:21	Screen 2	14.558	7.88	1.2	8.31	190.3
5/20/2019	11:13:21	Screen 2	15.232	7.77	9.4	7.99	213.1
5/20/2019	11:43:21	Screen 2	15.759	7.67	9.7	7.74	229.8
5/20/2019	12:13:21	Screen 2	15.989	7.64	9.5	7.56	246.3
5/20/2019	12:43:21	Screen 2	15.861	7.66	9.3	7.46	255.2
5/20/2019	13:13:21	Screen 2	15.615	7.69	7.1	7.44	263.2
5/20/2019	13:48:13	Screen 2	21.032	6.39	286.6	8.12	173.4
5/20/2019	14:06:56	Screen 2	21.215	6.48	288.4	8.12	164.7
5/20/2019	14:36:56	Screen 2	21.779	6.87	294.1	8.12	190.4
5/20/2019	15:06:56	Screen 2	21.527	6.15	290.1	8.13	199.5
5/20/2019	15:36:56	Screen 2	19.708	6.16	289.4	8.12	209.5
5/20/2019	16:01:11	Screen 2	17.663	6.27	289.3	8.12	209.7
5/20/2019	16:31:10	Screen 2	21.514	6.61	289	8.12	202.8
5/20/2019	17:01:10	Screen 2	21.303	6.81	289.1	8.12	203.3
5/20/2019	17:31:10	Screen 2	21.351	6.76	290.4	8.13	198.3
5/20/2019	18:01:10	Screen 2	17.08	6.66	291.5	8.12	210.9
5/20/2019	18:31:10	Screen 2	13.511	6.84	290.3	8.12	213.6
5/20/2019	19:01:10	Screen 2	10.61	7.01	290.1	8.13	214.4
5/20/2019	19:31:10	Screen 2	8.678	7.13	290.1	8.13	214.2
5/20/2019	20:01:10	Screen 2	7.438	7.13	290.5	8.15	213.6
5/20/2019	20:31:10	Screen 2	6.259	7.16	291.4	8.15	212.1
5/20/2019	20:33:15	Screen 2	6.204	7.16	291.5	8.16	212
5/20/2019	20:37:55	Screen 1	6.127	7.16	291.2	8.16	212
5/20/2019	21:33:07	Screen 1	18.19	7.75	290.9	8.14	194.8
5/20/2019	22:03:07	Screen 1	21.097	6.32	192.1	8.15	210.4
5/20/2019	22:33:07	Screen 1	20.849	6.47	195.3	8.1	220.6
5/20/2019	23:03:07	Screen 1	16.611	6.78	193.4	8.14	217.8
5/20/2019	23:33:07	Screen 1	19.134	6.59	200	8.14	209.8
5/21/2019	0:03:07	Screen 1	20.761	6.46	193.6	8.14	225.8
5/21/2019	0:33:07	Screen 1	21.365	7.55	198.6	8.15	222.6
5/21/2019	1:03:07	Screen 1	21.271	7.78	191.9	8.15	219.3
5/21/2019	1:33:07	Screen 1	21.368	7.76	191.7	8.15	221.7
5/21/2019	14:06:56	Screen 1	21.345	7.88	191.2	8.15	223.5
5/23/2019	7:28:01	Screen 1	20.895	6.95	0.7	7.49	234.4

Table 8.2-1
Water Produced During R-70 Aquifer Testing

Date	Screen	Start Reading	End Reading	Volume (gal.)	Cumulative Volume (gal.)
5/22/2019	Both	107,780	109,406	1626	1626
5/23–5/24/2019	Upper	109,406	240,197	130,791	132,417
5/26–5/27/2019	Lower	240,727	370,151	129,424	261,841

Table 8.5-1
R-70 Survey Coordinates

Identification	Northing	Easting	Elevation (ft amsl)
R-70 brass cap embedded in pad	1768192.8201	1640837.3052	6692.62
R-70 ground surface near pad	1768195.3510	1640836.6308	6692.49
R-70 top of stainless-steel well casing	1768186.6876	1640838.0377	6694.56
R-70 top of 16-in. protective casing	1768187.7409	1640838.7232	6695.71

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

Table 8.6-1
Summary of Waste Characterization Samples Collected During Drilling, Construction, Development, and Sample System Installation at R-70

Location ID	Sample ID	Date	Depth (ft MD)	Type
R-70	WST05-19-167507	3/9/2019	75–80	Drill fluids
R-70	WST05-19-167513	3/9/2019	75–80	Drill fluids
R-70	WST05-19-167479	3/13/2019	n/a*	Cuttings
R-70	WST05-19-167468	3/16/2019	530–536	Cuttings
R-70	WST05-19-167508	3/16/2019	530–560	Drill fluids
R-70	WST05-19-167512	3/16/2019	530–560	Drill fluids
R-70	WST05-19-167509	3/26/2019	990–995	Drill fluids
R-70	WST05-19-167511	3/26/2019	990–995	Drill fluids
R-70	WST05-19-167478	4/8/2019	1100	Cuttings
R-70	WST05-19-167470	4/8/2019	1100	Cuttings
R-70	WST05-19-174841	5/6/2019	n/a	Decon. fluids
R-70	WST05-19-174843	5/6/2019	n/a	Decon. fluids
R-70	WST05-19-174844	5/6/2019	n/a	Decon. fluids
R-70	WST05-19-174846	5/7/2019	n/a	Decon. fluids
R-70	WST05-19-167503	5/30/2019	1100	Drill fluids
R-70	WST05-19-167506	5/30/2019	1100	Drill fluids
R-70	WST05-19=167510	5/30/2019	n/a	Drill fluids
R-70	WST05-19-167518	5/30/2019	1100	Drill fluids
R-70	WST05-19-167750	5/30/2019	1100	Drill fluids

Table 8.6-1 (continued)

Location ID	Sample ID	Date	Depth (ft MD)	Type
R-70	WST05-19-167516	6/10/2019	n/a	Drill fluids
R-70	WST05-19-175488	6/10/2019	n/a	Decon. fluids
R-70	WST05-19-175490	6/10/2019	n/a	Decon. fluids
R-70	WST05-19-175492	6/10/2019	n/a	Decon. fluids
R-70	WST05-19-175494	6/10/2019	n/a	Decon. fluids

* n/a = Not applicable.

Appendix A

Borehole R-70 Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-70	**TECHNICAL AREA (TA):** 05	
DRILLING COMPANY: Holt Drilling Services	**START DATE/TIME:** 03/07/19; 0700	**END DATE/TIME:** 03/26/19; 1726
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR-24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION: 6691 FT AMSL		**TOTAL DEPTH:** 1100 ft measured distance (MD) down the borehole
DRILLERS: D. Sandy, A. Soto, M. Hiatt, C. Perry, D. McDonald, L. Mitchell	**SITE GEOLOGISTS:** E. Tow, C. Goetz, G. WoldeGabriel	

Depth (ft MD)	Lithology	Lithologic Symbol
0–35	Alluvium was encountered from 0 to 35 ft MD. The alluvium consists of moderately sorted and unconsolidated coarse sand. Light- to dark gray angular to subangular porphyritic felsic lava fragments are present. Quartz and feldspar crystals and rounded tuff fragments dominate the fine fraction. Minor obsidian clasts. Sorting, abundance of silt, and types of rock fragments vary with depth. The basal unit is matrix-supported, poorly sorted, and heavily coated clasts with tuffaceous silt, containing pinkish gray tuff fragments, quartz and feldspar grains, minor pumice, and sparse felsic lava fragments. Mineral content up to 35% in the finer fraction. The basal alluvium contains abundant white devitrified tuff in addition to the light pinkish gray tuff fragments, pumices, few grains of quartzite, and abundant quartz and feldspar. The amount of white, crystal-rich, and devitrified tuff fragments similar to Qbt 1v significantly increase as light pinkish gray tuff fragments decrease with depth. Quartz and feldspar grains are lightly coated with white pulverized tuffaceous silt. Minor pumice and light gray lava fragments.	Qal
35–60	Cuttings are matrix-supported, poorly sorted clasts embedded in a pumiceous coarse sand that consists of white devitrified tuff fragments mixed with abundant large (>1 cm) gray pumice clasts and minor felsic lava fragments. Pulverized tuffaceous matrix lightly coats the feldspar and quartz grains. The pumice fragments are mostly gray, inflated, and partially stretched. Minor light pinkish gray clasts. The finer fraction contains abundant crystals that decreased with depth.	Qbt 1g
60–280	Poorly sorted crystal-rich gravelly pumiceous sand, containing abundant feldspars and quartz grains in an ashy glassy matrix. Equal amounts of light gray and light brown pumice; light gray pumice up to 2 cm, angular to subangular, partially inflated; and light brown, subrounded, reworked, and coated by light brown tuffaceous silt. Lithic lava fragments are sparse. Minor coarse (>4 cm), unstained pumice. Abundant light gray and medium- to dark gray lava fragments increase at 80 to 85 ft. No recovery of cuttings from 100 to 105 ft. Lithic-rich ash-flow tuff, with abundant subrounded to rounded medium gray and pale red dacite lava fragments mixed with abundant rounded gray pumice and minor perlite and obsidian fragments. Pumice clasts lightly coated with light brown silt decrease with depth. Rendija Canyon lava fragments are common and more abundant than the other lava fragments. Lithic lava fragments are more abundant than pumices; crystals are sparse. Sparse perlite fragments persisted with depth. Rare rust-red pumice clasts. Generally, pumice clasts are coarser grained than lava fragments, but pumice content varies with depth. Locally there are more pumice clasts than lava fragments. At the base of the sequence, the pumices are coarser, inflated, relatively stretched, and more abundant than the medium- to dark gray lava fragments.	Qbo

Depth (ft MD)	Lithology	Lithologic Symbol
280–300	The Guaje Pumice Bed consists of dense white pumice fragments mixed with abundant medium- to dark gray, subrounded to rounded dacite lava fragments, and minor light gray and banded rhyolite. The bulk of the white pumice clasts are less inflated, coarser, and rounded than the lava fragments. Partially oxidized dacite lava fragments coated with reddish orange stain are common. A few Rendija Canyon lava fragments are present. Crystals are coarse and abundant.	Qbog
300–323	Abundant clast-supported, rounded, and indurated light brown silty sandstone mixed with medium to dark dacite lava and pumice fragments. The brown sandstone fragments decreased with depth, whereas the light- to medium gray felsic lava fragments significantly increased with depth. Crystals are generally sparse.	Tpf
323–500	Dark gray basalts mixed with abundant light brown silty sandstone fragments mark the transition to the Cerros del Rio basalt sequence. Basalt fragments are porphyritic, vesicular, massive, dark gray, and microcrystalline with fractured and partially altered mafic minerals of pyroxene, olivine, and plagioclase. No recovery of cuttings from 375 to 380 ft. Subequal amounts of medium to dark gray, weathered and oxidized, porphyritic, and vesicular basalt fragments and reddish brown scoriaceous clasts. The medium gray and reddish brown oxidized lava fragments persisted with depth. From 410 to 435 ft, reddish brown oxidized fragments significantly increased, with rare scoria. The reddish brown lava fragments decreased with depth and medium gray porphyritic and crystalline fragments became dominant. Partially altered dark gray basalt fragments are present. Dark gray basalt increased with depth from 480 to 490 ft. Partially altered porphyritic and massive medium gray basalt fragments mixed with minor reddish brown clasts are common.	Tb4
500–520	Light gray dacite fragments mixed with medium gray porphyritic and microcrystalline basalt lava clasts. Light- to medium gray basalt is more abundant than dacite. Dacite clasts decrease with depth. Minor rock fragments include Rendija Canyon dacite, perlite, banded rhyolite, and reddish brown oxidized basalt. The dacite fragments are subrounded to rounded, fine-grained, and porphyritic, containing coarse quartz, feldspar, few mafic minerals.	
520–600	Abundant microcrystalline and porphyritic light- to medium gray, dark gray, and fine-grained reddish brown basalt fragments; no dacite or rhyolite lava clasts. Fractured and altered olivine and pyroxene phenocrysts are common in the grayish and dark gray basalt fragments. The reddish brown oxidized lava fragments, partially scoriaceous, partially weathered, are less abundant. Vesicular and partially weathered dark gray basalt fragments increased with depth. No recovery of cuttings from 580 to 585 ft.	Tb4
600–605	Lithic fragments consist of minor reddish and dark gray scoria, pinkish gray porphyritic lava clasts similar to the Rendija Canyon dacite, and abundant light gray, sparsely vesicular, and altered dark gray basaltic lava fragments.	Tb4
605–620	Abundant pinkish gray lava clasts with light to medium and dark gray basalt fragments mixed with minor reddish brown basalt fragments and rare light pinkish gray claystone and pinkish gray dacite lava clasts.	Tb4

Depth (ft MD)	Lithology	Lithologic Symbol
620–660	Similar basaltic clasts as above, with some medium gray cement fragments used to stabilize the well.	Tb4
660–680	Light gray and pale red dacite, quartzite, and sandstone; coarse quartz and feldspar minerals; and minor basaltic fragments. The dacite clasts are mostly subrounded to rounded and larger in size (>0.5 in.) compared with the basalt fragments. Minerals and dacite fragments are partially coated with light brown and white crust. Rendija Canyon dacite fragments are common.	
685–725	Subequal amounts of dark and light- to medium gray basalt fragments, minor dacite, and light pinkish gray claystone fragments. No recovery of cuttings from 690 to 695 ft. Basaltic clasts as above. Some basalt fragments are heavily coated with pulverized rock dust. The lower part of the basaltic lava sequence is dominated by sparsely vesicular and partially weathered dark gray fragments mixed with subordinate light- to medium gray porphyritic crystalline lava clasts. Few reddish brown oxidized lava fragments are present.	Tb4
725–734	Abundant sparsely vesicular and partially weathered dark gray basaltic cuttings, minor light- to medium gray basalt clasts, and minor light pinkish gray claystone fragments.	Tb4
734–760	Two types of abundant basaltic lava clasts and minor dacite clasts dominated by Rendija Canyon lava fragments. No recovery of cuttings from 760 to 765 ft.	Tp
760–830	Abundant Puye Formation dacite fragments appeared at 765 ft. However, the gamma log defines the contact between the Cerros del Rio basalts and the Puye Formation at about 734 ft depth. Detailed examination of bulk cuttings simultaneously collected with the chip-tray samples from the 730- to 760-ft interval indicate the first appearance of abundant matrix-supported gravelly sand dominated by dacite lava fragments within the 730- to 740-ft depth interval. This observation is consistent with the stratigraphic contact established by gamma log data at 734 ft MD. Thereafter, the Puye Formation cuttings contain comparable amounts of light- to medium gray and pale red dacite lavas dominated by Rendija Canyon fragments mixed with minor basalt clasts as contaminants. Similar lithologies continued to 780 ft. No recovery of cuttings from 820 to 830 ft.	Tp
830-1050	Pale red fragments of the Rendija Canyon dacite predominate with depth. The base of the Puye Formation consists of pale red and medium gray dacite lava fragments, minor white lava clasts, and sparse quartz and feldspar grains.	Tp
1050–1100	Two types of abundant lava fragments, minor pumice clasts, and sparse mineral grains. The lava fragments consist of subrounded to rounded light- to medium gray and pale red porphyritic dacite clasts up to 6 cm. Abundant pale red Rendija Canyon dacite. Common white pumice fragments partially covered by light reddish brown silt. Pumice clasts increased with depth. Most pumice fragments are lightly covered by light brown silt. Quartz and feldspar grains are sparse.	Tp

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

MD = measured distance (down the borehole)

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-70

B-1.0 GROUNDWATER SCREENING ANALYSIS AT R-70

Well R-70 is a regional aquifer monitoring well located in Technical Area 05 (TA-05) that was installed as part of the Chromium Groundwater Project monitoring network. R-70 was drilled at a 25° angle from the vertical with two screens from 963.0 ft measured distance down the borehole (MD) to 1004.0 ft MD (screen 1) and from 1048.0 ft MD to 1068.5 ft MD (screen 2) in the Puye Formation. This appendix presents the screening results for samples collected during well development and aquifer testing at R-70.

B-1.1 Laboratory Analysis

At the end of each aquifer test, samples were collected and analyzed for the full groundwater characterization suite, total organic carbon (TOC), and tracers introduced in nearby wells.

Table B-1.1-1 lists the key analytical results for these two samples.

B-1.2 Field Analysis

Groundwater field parameters were collected during aquifer testing from two samples that were subsequently submitted for laboratory analysis, one from each screen. Field parameters included temperature, pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), specific conductance, and turbidity. The time of sample collection and discharge rate were also recorded for each of these samples. The field parameters were subsequently monitored during 24-hr pumping tests during aquifer testing.

Table B-1.1-2 lists the field parameters recorded for these two samples.

B-2.0 SCREENING ANALYTICAL RESULTS

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

B-2.1 Total Organic Carbon

TOC concentrations were below the target concentration of 2.0 mg/L in two groundwater samples collected during aquifer testing at R-70 (Table B-1.1-1). All TOC analyses were performed according to U.S. Environmental Protection Agency method SW-846:9060.

B-2.2 Field Parameters

Table B-1.1-2 presents results of field parameters, including temperature, pH, ORP, DO, specific conductance, and turbidity, which were monitored for samples collected from each screen for analytical laboratory analysis. One sample each was collected from screen 1 and screen 2; in the following comparisons screen 1 data are always reported first. The two temperature measurements varied from 20.8° to 21.4°C and pH varied from 8.02 to 8.00 respectively. Concentrations of DO varied from 7.92 to 7.11 mg/L, and noncorrected values of ORP varied from 287.6 to 219.6 mV. Specific conductance varied from 197.6 to 293.4 µS/L, and turbidity varied from 0.55 to 0.61 nephelometric turbidity units (NTU).

Aquifer testing was conducted for 8 days, from May 20 to May 28, 2019. During aquifer testing, several longer and shorter pumping intervals were conducted on each screen before the 24-hr pumping test for each screen. During these pumping intervals of varying lengths, temperature, DO, specific conductance, pH, and ORP were monitored in approximately 30-min intervals. From May 20 to 21, 2019, temperature varied from 6.259° to 21.779°C, DO varied from 6.15 to 7.88 mg/L, specific conductance varied from 1.2 to 294.1 µS/cm, pH varied from 7.44 to 8.36, and ORP varied from 164.7 to 263.2 mV. From May 23 to 24, 2019, temperature varied from 20.573° to 21.234°C, DO varied from 5.62 to 8.24 mg/L, specific conductance varied from 0.6 to 253.9 µS/cm, pH varied from 7.48 to 8.03, and ORP varied from 167.9 to 286.6.

Table B-2.2-1 presents the field parameters monitored during the aquifer testing.

B-3.0 SUMMARY OF SCREENING ANALYTICAL RESULTS

TOC concentrations in screens 1 and 2 were below the target level of 2.0 mg/L and turbidities were from 0.55 to 0.61 NTU, respectively. Well R-70 will be sampled at the same intervals as the other Chromium Groundwater Project monitoring network wells. R-70 will also be sampled like the interim measures performance monitoring wells.

Table B-1.1-1
Analytical Results from Aquifer Test Samples

Screen	Sample ID	Sample Date	Analyte	Report Result[a]	Lab Qualifier
Screen 1	WST05-19-181523	05/24/2019	Chromium	15.2 µg/L	n/a[b]
	WST05-19-181523	05/24/2019	Nitrate	3.59	n/a
	WST05-19-181523	05/24/2019	Sulfate	6.77	n/a
	WST05-19-181523	05/24/2019	Perchlorate	0.657 µg/L	n/a
	WST05-19-181524	05/24/2019	Tritium	0.356 pCi/L	U
	WST05-19-181522	05/24/2019	Naphthalene[1-] sulfonic acid	0.002	U[c]
	WST05-19-181522	05/24/2019	Naphthalene[1,5-] disulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Naphthalene[2,7-] disulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Naphthalene[1,6-] disulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Naphthalene[2,6-] disulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Naphthalene[1,3,6-] trisulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Naphthalene[2-] sulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Naphthalene[1,3,5-] trisulfonic acid	0.002	U
	WST05-19-181522	05/24/2019	Rhenium	0.1 µg/L	U
	WST05-19-181522	05/24/2019	Total organic carbon	0.701	n/a
Screen 2	WST05-19-181527	05/27/2019	Chromium	246 µg/L	n/a
	WST05-19-181527	05/27/2019	Nitrate	4.67	n/a
	WST05-19-181527	05/27/2019	Sulfate	28.1	n/a
	WST05-19-181527	05/27/2019	Perchlorate	0.93 µg/L	n/a
	WST05-19-181555	05/27/2019	Tritium	56.201 pCi/L	n/a
	WST05-19-181526	05/27/2019	Naphthalene[1-] sulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[1,5-] disulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[2,7-] disulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[1,6-] disulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[2,6-] disulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[1,3,6-] trisulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[2-] sulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Naphthalene[1,3,5-] trisulfonic acid	0.002	U
	WST05-19-181526	05/27/2019	Rhenium	0.1 µg/L	U
	WST05-19-181526	05/27/2019	Total organic carbon	0.685	n/a

[a] Result reported in mg/L unless otherwise stated.

[b] n/a = Not applicable.

[c] U = The material was analyzed for but was not detected above the level of the detection limit.

Table B-1.1-2
Field Parameter Results from Aquifer Test Samples

Sample ID	Date	Time	Temperature (°C)	pH	ORP (mV)	DO (mg/L)	Spec. Cond. (µS/cm)	Turbidity (NTU)[a]	Discharge Rate (gpm)[b]
WST05-19-181522[c]	05/24/2019	0713	20.8	8.02	287.6	7.92	197.6	0.55	91
WST05-19-181526[d]	05/27/2019	0711	21.4	8	219.6	7.11	293.4	0.61	90

[a] NTU = Nephelometric turbidity unit.

[b] gpm = Gallons per minute.

[c] Screen 1 sample.

[d] Screen 2 sample.

Table B-2.2-1
Field Parameters Monitored during Aquifer Testing

Date	Time	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm)	pH	ORP (mV)
05/20/2019	9:34:30	14.256	7.78	5	8.36	179.3
05/20/2019	9:43:21	14.302	7.77	4.7	8.35	179.7
05/20/2019	10:13:21	14.297	7.77	5	8.51	180.5
05/20/2019	10:43:21	14.558	7.88	1.2	8.31	190.3
05/20/2019	11:13:21	15.232	7.77	9.4	7.99	213.1
05/20/2019	11:43:21	15.759	7.67	9.7	7.74	229.8
05/20/2019	12:13:21	15.989	7.64	9.5	7.56	246.3
05/20/2019	12:43:21	15.861	7.66	9.3	7.46	255.2
05/20/2019	13:13:21	15.615	7.69	7.1	7.44	263.2
05/20/2019	13:48:13	21.032	6.39	286.6	8.12	173.4
05/20/2019	14:06:56	21.215	6.48	288.4	8.12	164.7
05/20/2019	14:36:56	21.779	6.87	294.1	8.12	190.4
05/20/2019	15:06:56	21.527	6.15	290.1	8.13	199.5
05/20/2019	15:36:56	19.708	6.16	289.4	8.12	209.5
05/20/2019	16:01:11	17.663	6.27	289.3	8.12	209.7
05/20/2019	16:31:10	21.514	6.61	289	8.12	202.8
05/20/2019	17:01:10	21.303	6.81	289.1	8.12	203.3
05/20/2019	17:31:10	21.351	6.76	290.4	8.13	198.3
05/20/2019	18:01:10	17.08	6.66	291.5	8.12	210.9
05/20/2019	18:31:10	13.511	6.84	290.3	8.12	213.6
05/20/2019	19:01:10	10.61	7.01	290.1	8.13	214.4
05/20/2019	19:31:10	8.678	7.13	290.1	8.13	214.2
05/20/2019	20:01:10	7.438	7.13	290.5	8.15	213.6

Table B-2.2-1 (continued)

Date	Time	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm)	pH	ORP (mV)
05/20/2019	20:31:10	6.259	7.16	291.4	8.15	212.1
05/20/2019	20:33:15	6.204	7.16	291.5	8.16	212
05/20/2019	20:37:55	6.127	7.16	291.2	8.16	212
05/20/2019	21:33:07	18.19	7.75	290.9	8.14	194.8
05/20/2019	22:03:07	21.097	6.32	192.1	8.15	210.4
05/20/2019	22:33:07	20.849	6.47	195.3	8.1	220.6
05/20/2019	23:03:07	16.611	6.78	193.4	8.14	217.8
05/20/2019	23:33:07	19.134	6.59	200	8.14	209.8
05/21/2019	0:03:07	20.761	6.46	193.6	8.14	225.8
05/21/2019	0:33:07	21.365	7.55	198.6	8.15	222.6
05/21/2019	1:03:07	21.271	7.78	191.9	8.15	219.3
05/21/2019	1:33:07	21.368	7.76	191.7	8.15	221.7
05/21/2019	2:03:07	21.345	7.88	191.2	8.15	223.5
05/23/2019	7:28:01	20.895	6.95	0.7	7.49	234.4
05/23/2019	7:37:05	20.807	7.05	0.6	7.48	239.6
05/23/2019	7:41:30	21.041	7.05	0.8	7.58	236.5
05/23/2019	8:04:01	20.573	5.62	253.9	7.69	199.6
05/23/2019	8:34:01	21.023	6.92	207.4	7.87	167.9
05/23/2019	9:04:01	21.033	6.97	196.9	7.9	172.8
05/23/2019	9:34:01	21.156	7.13	198.2	7.92	184.4
05/23/2019	10:04:01	21.198	7.25	195.8	7.93	192.5
05/23/2019	10:34:01	21.234	7.34	195.6	7.93	203.9
05/23/2019	11:04:01	21.194	7.41	196.7	7.94	213.1
05/23/2019	11:34:01	21.117	7.47	198.2	7.95	221.3
05/23/2019	12:04:01	21.096	7.51	197	7.96	228.1
05/23/2019	12:34:01	21.166	7.56	197	7.96	234.2
05/23/2019	13:04:01	21.141	7.59	196.4	7.97	236.6
05/23/2019	13:34:01	21.103	7.63	196.9	7.97	242
05/23/2019	14:04:01	21.125	7.67	197.2	7.97	244.2
05/23/2019	14:34:01	21.132	7.67	197.3	7.97	245.7
05/23/2019	15:04:01	21.051	7.77	196.9	7.98	246.1
05/23/2019	15:34:01	21.18	7.7	197.4	7.98	251.1
05/23/2019	16:04:01	21.099	7.69	197.9	7.98	251.7
05/23/2019	16:34:01	21.077	7.73	197	7.99	255.8
05/23/2019	17:04:01	21.06	7.75	197.6	7.99	254.9
05/23/2019	17:34:01	21.039	7.73	197.4	7.99	256.3
05/23/2019	18:04:01	21.038	7.73	197.5	7.99	258.6

Table B-2.2-1 (continued)

Date	Time	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (µS/cm)	pH	ORP (mV)
05/23/2019	18:34:01	20.952	7.76	197.5	7.99	261.3
05/23/2019	19:04:01	21.004	7.73	197.7	7.99	263.8
05/23/2019	19:34:01	20.913	7.87	197.6	8	265.3
05/23/2019	20:04:01	20.909	7.87	197.7	8	267.3
05/23/2019	20:34:01	20.901	7.9	197.5	8	269.1
05/23/2019	21:04:01	20.851	7.82	197.7	8	272.1
05/23/2019	21:34:01	20.84	7.87	197.4	8	273.1
05/23/2019	22:04:01	20.827	7.83	197.7	8	273.6
05/23/2019	22:34:01	20.85	7.83	197.6	8	273.7
05/23/2019	23:04:01	20.788	7.83	197.3	8.01	274.6
05/23/2019	23:34:01	20.783	7.83	198.1	8.01	275.7
05/24/2019	0:04:01	20.755	8.01	197.4	8.02	276.7
05/24/2019	0:34:01	20.711	7.9	197.3	8.01	276.6
05/24/2019	1:04:01	20.79	7.84	197.4	8.01	278.1
05/24/2019	1:34:01	20.709	7.85	197.4	8.01	282.8
05/24/2019	2:04:01	20.693	7.82	197.5	8.01	284.2
05/24/2019	2:34:01	20.737	7.86	197.3	8.02	280.1
05/24/2019	3:04:01	20.658	7.9	197.1	8.02	284.5
05/24/2019	3:34:01	20.678	7.87	197.6	8.01	283.2
05/24/2019	4:04:01	20.647	8.17	197.5	8.02	282.8
05/24/2019	4:34:01	20.643	7.88	197.4	8.02	283.7
05/24/2019	5:04:01	20.716	7.88	197.7	8.02	285.8
05/24/2019	5:34:01	20.663	7.88	197.5	8.02	286
05/24/2019	6:04:01	20.65	7.96	197.4	8.02	285.5
05/24/2019	6:34:01	20.665	7.95	197.8	8.02	285.9
05/24/2019	7:04:01	20.795	8.05	197.6	8.02	286.3
05/24/2019	7:34:01	20.938	8.24	197.7	8.02	286.6
05/24/2019	8:04:01	20.798	7.32	198.3	8.03	284.1

Appendix C

Geophysical Log
(on CD included with this document)

Appendix D

Final Well Design and
New Mexico Environment Department Approval

From: Danny Katzman
To: Andersen, Dane, NMENV; Dhawan, Neelam, NMENV
Cc: cheryl.rodriguez@em.doe.gov; Mark C. Everett; David Nickless
Subject: R-70 Proposed Well Design_Rev 3
Date: Thursday, April 4, 2019 5:32:35 PM
Attachments: R-70 well_design_ plan_4-4-19_rev3.docx

Dane- see attached rev 3 of the R-70 well design. This revision includes the updated Figure 1 and is intended to reflect today's discussions and agreements.

Let us know if you have any questions.

Thanks.

Danny

R-70 Well Design Plan

1.0 Objectives

Regional well R-70 has two primary objectives. The first objective is to monitor the plume response to CrEX-5 (reconfigured well CrIN-6) in a timely manner in order to guide adaptive management of the IM operational approach in that area. The second objective is to further characterize the lateral and vertical extent of the chromium contamination in the northeastern portion of the plume. The proposed location for R-70 was selected to achieve those two goals and was based on modeling results and drilling accessibility.

2.0 Recommended Well Design

The R-70 well was drilled at an angle of 25° from vertical and an azimuth N7.8°E to 1100 ft measured depth (MD) and intersected the regional water level at 948 ft MD (5832 ft amsl.). The water level at 948 ft MD has been verified with multiple manual measurements and is consistent with a response shown in the attached Jet West neutron and natural gamma logs.

The R-70 monitoring well is proposed as a two-screen design (Fig. 1) in an 8-inch stainless steel well. The upper well screen would extend from 963 ft to1003 ft MD (5818 to 5782 ft amsl), and the lower screen will extend from 1048 ft to 1068 ft MD (5741 to 5723 ft amsl). Because of the angle of the well, a 40 ft length of screen translates to approximately 36 vertical ft of aquifer monitored by the well screen. The proposed 40-ft (36 ft) screen for the upper screen and 20-ft (18 ft) lower screen provides a conservative approach to ensuring that the well will appropriately meet the performance monitoring objective for the IM and provide for characterization of chromium concentrations at R-70 based on the considerations presented below.

2.1 Performance Monitoring

The hydraulic control objective of the IM involves use of extraction wells and injection wells that have screens that generally penetrate 50-55 ft of aquifer thickness. The intent of those screen lengths is to ensure that key strata with mass flux are captured during extraction and accessed through injection. Because it would be essentially impossible to characterize and target numerous discrete interval(s) with maximum mass flux at every location within the aquifer, longer screens provide the advantage of ensuring that preferential pathways of importance for hydraulic control are captured. Extraction and injection will inherently favor the high hydraulic conductivity zones. The top of the upper screen at R-70 will be submerged 14 ft below the water table, allowing groundwater collection in the upper part of the regional aquifer while maintaining enough submergence to ensure adequate well development. Use of a 40-ft (36 ft) upper screen at R-70 in the portion of the aquifer is predicated in part by the presence of a neutron anomaly detected by borehole geophysics in the upper part of the aquifer (see section 2.2 below). The upper screen is long enough to sample groundwater from rocks above and below the neutron anomaly, which is potentially a less transmissive zone. The top of the lower well screen is submerged 91 ft below the water table, allowing groundwater collection in the lower portion of the chromium plume and monitoring of hydraulic responses due to activities at nearby injection and extraction wells.

The R-70 well design is consistent with the screened intervals of the IM infrastructure wells and will enable comparable monitoring of trends of chromium concentrations specifically related to IM operations. It is anticipated that the upper screen at R-70 will show chromium concentrations lower than the 260-270 ppb observed at CrEX-5, but higher than 50 ppb. The concept of performance monitoring at R-70 is to monitor dissipation of chromium concentrations associated with the IM operations at CrEX-5 and CrIN-1 and -2. If anticipated performance of the IM to obtain hydraulic control is not achieved under this scenario, this proposed construction design and the well attributes (e.g., screen length, screen slot size, well diameter, and extended filter-pack design) will enable the well to be repurposed as either an injection or extraction well to assist in hydraulic control.

2.2 Chromium Characterization

Characterization of chromium concentrations at R-70 is an important second objective for R-70**.** The proposed design achieves the characterization objectives in the following manner.

Upper Well Screen

The upper screen is proposed as a 40-ft screen (36 ft) screen from 963 to 1003 ft MD and will characterize the chromium in the upper portion of the aquifer that contains three intervals with somewhat different neutron signals. Figure 2 shows representative photos of cuttings from 5-ft intervals within and surrounding the proposed screened intervals. The central part of the upper screen includes an approximately 5 to 10-ft thick positive neutron anomaly that appears to represent strata with lower porosity than strata above and below. Cuttings collected during drilling indicate the 980-985 ft interval associated with the neutron anomaly contains abundant fine-grained material and the hydraulic conductivity of this zone is likely less than that found in strata above and below it. The portion of the upper screen above the anomaly includes approximately 15 to 17 ft of relatively high porosity strata (neutron low counts). This zone contains clean coarse sands with little fine-grained material in the matrix. The lower portion of the upper screen (994 ft to 1003 ft MD) includes approximately 16 to 18 ft of high porosity strata similar to those found in the upper part of the well screen. This lower zone contains more fine-grained matrix than the uppermost zone, but significantly less that than the zone from 980-985 ft in the neutron anomaly interval. The upper screen aligns well with the upper portion of the screen at CrEX-5 (see Figure 3 showing aligned neutron logs and screen intervals for CrEX-5 and R-70). This screen length and position within the aquifer optimizes characterization of chromium concentrations in the upper portion of the aquifer. As shown in the attached figure, the lithology described from cuttings indicates an increase of fines present from approximately 1000 to 1040 ft MD.

The strategy of using a 40-ft (36 ft) screen could, in principle, result in a lower net chromium concentration measured in samples because of mixing that would occur with strata containing lower chromium concentrations during purging. However, it is just as probable that the net chromium concentrations measured during sampling would still be dominated by the concentrations in the primary mass flux strata encountered in the screen regardless of screen length. A 40-ft (36 ft) screen provides greater confidence (more conservative) that chromium flux in the R-70 area would be appropriately characterized.

Lower Well Screen

The lower screen is proposed as a 20-ft (18 ft) screen length beneath a 45-ft blank section of well casing and would characterize the aquifer at a depth of 1048 to 1068 ft MD (5741 to 5723 ft amsl), providing partial overlap with R-45 Screen 2 (5729 to 5709 amsl), which shows the presence of increasing chromium concentrations. This well screen will therefore provide important characterization information about the lateral extent of deeper chromium contamination and the vertical extent present at R-70. It is anticipated that concentrations may be above background at R-70 screen 2. Strata in the screen interval contain a moderate amount of fine matrix, and this zone may not be as productive as screen 1. However, all of the cuttings for the lower Puye Formation contain considerable fine-grain sand and the selected location for screen 2 contains intervals of coarse sand that may be relatively transmissive.

3.0 Design Details

Both will be constructed as 30-ft stainless-steel, 40-slot, rod-based wire-wrapped screens. The filter packs of the two well screens are separated by 33 ft of bentonite. The well would be constructed like other chromium IM infrastructure wells to enable potential repurposing as an extraction or injection well, if necessary, to meet the IM objective of hydraulic control of the plume. The well could also serve as a location to disposition excess extraction water in the future, even if it is not used specifically for near-term IM objectives. As such, the proposed well design includes primary (10/20) filter sand extending a length of 50 ft above the top of the upper screen slots. This filter-pack configuration would accommodate passive, continuous vadose-zone access for injection water if the well is repurposed for injection. It is expected that a steady-state water level caused by the head within the well itself will establish within the filter pack outside of the well. The filter pack design allows pressures established inside the well to equilibrate within the filter pack outside of the well without putting potentially erosive pressure on the overlying bentonite seal or the filter pack. Extending the filter pack above the upper screen will not present any adverse effects should the well be used for long-term monitoring, or if repurposed for extraction. The deeper screen will retain the standard monitoring well filter pack length, extending 5 ft above and 5 ft below the screen slots.

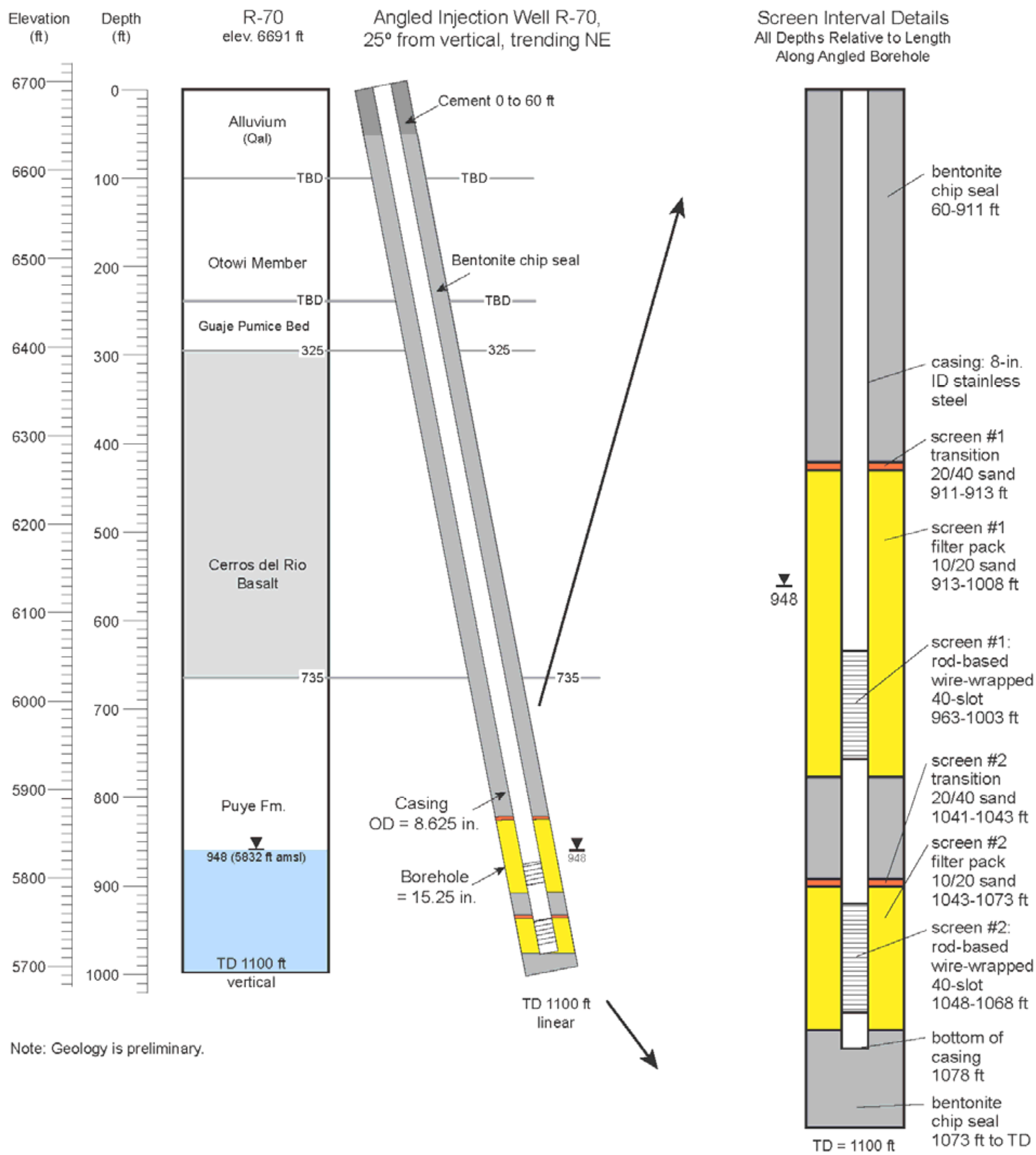


Figure 1 **Preliminary stratigraphy, and proposed well design for well R-70**

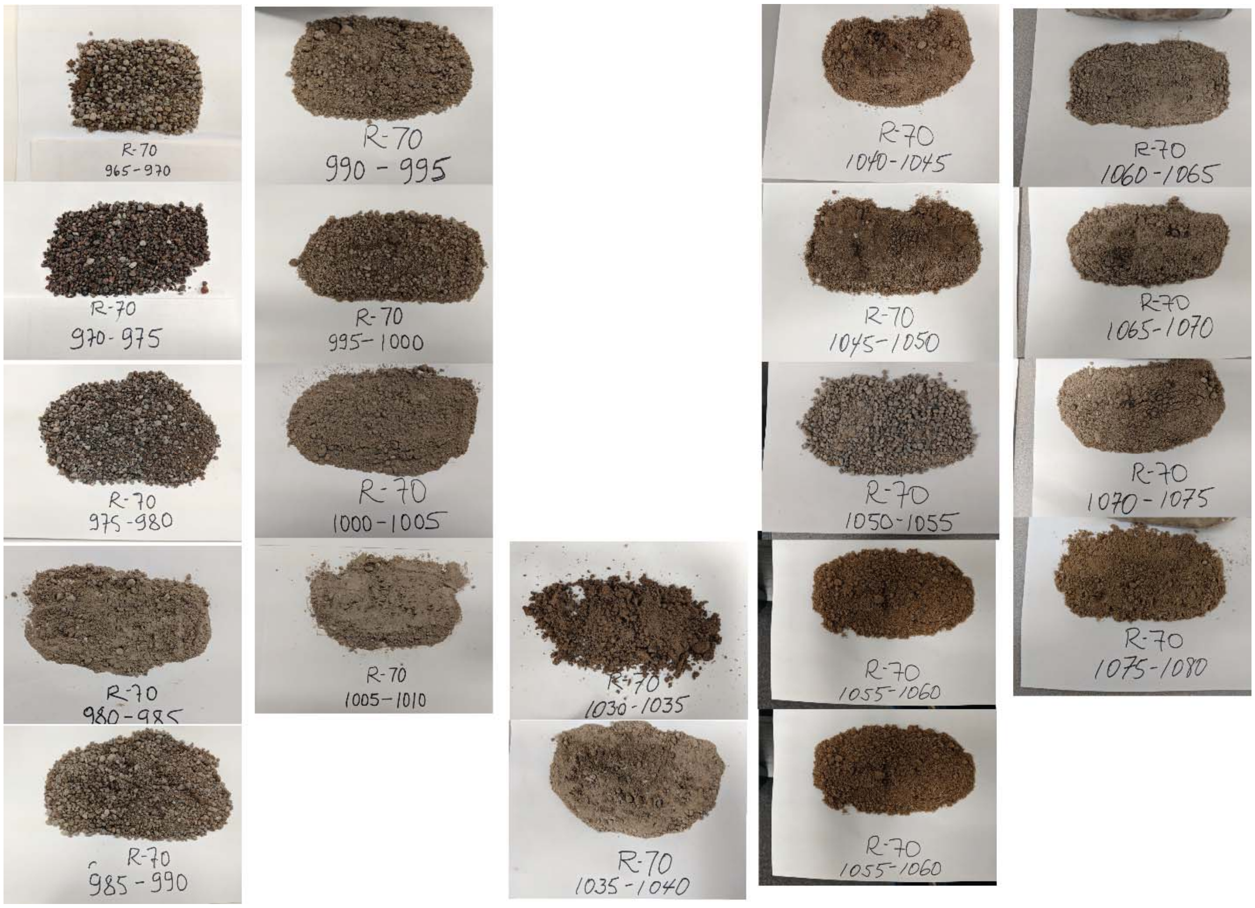


Figure 2 **Photographs of Puye Formation drill cuttings within the regional aquifer**

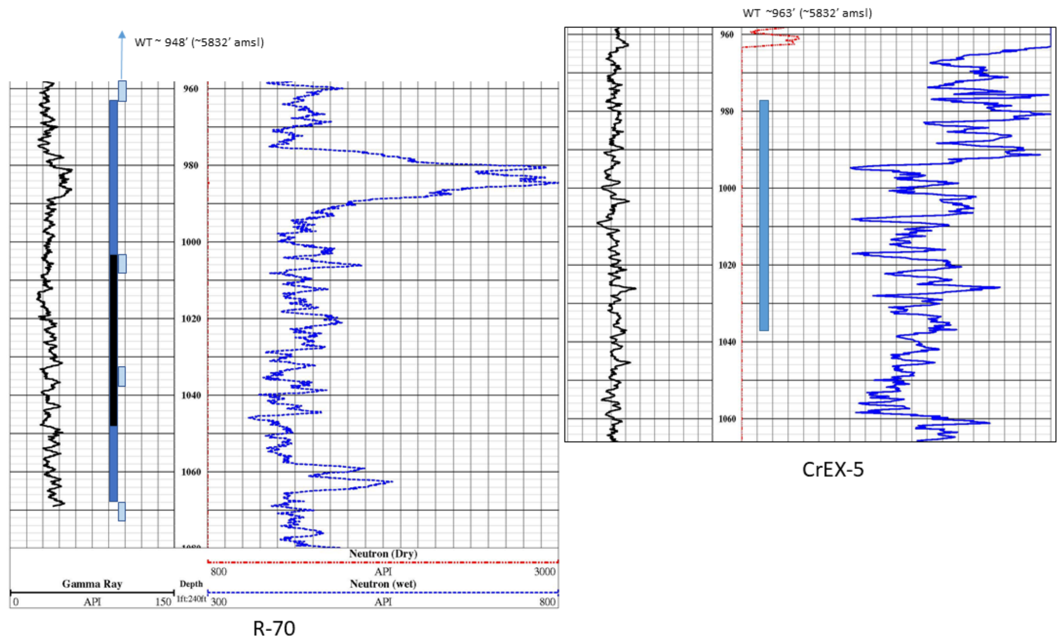


Figure 3 **Depth-adjusted neutron logs and screen intervals for CrEX-5 and R-70**

From: Dhawan, Neelam, NMENV <neelam.dhawan@state.nm.us>
Sent: Friday, April 5, 2019 8:54 AM
To: Danny Katzman; cheryl.rodriguez@em.doe.gov; Arturo Duran
Cc: Andersen, Dane, NMENV; Murphy, Robert, NMENV; Dale, Michel, NMENV; dylan.boyle2 @state.nm.us; Mark C. Everett; 'hai.shen@nnsa.doe.gov'; Kieling, John, NMENV; Mark C. Everett; David Nickless
Subject: RE: R-70 Well design

Cheryl, Danny and Arturo

Based on our phone discussions and the lines of evidence you have provided in your email, you have addressed NMED's concerns about vertical migration of chromium through the R-70 filter pack. Please be aware that if vertical migration does occur as a result of well R-70, NMED will require DOE to address this issue. NMED hereby approves the installation of the regional aquifer well R-70 as proposed in your e-mail, with attachment, that was received April 4, 2019 (Rev 3) . This approval is based on information provided by DOE to NMED at the time of the approval. DOE must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such information becomes available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, step-drawdown test, and aquifer testing at R-70.
Please call if you have any questions concerning this approval.

Thanks,

Neelam Dhawan
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From: Danny Katzman <danny.katzman@em-la.doe.gov>
Sent: Thursday, April 4, 2019 5:14 PM
To: Dhawan, Neelam, NMENV <neelam.dhawan@state.nm.us>; cheryl.rodriguez@em.doe.gov; Arturo Duran <arturo.duran@em.doe.gov>
Cc: Andersen, Dane, NMENV <Dane.Andersen@state.nm.us>; Murphy, Robert, NMENV <Robert.Murphy@state.nm.us>; Dale, Michel, NMENV <Michel.Dale@state.nm.us>; Boyle, Dylan, NMENV <Dylan.Boyle2@state.nm.us>; Mark C. Everett <mark.everett@em-la.doe.gov>; 'hai.shen@nnsa.doe.gov' <hai.shen@nnsa.doe.gov>; Kieling, John, NMENV <john.kieling@state.nm.us>; Mark C. Everett <mark.everett@em-la.doe.gov>; David Nickless <david.nickless@em.doe.gov>
Subject: [EXT] RE: R-70 Well design

Neelam, others- thanks for taking the time for the discussion following your email. And following on your request, here are the points that we raised regarding our concerns with NMED's proposed well design.

- The filter pack intervals that would be required above (5 ft primary + 2 ft transition) and below (5 ft primary) a 20' screen set from 960-980 MD would place filter pack in the fine-grained sand interval that NMED appears to want to avoid.
- Moving the 20' screen up by 5' to 955-975' would leave only 6 ft of submergence between the water table and the top of the filter pack. Such a configuration could cause significant issues with the ability to adequately develop the well. Inadequate development would potentially leave drilling foam in the aquifer that has historically caused mutual concerns with representativeness of redox sensitive constituents like chromium.
- We also discussed the concept suggested by NMED that contamination could move downward through the filter pack from contaminated strata above the neutron anomaly to strata below the anomaly causing contamination to enter portions of the aquifer where it may not currently exist. DOE/N3B completely agrees with the desire to avoid cross contamination under any circumstances. We believe however that cross contamination through the filter pack is improbable because of indications that there are not downward gradients in the R-70 area as manifested by the common heads present in Screens 1 and 2 in nearby R-45 (85' of screen separation) and by the highly stratified nature of the aquifer throughout the Cr plume area.
- The DOE's proposed 40' screen, while not typical of monitoring wells with shorter screens normally required by NMED, is justified in this case because of the specific nature of the performance monitoring objective for R-70 which is to monitor the intended reductions in Cr concentrations associated with Interim Measures activities involving extraction at CrEX-5 and injection at CrIN-1 and CrIN-2.
- We also maintain that the extended filter pack above the upper screen provides additional potential functionality, if R-70 is ever needed for use as an injection well. The extended filter pack does not pose any adverse aspects in use of R-70 as a performance monitoring well.

Please copy all on any follow up correspondence so that folks who need to take any necessary actions are in the loop.
Thanks!
Danny

From: Dhawan, Neelam, NMENV <neelam.dhawan@state.nm.us>
Sent: Thursday, April 4, 2019 2:48 PM
To: cheryl.rodriguez@em.doe.gov; Arturo Duran <arturo.duran@em.doe.gov>
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Subject: R-70 Well design

Cheryl and Arturo
I'm following up on our phone call from yesterday. We have reviewed your well design for R-70. Michel went and observed the drill cuttings this morning, we have discussed it internally and have reached consensus. Here are NMED's recommendations.

On March 30, 2019, DOE submitted to NMED a proposed well design for regional aquifer well R-70. The design proposed a dual screen completion with 30 ft screened intervals from 968 to 998 ft measured distance (MD) for the upper screen and 1038 to 1068 ft MD for the lower screen. The intent of the proposed upper screened interval was to capture a neutron porosity peak apparent from the R-70 geophysical logs from approximately 975 to 990 ft MD. In the initial well design, DOE interpreted this neutron porosity peak as a potential **high-flux zone** for chromium.

Following review of the geophysical log and well design, NMED questioned DOE's interpretation of the neutron porosity peak as a high-flux zone in an email sent to DOE on April 1, 2019. On April 2, DOE responded with a revised well design (revision 1) which reinterpreted the neutron porosity peak as a zone of **low porosity**, which, according to the revision 1 well design, **"may or may not be proportional to hydraulic conductivity values."** The revision 1 well design proposed an upper screened interval from 963 to 993 ft MD to capture the 16 ft neutron porosity peak and the 14 ft zone immediately above it.

Following further discussion between NMED and DOE on the proposed well design, DOE submitted a revised well design (revision 2) on April 3, 2019. The revision 2 well design included a third interpretation of the geophysical logs, which incorporated observations from the R-70 drill cuttings. The third interpretation identified the neutron porosity peak as a zone with **"low porosity and potentially low hydraulic conductivity."** This interpretation is supported by fine-grained sediments observed in the drill cuttings sample from 980-985 ft MD. DOE also interpreted two zones of relatively higher permeability immediately above and below the neutron porosity peak (approximately 963 to 980 ft MD and 994 to 1003 ft MD). The revision 2 well design proposes a 40 ft upper screen from 963 to 1003 ft MD, which is intended to capture the potentially low permeability zone represented by the neutron porosity peak and the two adjacent high permeability zones, as interpreted by DOE in their revision 2 well design.

In summary, within the proposed upper screened interval, DOE has interpreted two high permeability zones which are vertically separated by a zone of relatively lower permeability. The two high permeability zones potentially have different chromium mass concentrations and flow paths. DOE's proposed well design for the upper screen would effectively connect these high permeability zones through the R-70 filter pack. Connection of these two zones (which have unknown chromium concentrations) could potentially facilitate vertical chromium transport through the R-70 filter pack.

NMED cannot approve a well design which could potentially facilitate the vertical migration of chromium. Instead, NMED proposes that the upper screen be completed from 960-980 ft MD with bentonite seals 5 feet above and below the screened interval. This design can accomplish the stated goals of IM performance monitoring and characterizing the extent of chromium without potentially damaging the regional aquifer.

NMED agrees with DOE's proposed lower screen placement from 1048 to 1068 ft MD.

Let me know if you have any questions.
Thanks

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Appendix E

Aquifer Testing Report for Well R-70

E-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted in May 2019 at well R-70, an angled, dual-screened regional aquifer well located in Mortandad Canyon at Los Alamos National Laboratory (LANL or the Laboratory). The tests on R-70 were conducted to characterize the saturated materials, quantify the hydraulic properties of the screened intervals, and evaluate the hydraulic connection between R-70 and other R-wells in the vicinity. Testing consisted of brief trial pumping during well development, background water-level data collection, and a 24-hr constant-rate pumping test on each of the two screen zones.

As in most of the R-well pumping tests conducted on the Pajarito Plateau, an inflatable packer system was installed in R-70. 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 effective at eliminating or minimizing storage effects.

The filter pack at screen 1 extended above the screen and intersected the water table 15 ft above the top of the screen. This meant that filter pack drainage and refilling would occur during pumping and recovery at screen 1, creating the possibility of a storage effect on the test data. However, because the water table did not directly intersect the well screen, the drainage rate in the filter packed annulus was not expected to be as immediate and rapid as it would have been had the screen straddled the water level. Thus, the drainage effect was expected to be delayed and muted and have limited effect on the test data. Indeed, inspection of the data suggested that there was minimal storage effect on the resulting pumping test data.

R-70 was drilled at an angle of 25 degrees off vertical and in a direction 20.3 degrees east of north. In this report, well dimensions generally refer to “measured” distance, that is, the total distance along the well casing. Where these dimensions appear, the corresponding effective vertical depth is listed parenthetically for reference. All conversions from measured distance to vertical depth were based on the assumption of an average drill angle of 25 degrees.

Conceptual Hydrogeology

Well R-70 is completed within Puye Formation deposits. Screen 1 is 40.98 ft long, extending from a measured distance down the borehole (MD) of 963 to 1003.98 ft (872.77 to 909.91 ft vertical depth below ground surface [bgs]). Screen 2 is completed within the Pumiceous Puye deposits and is 20.49 ft long, set between 1048 and 1068.49 ft MD (949.81 to 968.38 ft vertical depth bgs). The composite static water level measured on May 30, several days after the conclusion of testing, was just 15 ft above screen 1 at 948.15 ft MD (859.02 ft vertical depth bgs). The static water level fell within the Puye sediments, suggesting unconfined aquifer conditions.

During the inflation and deflations of the downhole packers, attempts were made to determine the relative changes in water levels at each screen in order to discern the individual static water levels of the two screen zones and the difference in water levels between the zones. An accurate determination of the zone-specific water levels was made difficult by several factors:

- The difference in water levels between the two screen zones was very small.
- The transducer output was abnormally “noisy” with data scatter often approaching a magnitude of 0.10 ft.
- A persistent leak through a defective coupling connection in the bottom joint of the 2-in. drop-pipe string continuously allowed drainage of drop-pipe water into the well, altering water levels slightly.

- Any time that packers are inflated or deflated, there is a substantial change in the tension to which the drop pipe is subjected. As a result, there can be slight physical movement of portions of the pipe string, which cause slight vertical movement of the attached transducers.

The combination of data scatter, drop-pipe leak, and changing tension in the drop pipe contributed to obscuring accurate data measurement. Three episodes of packer inflation/deflation produced inconsistent and contradictory measurements.

Nevertheless, the results suggested a slight upward gradient from screen 2 to screen 1 under ambient conditions. Measurements showed the screen 1 water level to be approximately 0.01 ft below the composite water level and the screen 2 water level to be approximately 0.05 ft above the composite level. Thus, the overall difference in the water levels was estimated to be 0.06 ft.

Note that these measurements are contradictory. The actual water-level changes in any two aquifer zones are in inverse proportion to the relative specific capacities of the two zones. The specific capacities of screens 1 and 2 were 13.47 and 7.5 gallons per minute (gpm)/ft, respectively. Thus, a head difference of 0.06 ft would imply a water level in screen 1 about 0.021 ft below the composite level and a screen 2 level approximately 0.039 ft higher than the composite level (as opposed to the measured averages of 0.01 and 0.05 ft, respectively).

Given the estimated head difference of 0.06 ft between the screen zones, it was possible to compute a cross-flow estimate using the following equation:

$$Q = h\frac{c_1 c_2}{c_1 + c_2} \qquad \textbf{Equation E-1}$$

Where, Q = cross-flow rate, in gpm

c_1 = specific capacity of screen 1, in gpm/foot

c_2 = specific capacity of screen 2, in gpm/foot

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

The resulting cross-flow estimate was 0.29 gpm from screen 2 to screen 1.

R-70 Testing

Well R-70 was tested from May 20 to 28, 2019. Brief trial testing was performed from May 20 to 21 as part of the well development operation. Trial testing of each zone consisted of (1) a shutdown for measurement of short-term recovery data and (2) a pump restart for measurement of short-term drawdown data. This approach offered the advantage of monitoring groundwater quality parameters before and after shutdown to check for possible changes, if any, associated with shutting down and restarting the pump.

After well development and trial testing were complete, the 3-in. steel drop-pipe string used for development was pulled and replaced with 2-in. stainless-steel drop pipe for the 24-hr pumping tests and water sampling. The 24-hr pumping tests were conducted from May 23 to May 28.

As stated above, the bottom joint of 2-in. drop pipe had a defective coupling that allowed drop-pipe water to leak continuously throughout testing. The primary effects of this were (1) interference with accurate water level measurements needed to determine the head difference between the two screen zones and (2) partially emptying the drop pipe before each of the 24-hr tests.

The empty drop pipe meant that when the 24-hr tests were started, the pump operated against reduced head and therefore produced a greater discharge rate initially (for a minute or two). As the drop pipe filled, the flow rate gradually declined to the steady-state rate. This had the effect of skewing the early drawdown data and complicating the analysis.

R-70 Screen 1 Testing

Screen 1 was trial tested late on May 20, extending into the early morning of May 21. After the pump was run at a discharge rate of 46.5 gpm for 60 min, the pump was shut down at 10:30 p.m. on May 20 and rapid data measurements of recovery were made for 60 min until 11:30 p.m. Then the pump was restarted at a discharge rate of 46.5 gpm and drawdown data were recorded for 173 min until 2:23 a.m. on May 21.

Subsequently, after the steel drop pipe had been replaced with stainless steel, the 24-hr pumping test began at 8:01 a.m. on May 23 at a discharge rate of 90.8 gpm and continued for 1440 min until 8:01 a.m. on May 24. Following pump shutdown, recovery data were recorded for 1440 min until 8:01 a.m. on May 25, when the packers were deflated and the pump was moved to screen 2.

R-70 Screen 2 Testing

Screen 2 was trial tested on May 20. After the pump was run at a discharge rate of 46.5 gpm for 60 min, the pump was shut down at 3:00 p.m. on May 20 and rapid data measurements of recovery were made for 60 min until 4:00 p.m. Then the pump was restarted at a discharge rate of 46.3 gpm and drawdown data were recorded for 100 min until 5:40 p.m.

The 24-hr test on screen 2 began at 8:00 a.m. on May 26 at a discharge rate of 90.4 gpm and continued for 1440 min until 8:00 a.m. on May 27. Following pump shutdown, recovery data were recorded for 1440 min until 8:00 a.m. on May 28, when the packers were deflated and the pump was pulled from the well.

During the 24-hr test, the on-site generator failed on three occasions, shutting down the pump on May 26 for 5 min at 2:28 p.m. and 1 min at 4:46 p.m. and on May 27 for 2 min at 6:54 a.m. Each time, generator and pump operation were restored promptly, so the shutdowns had negligible effect on the test results.

E-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.

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-70, have used nonvented 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 nonvented 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 Technical Area 54 (TA-54) tower site from LANL's Environmental Protection and Compliance Programs Division. The TA-54 measurement location is at an elevation of 6548 ft above mean sea level (amsl), whereas the wellhead elevation is approximately 6691 ft amsl. The composite static water level in R-70 was 859.02 ft vertical depth bgs, making the water-table elevation approximately 5832 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-70.

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

$$P_{WT} = P_{TA54}\left[-\frac{g}{3.281R}\left(\frac{E_{R-70}-E_{TA54}}{T_{TA54}}+\frac{E_{Wt}-E_{R-70}}{T_{WELL}}\right)\right] \qquad \textbf{Equation E-2}$$

Where, P_{WT} = barometric pressure at the water table inside R-70

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

g = acceleration of gravity, in meters per second squared (9.80665 m/s^2)

R = gas constant, in joules per kilogram per degree Kelvin (287.04 J/kg/K)

E_{R-70} = elevation at R-70 site, in feet (6691 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-70, in feet (5832 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 55.4°F, or 286.2 K)

T_{WELL} = air column temperature inside R-70, in degrees Kelvin (assigned a value of 65.8° F, or 291.9 K)

This formula is an adaptation of an equation LANL 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.

E-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 E-3

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

D = inside diameter of well casing, in inches

d = outside diameter of column pipe, in inches

Q = discharge rate, in gpm

s = drawdown observed in pumped well at time t_c, in 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 E-4

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 E-3 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.

E-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 E-5**

Where,

$$W(u) = \int_u^\infty \frac{e^{-x}}{x} dx$$ **Equation E-6**

and

$$u = \frac{1.87r^2S}{Tt}$$ **Equation E-7**

and where s = drawdown, in feet

Q = discharge rate, in gpm

T = transmissivity, in gallons per day (gpd) 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 E-8**

$$S = \frac{Tut}{2693\, r^2}$$ **Equation E-9**

Where, T = transmissivity, in gpd 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

r = distance from center of pumpage, in feet

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 E-10

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 E-11

Where, T = transmissivity, in gpd per foot

Q = discharge rate, in gpm

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 E-12

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

Where, in consistent units, s, Q, T, r, 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

$$\beta = \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}. \qquad \textbf{Equation E-13}$$

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

Another solution for partially penetrating wells is the Neuman method (Neuman 1974, 085421), which applies to unconfined conditions and accounts for delayed yield. This method was considered applicable to the R-70 pumping tests because it appeared that the pumped aquifer was unconfined and the observed data seemed to confirm unconfined, delayed yield response. The relevant equations are large, numerous, and cumbersome and are not restated here. Refer to Neuman's 1974 paper for more information.

E-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:

$$T = \frac{264Q}{\Delta s} \qquad \textbf{Equation E-14}$$

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.

E-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:

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right] \qquad \textbf{Equation E-15}$$

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:

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right) \qquad \textbf{Equation E-16}$$

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

In these equations, it is assumed that the well screen of length *L* is oriented vertically. In flat lying sediments, the expected yield of an angled screen is slightly less than that of a vertical screen of the same length because the angled screen cuts across fewer horizontal strata. However, the difference in yield is small and may be ignored with minimal error.

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-70, the well log and pumping data suggested unconfined response. 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. A value of 0.05 was used for the R-70 calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. This parameter is not well known but has been estimated at about 160 ft, on average, in Mortandad Canyon (David Schafer & Associates 2013, 700689).

Although permeable saturated sediments extend for thousands of feet beneath the surface, most of the saturated materials penetrated by the monitoring wells in Mortandad Canyon appear to form an upper hydraulically contiguous aquifer that is somewhat hydraulically isolated from the greater (deeper) regional water supply aquifer. Hydrographs (Koch and Schmeer 2011, 201566) show that wells above certain elevations respond only slightly to municipal pumping, typically showing a short-term response magnitude on the order of inches, and an annual fluctuation of around a foot up and down in response to seasonal pumping and water usage patterns, while below certain critical depths, some monitoring intervals respond dramatically to production well operation, exhibiting many feet of water-level response, suggesting that they lie below the upper hydraulically contiguous zone.

In addition to the minimal response to municipal pumping exhibited in shallow screens, other evidence supports the idea of treating the uppermost unit as a hydraulically separate zone. First, after half a century of migration, the hexavalent chromium [Cr(VI)] plume is not diving rapidly in response to municipal production pumping but appears to be on a trajectory that would allow it to pass above the production wells. (Even at the distal leading edge of the plume, contaminants are found at relatively shallow depths.) Second, a major 10-day pumping test conducted on R-28 in the upper aquifer (LANL 2012, 228624) showed no evidence of leakage from the underlying larger aquifer throughout the 10 days of pumping and 10 days of recovery.

Monitoring well depths and responses were examined to estimate the effective thickness of the upper aquifer. Table E-6.0-1 shows the supporting data used to make this interpretation. Most of the wells listed in the table have limited hydraulic responses to production well pumping that place them in the upper unit and, thus, impose lower-bound limits on the thickness of the upper hydraulically contiguous zone. The few exceptions are R-33 screen 2, which shows significant response to operation of production well PM-5, and R-8 screen 2 and R-35a, which respond strongly to operation of PM-3. Thus, the saturated depths of these three screens are assumed to extend beneath the upper unit and place upper bounds on the upper aquifer thickness at those particular locations.

According to Table E-6.0-1, the R-8, R-33, and R-35a data points imply an effective aquifer thickness *less than* 111 to 218 ft while the other data points suggest an effective aquifer thickness *greater than* 85 to 215 ft, depending on which well or borehole is examined. Undoubtedly, the actual thickness of the uppermost hydraulically contiguous zone varies spatially around the site. However, there are no locations that provide a definitive value for the effective thickness, let alone multiple locations providing information that would allow contouring an effective base for the upper aquifer.

Based on the data from Table E-6.0-1, the effective average saturated aquifer thickness in Mortandad Canyon was estimated at 160 ft. The lower-bound transmissivity calculation is not particularly sensitive to the assigned value of saturated thickness. It is necessary only 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. Thus, the estimated thickness of 160 ft was deemed adequate for the calculations.

E-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-70 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure E-7.0-1 shows aquifer pressure data from R-70 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-70 data measurements reflect the sum of the water pressure and barometric pressure that was recorded using nonvented pressure transducers. The times of the pumping test periods for the R-70 pumping tests are included in the figure for reference.

Figure E-7.0-2 shows an expanded-scale illustration of the data. The figure title incorporates the term “adjusted hydrograph.” This is because the water-level data were collected over two test periods involving separate pump positions 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. 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 little change in the apparent hydrograph, meaning the changes in water level were approximately equal to and opposite of changes in barometric pressure.

The data showed a clear response in screen 1 to pumping screen 2 with a drawdown of about 0.32 ft.

Examining the hydrographs showed a difference in data scatter from the left half of the figures to the right half. The data on the left were recorded with the transducer located between the inflatable packers to monitor the pumped interval (screen 1) while it was being pumped. The data on the right were measured with the transducer located above the upper packer to monitor screen 1 while screen 2 was being pumped. Ostensibly, the two transducers were identical but the magnitude of data scatter shown on the left was greater than normally seen from these instruments. There was no obvious explanation for the unusual output other than the transducer may have been slightly defective.

Figure E-7.0-3 shows the adjusted hydrograph data from R-70 screen 2. Figure E-7.0-4 shows an expanded-scale graph of the data. As with screen 1, there was little correlation between the adjusted hydrograph and barometric pressure curve, suggesting a high barometric efficiency.

The data showed a clear response in screen 2 to pumping screen 1 with a drawdown of about 0.35 ft.

Again, the transducer output from the unit placed between the packers (right side of these graphs) showed abnormal scatter, substantially greater than that on the left side of the plots, which was generated by a third transducer placed beneath the lower packer.

E-8.0 WELL R-70 DATA ANALYSIS

This section presents the data obtained from the R-70 pumping tests and the results of the analytical interpretations. Data are presented for both the trial tests and the 24-hr tests for screens 1 and 2.

E-8.1 Well R-70 Screen 1 Trial Test

Brief trial testing was performed at R-70 screen 1 to obtain “snapshots” of early pumping and recovery response to try to quantify properties of the subsurface materials immediately around the wellbore.

The trial testing was performed during the well development effort by shutting down the pump to obtain rapid recovery data and then restarting the pump to measure the drawdown response. This approach provided the additional opportunity of monitoring groundwater quality parameters both before and after the shutdown to assess any changes that might be seen when the pump was restarted.

Figure E-8.1-1 shows a semilog plot of the trial recovery data collected from R-70 screen 1 following 60 min of constant-rate pumping at 46.5 gpm. The transmissivity determined from the earliest line of fit on the graph was 12,700 gpd/ft. Based on the well screen length of 40.98 ft, this implied an average hydraulic conductivity value of 310 gpd/ft^2, or 41.4 ft/day.

The earliest data points on the graph showed some scatter associated with inertial effects usually seen at the very outset of pumping or recovery. The late data showed a flattening of the curve associated with vertical expansion of the cone of impression and, possibly, delayed yield effects.

It is possible the calculated transmissivity value corresponded to a sediment thickness somewhat 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 slightly lower hydraulic conductivity than that calculated based on just the screen length. In other words, the computed hydraulic conductivity values may be considered maximum, or upper-bound, values. They are likely very close to, but slightly greater than, the true values.

Figure E-8.1-2 shows the drawdown data obtained when the pump was restarted. The data showed substantial scatter (nearly 1 ft) unrelated to actual water-level changes—in excess of any such response previously observed in test pumping the R-wells at LANL. The erratic transducer response likely was caused by mechanical noise and vibration associated with pump operation.

While the explanation for the observed response is not known, it is possible that it may result from running the pump off vertical. In vertical wells, the pump shroud may rest lightly against one side of the well casing, but the pump probably hangs away from the inner wall of the shroud. In angled wells, however, the pump shroud lies tightly against the well casing and the pump, in turn, may rest directly on the inner surface of the shroud. It is possible that this configuration could induce more vibration than would the vertical orientation.

To remove some of the “noise” in the data graph, the drawdown data were replotted as a rolling average on Figure E-8.1-3. The transmissivity value determined from graph was 13,100 gpd/ft. This implied an upper-bound hydraulic conductivity value for the screen 1 interval of 320 gpd/ft^2, or 42.7 ft/day.

The late data showed a flattening of the curve associated with vertical expansion of the cone of depression and delayed yield effects.

E-8.2 Well R-70 Screen 1 24-hr Test

Figure E-8.2-1 shows a semilog plot of the drawdown data collected during the 24-hr test on R-70 screen 1 at a discharge rate of 90.8 gpm. When pumping started, most of the drop pipe was empty, having leaked overnight through the defective coupling on the bottom joint of 2-in. stainless-steel pipe. Thus, initially, the pump started against very low backpressure and produced at its maximum discharge rate.

The initial discharge rate was not known because the pump curve does not cover this condition. An attempt was made to extrapolate the available pump performance data to project what the initial discharge rate might have been. This resulted in a rough estimate of 160 gpm although there could be substantial error in this figure. Over the next couple of minutes, as the drop pipe filled, the discharge rate gradually decreased to 90.8 gpm.

The transmissivity value determined from the initial slope was 16,700 gpd/ft. There was minimal confidence in the accuracy of this value because of the unknown discharge rate and the fact that the rate steadily declined during pumping. A slightly declining discharge rate would have the effect of flattening the plotted curve and, thus, exaggerating the transmissivity value.

The subsequent slope yielded a transmissivity value of 17,100 gpd/ft. As with the previous value, this likely overstates the true transmissivity because the slope of the data trace combines the effects of ongoing pumping at 90.8 gpm and slight ongoing recovery from the greater antecedent discharge rates.

Late data from the pumping test showed continuing flattening caused by vertical expansion of the cone of depression and delayed yield. Data from the last half of the pumping test actually showed a reduction in drawdown, likely attributable to ongoing development of the screen zone.

Figure E-8.2-2 shows recovery data recorded for 1440 min following cessation of the 24-hr pumping test on screen 1. The transmissivity value determined from the initial data was 13,300 gpd/ft, corresponding to an upper-bound screen 1 hydraulic conductivity value of 325 gpd/ft^2, or 43.4 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 delayed yield effects.

Figure E-8.2-3 shows screen 2 drawdown response to pumping screen 1 along with the Neuman analysis for partially penetrating wells in unconfined aquifers. The data plot clearly shows delayed yield response.

An assumed aquifer thickness of 160 ft was used in the calculations for Figure E-8.2-3. The results showed an estimated transmissivity of 56,400 gpd/ft, yielding an average hydraulic conductivity for the entire aquifer of 353 gpd/ft^2, or 47.1 ft/day. The analysis revealed estimated confined storage of 7×10^{-4}, specific yield of 0.05, and a vertical anisotropy ratio of 0.018 indicating strongly isotropic conditions.

Note that there can be some uncertainty in the results obtained from the Neuman solution because of the great number of unknowns—(1) aquifer thickness, (2) transmissivity, (3) vertical hydraulic conductivity, (4) elastic storage, and (5) specific yield. With so many unknowns, it is possible to find a range of solutions to the problem. Nevertheless, the solution depicted on Figure E-8.2-3 appears reasonable in terms of the magnitude of the resulting transmissivity as well as both storage parameters. Further, the minimal drawdown response observed in screen 2 when pumping screen 1 implies strong vertical anisotropy, consistent with the calculation result.

Figure E-8.2-4 illustrates response to the drop-pipe leak that occurred during the screen 1 24-hr pumping test. The plot shows data recorded in the annulus above the upper packer just above the top of screen 1. As shown in the figure, as soon as the downhole packers were inflated, water began accumulating in the annular space above the packer. The water level reached a height of approximately 60 ft overnight before the test. Once pumping began, the rate of rise was linear because the drop pipe remained full throughout the test, maintaining a constant head and steady leakage rate. During recovery after pump shutdown, the water level in the annulus continued to rise, eventually reaching a height of 173 ft by the time the packers were deflated.

E-8.3 Well R-70 Screen 2 Trial Test

Trial testing of screen 2 was performed as part of the development effort to provide early time recovery and pumping response. Recovery data were recorded for 60 min following pumping screen 2 at a constant rate of 46.5 gpm for 60 min. Following the recovery period, the pump was restarted at 46.3 gpm and drawdown data were monitored for 100 min.

Figure E-8.3-1 shows a semilog plot of the recovery data collected from the trial test on R-70 screen 2 when the pump was shut down. The transmissivity determined from the initial data was 16,900 gpd/ft. Based on the well screen length of 20.49 ft, this implied an upper-bound hydraulic conductivity value of 825 gpd/ft^2, or 110 ft/day.

Subsequent data showed continuous flattening of the recovery curve, consistent with vertical expansion of the cone of impression and delayed yield.

Figure E-8.3-2 shows the drawdown data obtained from screen 2 when the pump was restarted. The transmissivity value obtained from the initial data was 17,000 gpd/ft, corresponding to an upper-bound hydraulic conductivity of 830 gpd/ft^2, or 111 ft/day. Subsequent data showed flattening of the curve caused by vertical expansion of the cone of depression as well as delay yield.

E-8.4 Well R-70 Screen 2 24-hr Test

Figure E-8.4-1 shows a semilog plot of the drawdown data collected during the 24-hr test on R-70 screen 2 at a discharge rate of 90.4 gpm. The data showed the anomalous response caused by drainage of a portion of the drop pipe before the test. The three episodes of generator failure are clearly seen in the data plot as well.

Figure E-8.4-2 shows an expanded-scale plot of the drawdown data. The transmissivity value determined from the line of fit shown on the graph was 51,300 gpd/ft, corresponding to an upper-bound hydraulic conductivity value of 2500 gpd/ft^2, or 335 ft/day. These parameter values were considered unreliable because of the variable discharge rate that resulted from starting the test with a partially empty drop pipe.

Approximately 400 min into the pumping test, the drawdown graph showed a distinct increase in slope. This suggested the possibility of a permeability reduction in the sediments some distance from the well. An alternate explanation for this response was a steady and gradual permeability reduction adjacent to the wellbore. Such an occurrence could result from a gradual accumulation of air bubbles in the formation pore spaces. Many of the R-wells at LANL have shown the presence of air in the formation, presumably injected there during air drilling operations, so this was a plausible explanation for the observed response.

Figure E-8.4-3 shows recovery data recorded for 1440 min following cessation of the 24-hr pumping test on screen 2. The very early data on the plot showed an unusual response that had the appearance of a storage effect. While there was no obvious explanation for this response, the presence of a small amount of air accumulation, either in the formation pores near the wellbore or in the casing beneath the packer, could have caused the observed effect. (Head buildup during recovery compresses the air, reducing its volume. This volume must be refilled with water, analogous to the refilling of the casing annulus in conventional casing-storage phenomena.)

Figure E-8.4-4 shows an expanded-scale plot of the recovery data from screen 2. The transmissivity value determined from the initial data was 16,300 gpd/ft, corresponding to an upper-bound hydraulic conductivity value of 796 gpd/ft^2, or 106 ft/day. Subsequent data showed the effects of vertical expansion of the cone of impression and delayed yield.

Note, however, that the large, abrupt increase in slope seen at late time in the drawdown plot (Figures E-8.4-1 and E-8.4-2) was not duplicated at late time on the recovery graph. Had the slope increase on the drawdown graph been caused by a distant aquifer permeability reduction, a similar deflection in the curve would have been seen in the recovery graph at late time. The lack of such a response suggested that the drawdown slope increase had a cause other than permeability inhomogeneity (accumulation of air near the wellbore, for example).

Figure E-8.4-5 shows a comparison of the recovery responses observed in screen 2 during the trial test and the 24-hr test. The plots show specific recovery versus recovery time. Specific recovery (ft/gpm) is the magnitude of the recovery (ft) divided by the discharge rate of the test (gpm). At early recovery times, the two plots should be virtually identical. Clearly, however, the two responses were very different. This tended to confirm the idea of storage effects being absent during the trial test but being present during the recovery from the 24-hr pumping test. It was likely that the 60-min pumping period before the trial recovery was too brief for significant air accumulation to occur whereas the subsequent 24-hr pumping period was long enough for this to happen (apparently starting at about 400 min into the test).

Accumulation of air in the formation pores near the wellbore during the 24-hr pumping test would explain all of the observations presented here—(1) time-drawdown slope increase during the 24-hr pumping test, (2) no equivalent slope change during recovery, (3) no storage effect during trial test recovery, and (4) the presence of a storage effect during the 24-hr recovery test.

Figure E-8.4-6 shows screen 1 drawdown response to pumping screen 2 along with the Neuman analysis for partially penetrating wells in unconfined aquifers. The data plot clearly shows delayed yield response.

For the assumed aquifer thickness of 160 ft, the calculations from Figure E-8.4-6 showed an estimated transmissivity of 64,400 gpd/ft, yielding an average hydraulic conductivity for the entire aquifer of 403 gpd/ft^2, or 53.8 ft/day. The analysis revealed estimated confined storage of 7×10^{-4}, specific yield of 0.03, and a vertical anisotropy ratio of 0.018 suggesting strongly isotropic conditions.

E-8.5 Well R-70 Drawdown and Recovery Aquifer Coefficient Summary

Table E-8.5-1 summarizes the upper-bound aquifer parameters for R-70 screen 1. Excluding the anomalous values obtained from the 24-hr pumping period, the average upper-bound transmissivity for this approximately 41-ft thick zone was 13,030 gpd/ft, making the upper-bound hydraulic conductivity of the screen 1 zone 318 gpd/ft^2, or 42.5 ft/day. These values are likely close to the true values but may be overstated somewhat because of slight vertical growth of the cone of depression (or cone of impression) soon after pump startup (or shutdown).

Table E-8.5-2 summarizes the upper-bound aquifer parameters for R-70 screen 2. Excluding the anomalous values obtained from the 24-hr pumping period, the average upper-bound transmissivity for this approximately 20-ft thick zone was 16,730 gpd/ft, making the upper-bound hydraulic conductivity of the screen 2 zone 817 gpd/ft^2, or 109 ft/day. These values are likely close to the true values but may be overstated somewhat.

Table E-8.5-3 summarizes the results of Neuman analysis of screen 1 and 2 responses to each other's pumping. This method accounts for partial penetration and delayed drainage of the water table. Based on an estimated aquifer thickness of 160 ft, the results showed an average transmissivity of 60,400 gpd/ft and average hydraulic conductivity of 378 gpd/ft^2, or 50.5 ft/day. The estimated average storage coefficient was 7×10^{-4}; the specific yield was 0.04; and the vertical anisotropy computed to 0.018 implying strongly anisotropic conditions locally. Note that assuming a different aquifer thickness would yield conductivity values close to those calculated. It is primarily the transmissivity that would change—a greater value for a thicker aquifer and a smaller value for a thinner aquifer.

E-8.7 Well R-70 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-70 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 necessary only to assign an aquifer thickness substantially greater than the well screen length because sediments far from the screened interval have negligible effect on yield. As stated previously, the aquifer thickness was estimated to be 160 ft. The well screen lengths of 40.98 and 20.49 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 after 24 hr of pumping.

After 24 hr of operation, R-70 screen 1 produced 90.8 gpm with 6.74 ft of drawdown for a specific capacity of 13.47 gpm/ft. In addition to specific capacity and pumping time, other input values used in the calculations included an assigned storage coefficient value of 0.05 and a borehole radius of 0.8 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 a lower-bound hydraulic conductivity estimate of 43.6 ft/day. This result was nearly identical to the values obtained from test analysis that produced an average realistic/upper-bound hydraulic conductivity value for the screen 1 interval of 42.4 ft/day. The lower-bound value was actually greater than the value estimated from the pumping test, likely having been affected by the aquifer average conductivity (50.5 ft/day), which was greater than that of just the screen 1 zone. In other words, the preferentially permeable sediments above and below the screen 1 interval contributed to increasing its specific capacity above that which would have been achieved in homogeneous sediments. This, in turn, increased the lower-bound calculation, which was based on specific capacity. On balance, the two conductivity values agreed well and suggested a very efficient screen zone.

After 24-hr of pumping R-70 screen 2, the well produced 90.4 gpm with 12.05 ft of drawdown for a specific capacity at that time of 7.50 gpm/ft. Using this information along with the storage coefficient value of 0.05 and a borehole radius of 0.59 ft (inferred from the volume of filter pack required to backfill the screen zone), the computed lower-bound hydraulic conductivity was 43.3 ft/day. This result was well below the values obtained from test analysis that produced an average hydraulic conductivity for the screen 1 interval of 109 ft/day and suggested an inefficient screen zone.

E-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-70 screens 1 and 2 to gain an understanding of the hydraulic characteristics of the aquifer. Testing consisted of brief trial pumping and a 24-hr constant-rate pumping test on each screen zone. During testing, water levels were recorded in both screen zones as well as many nearby wells in Mortandad Canyon.

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

1. A comparison of barometric pressure and R-70 water-level data showed highly barometrically efficient screen zones. Large changes in barometric pressure caused little change in the apparent hydrographs from the well, obtained using nonvented transducers.
2. The transducer data showed substantial “noise,” or data scatter. This may have been caused by mechanical vibration associated with operating the pump/shroud resting tightly against the casing. One transducer in particular showed more variation in output than the others and may have been defective in that regard.
3. A leak in the 2-in. stainless-steel drop pipe allowed drainage of the pipe during nonpumping periods and contributed to invalidating the early pumping data from the 24-hr tests by allowing large discharge rate variations.

4. Anomalous responses at screen 2 suggested the possibility that air in the aquifer accumulated in the pores near the wellbore during pumping, reducing the permeability of the sediments near the well and altering the magnitude of the drawdown observed.
5. Because of unconfined aquifer conditions, most of the drawdown and recovery data were largely unanalyzable, reflecting the complex simultaneous effects of delayed yield and vertical expansion of the cone of depression throughout testing. Better information can be obtained from thick, unconfined aquifers by extending the pumping and recovery periods to several days, long enough to get past the effects of delayed yield and for the cone of depression to encompass the full thickness of the hydraulically contiguous sediments that make up the upper aquifer.
6. There appeared to be a small upward gradient from screen 2 to screen 1, with a head difference of approximately 0.06 ft. An accurate determination of the relative heads in the two zones was hampered by (1) the noisy transducer output, (2) the persistent drop-pipe leak, and (3) slight movement of the transducers in response to changing tension in the drop pipe when inflating and/or deflating the packers. The estimated head difference of 0.06 would imply a crossflow rate of 0.29 gpm from screen 2 to screen 1. If the actual head difference is greater or smaller, the crossflow rate would change in direct proportion to the actual driving head.
7. Operation of R-70 screen 1 at 90.8 gpm caused a drawdown of 0.35 ft in screen 2. Pumping screen 2 at 90.4 gpm caused 0.32 ft of drawdown in screen 1. Based on an assigned aquifer thickness of 160 ft, analysis of these two responses yielded an overall aquifer transmissivity of 60,400 gpd/ft, a hydraulic conductivity of 378 gpd/ft^2 (50.5 ft/day), a storage coefficient of 7×10^{-4}, a specific yield of 0.04, and a vertical anisotropy ratio of 0.018 implying strong vertical anisotropy near R-70. Had a different assumed aquifer thickness been used in the analysis, the computed conductivity would have been about the same. The resulting transmissivity would have been greater for an assumed thicker aquifer and smaller for an assumed thinner aquifer.
8. Test analysis showed a realistic/upper-bound transmissivity for the 40.98-ft screen 1 zone of 13,030 gpd/ft and a hydraulic conductivity of 318 gpd/ft^2, or 42.5 ft/day. Although described as upper bounds, these values are likely very close to the true values.
9. Similarly, analysis showed a realistic/upper-bound transmissivity for the 20.49-ft screen 2 zone of 16,700 gpd/ft and a hydraulic conductivity of 817 gpd/ft^2, or 109 ft/day.
10. Specific capacity analysis of the data from screen 1 yielded a lower-bound hydraulic conductivity of 43.6 ft/day, for all practical purposes equivalent to the value obtained from the pumping test analysis. This implied a highly efficient screen zone.
11. Specific capacity analysis of the data from screen 2 yielded a lower-bound hydraulic conductivity of 43.3 ft/day, well below the value obtained from the pumping test analysis. This implied a low efficiency for screen 2.

E-10.0 REFERENCES

The following reference list 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, Safety, and Health (IDs 600000 through 699999); and EMIDs are assigned by N3B (IDs 700000 and above). IDs are used to located documents in Newport News Nuclear BWXT-Los Alamos, LLC (N3B's) Records Management System and Master Reference Set. The New Mexico Environment Department (NMED) Hazardous Waste Bureau and N3B maintain copies of the Master Reference Set. The set ensures that NMED has references to review documents. The set is updated when new references are cited in documents.

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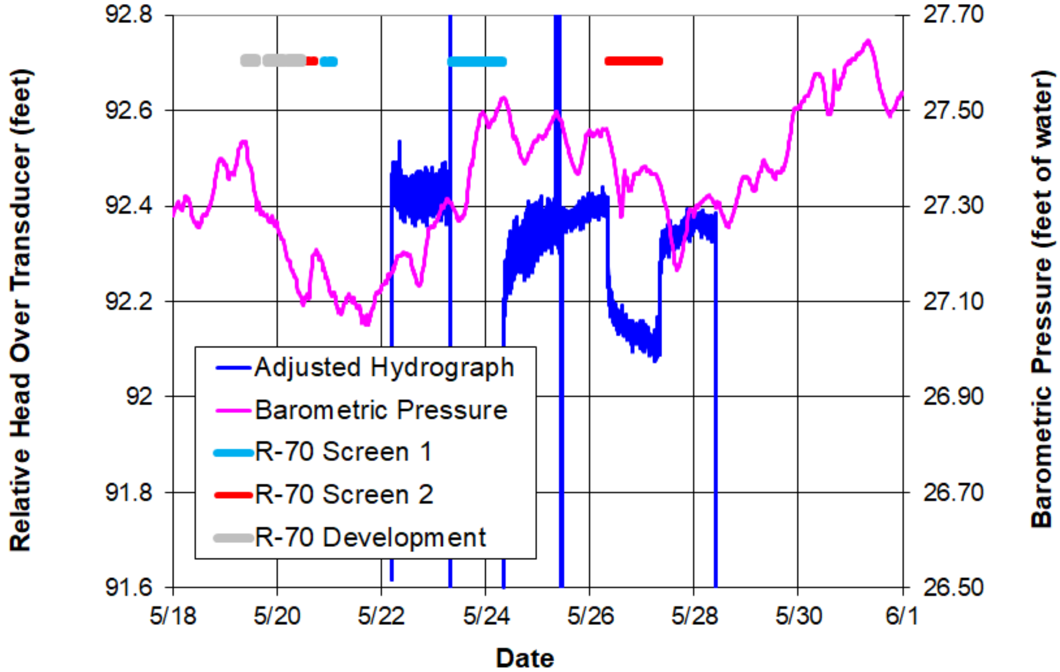

Figure E-7.0-1 Well R-70 screen 1 adjusted hydrograph

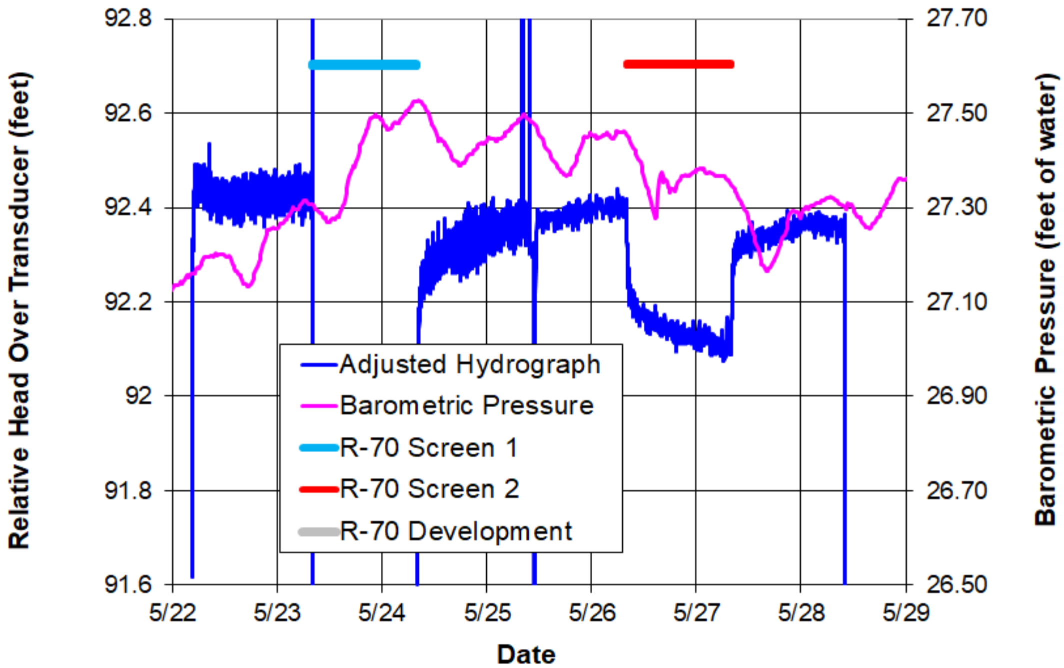

Figure E-7.0-2 Well R-70 screen 1 adjusted hydrograph – expanded scale

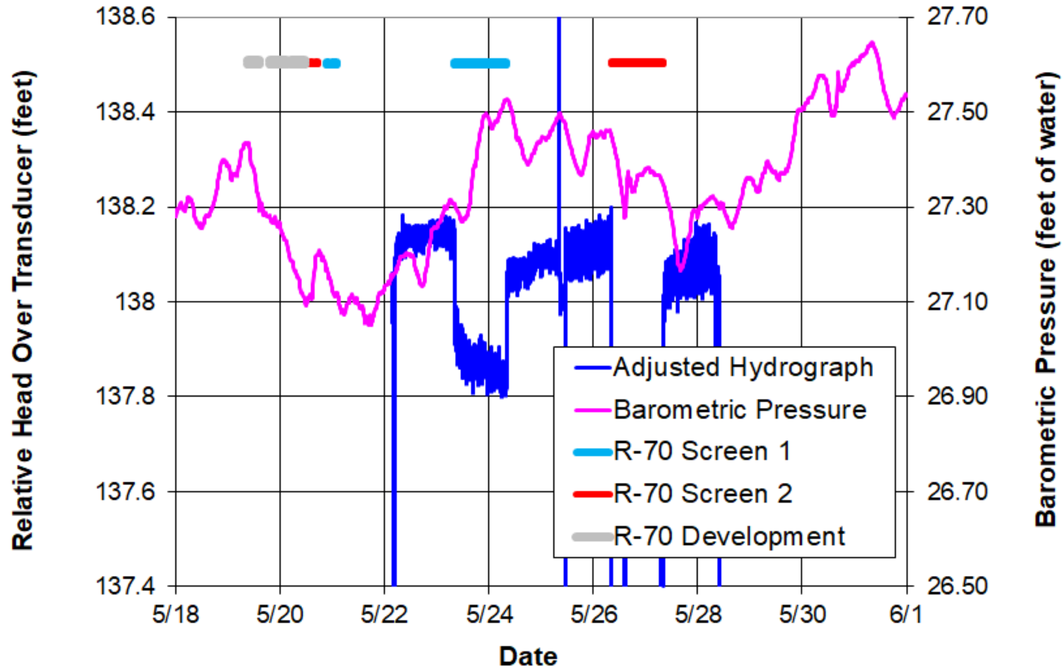

Figure E-7.0-3 Well R-70 screen 2 adjusted hydrograph

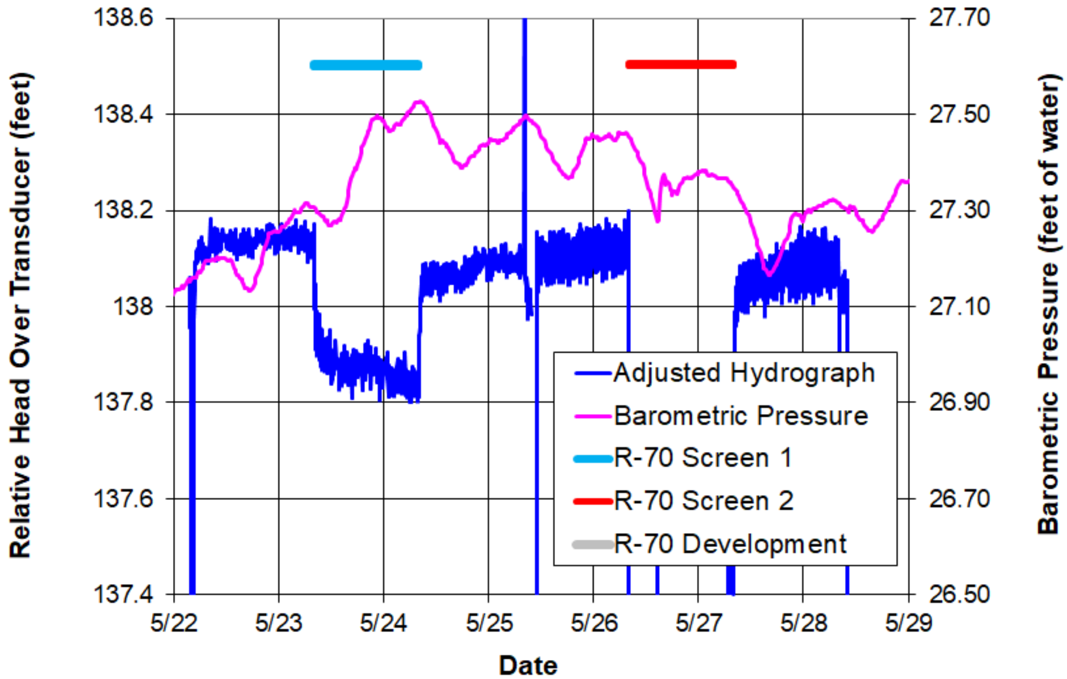

Figure E-7.0-4 Well R-70 screen 2 adjusted hydrograph – expanded scale

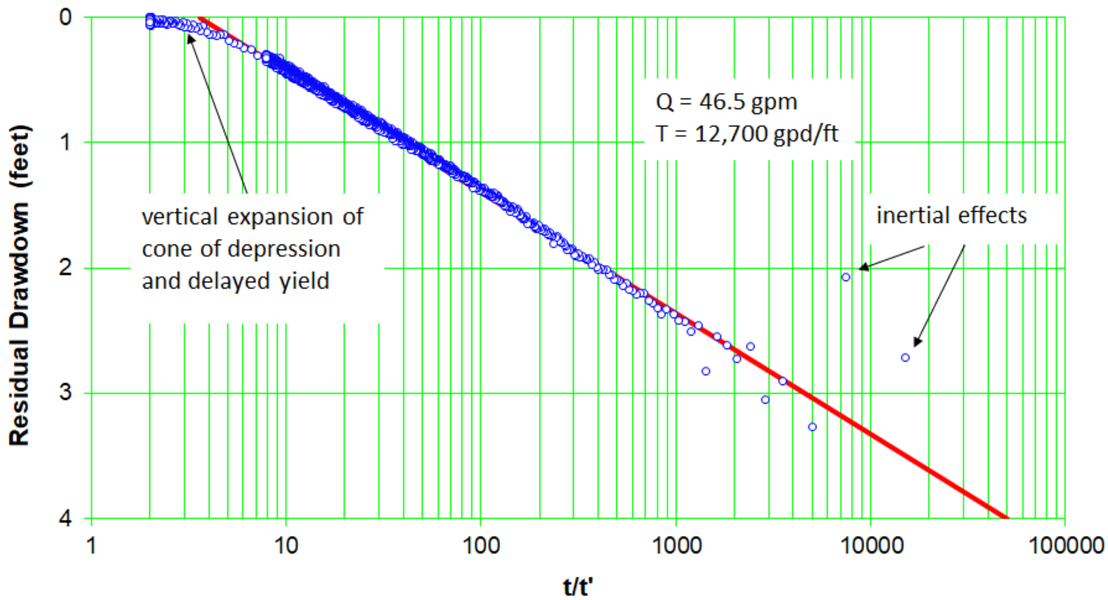

Figure E-8.1-1 Well R-70 screen 1 trial recovery

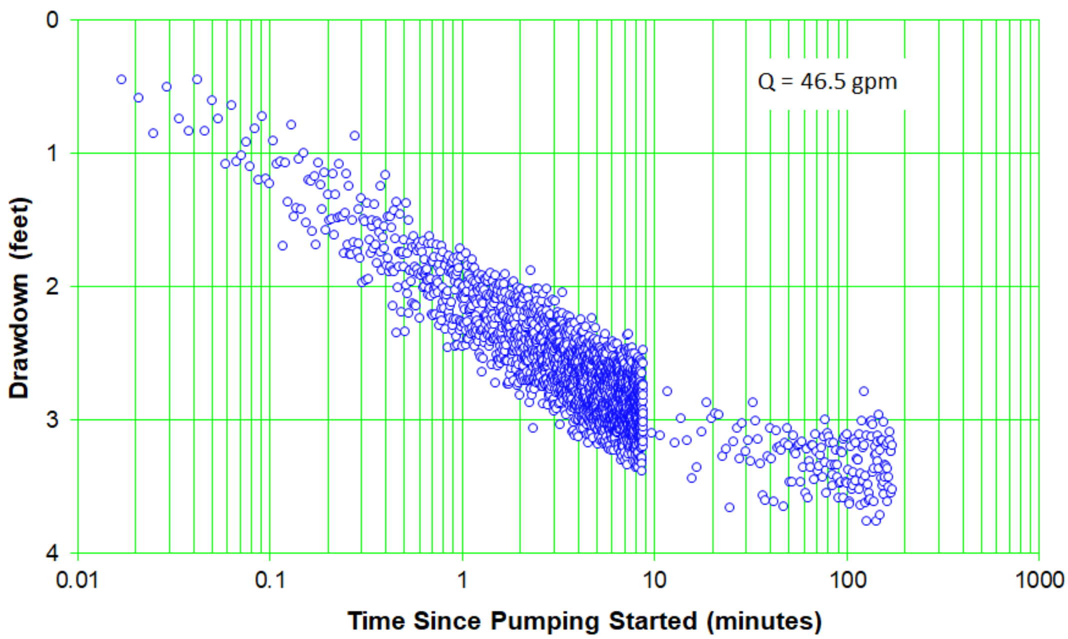

Figure E-8.1-2 Well R-70 screen 1 trial drawdown

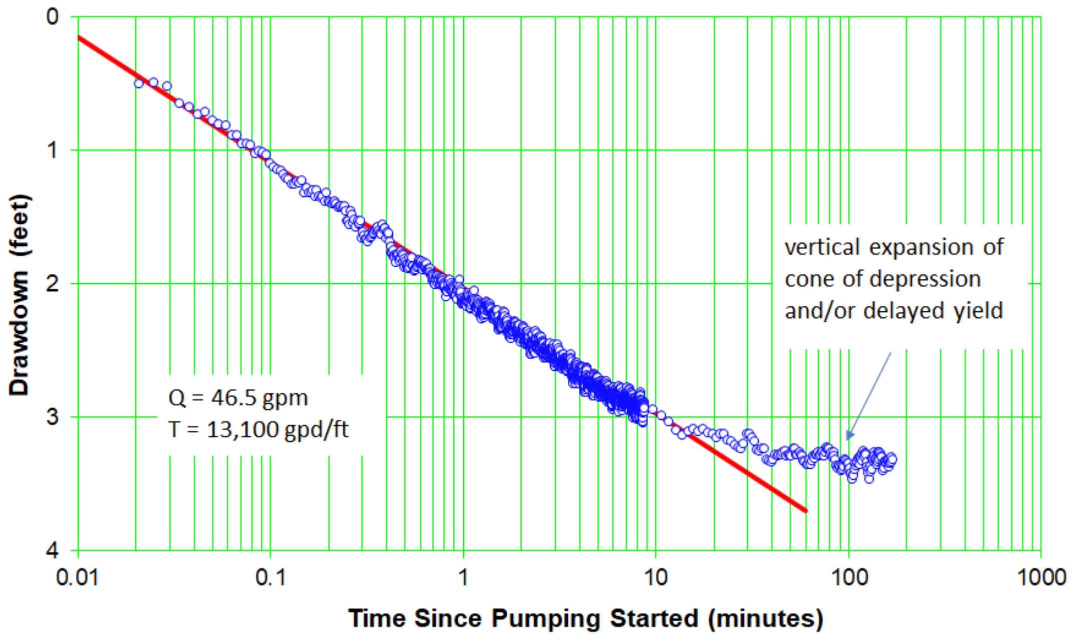

Figure E-8.1-3 Well R-70 screen 1 trial drawdown – rolling average

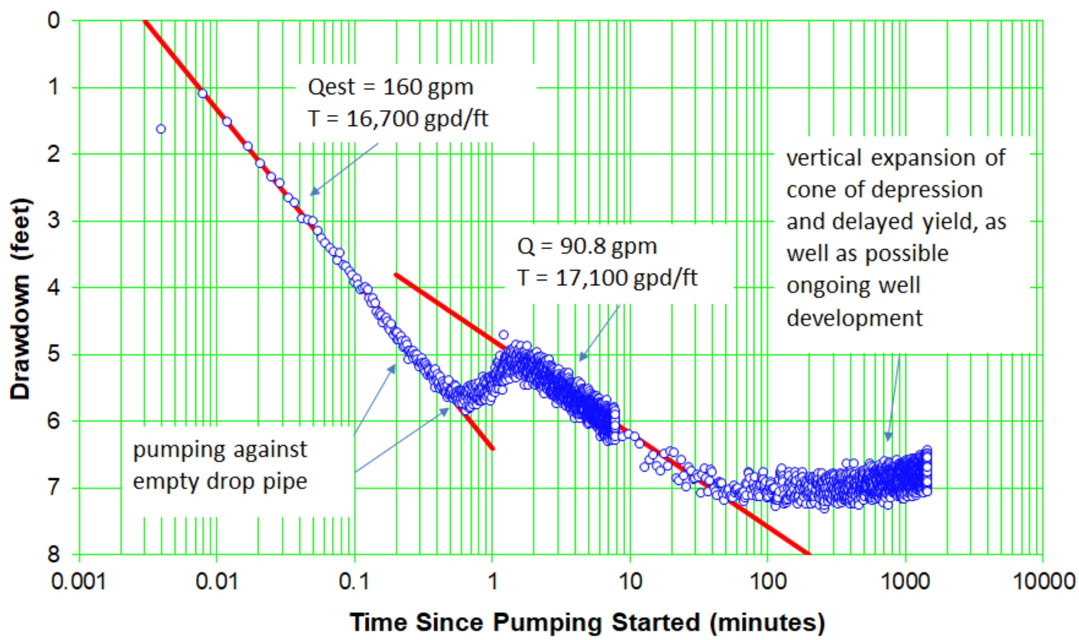

Figure E-8.2-1 Well R-70 screen 1 drawdown

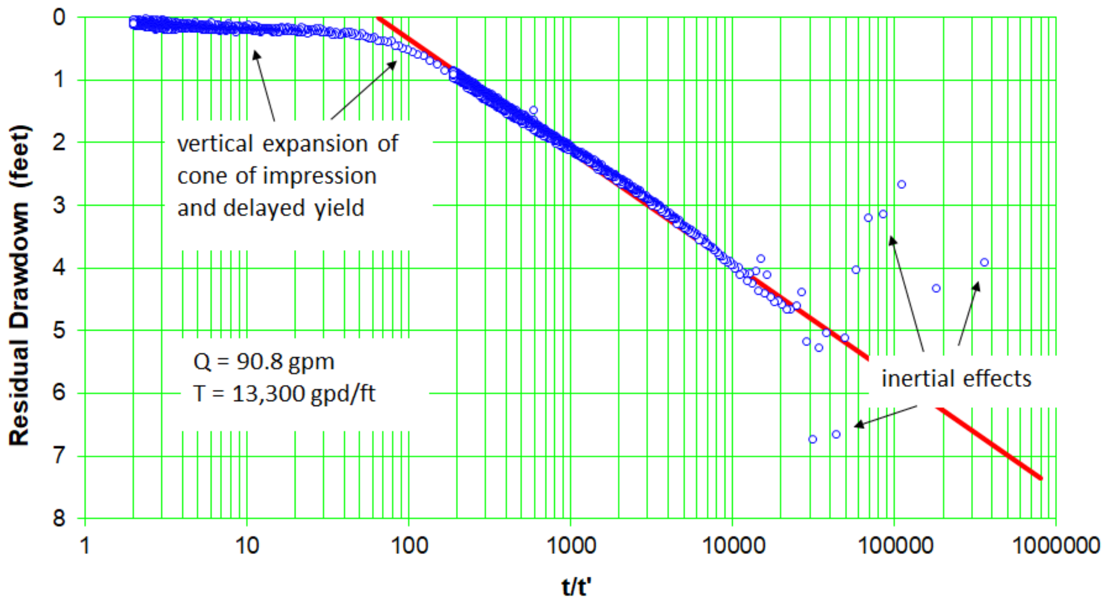

Figure E-8.2-2 Well R-70 screen 1 recovery

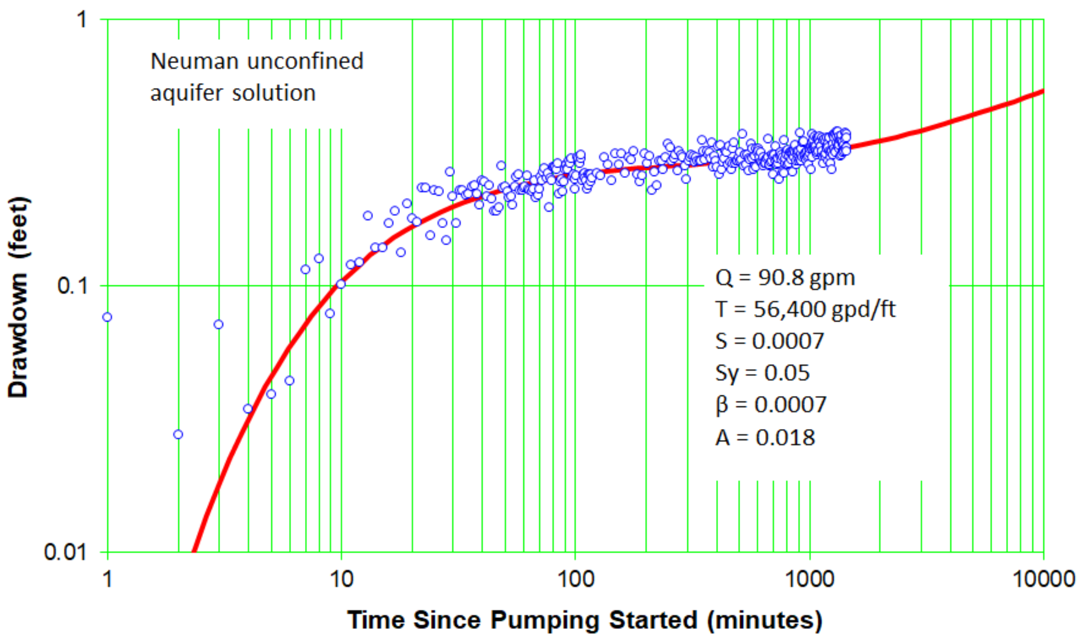

Figure E-8.2-3 Well R-70 screen 2 drawdown response to pumping screen 1

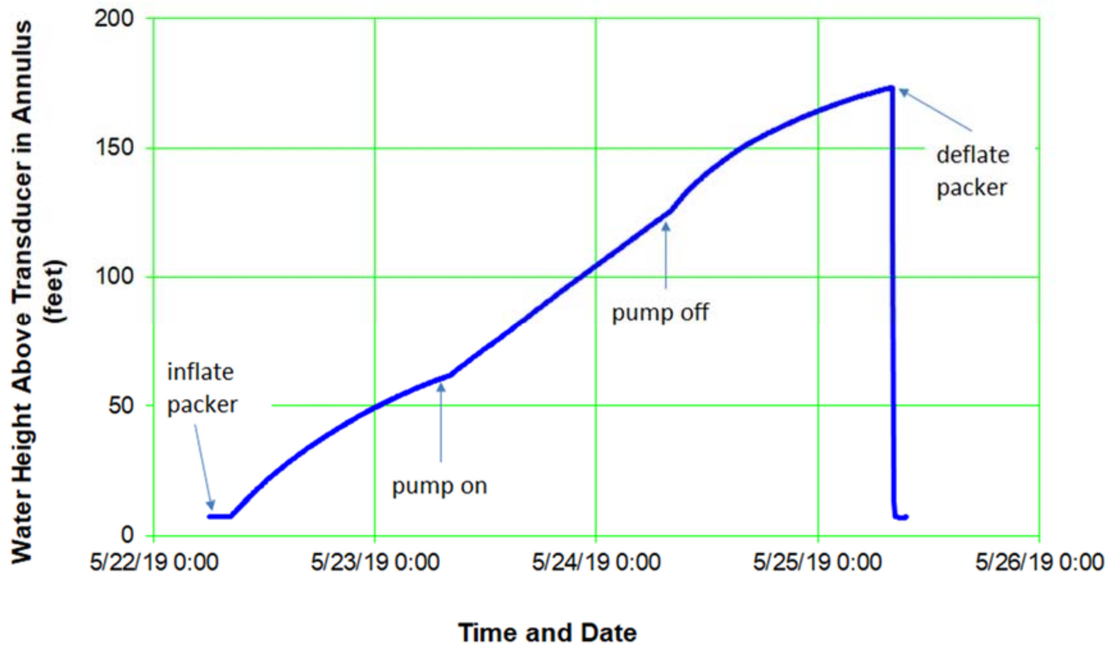

Figure E-8.2-4 Water buildup in annulus above packer during screen 1 24-hr test

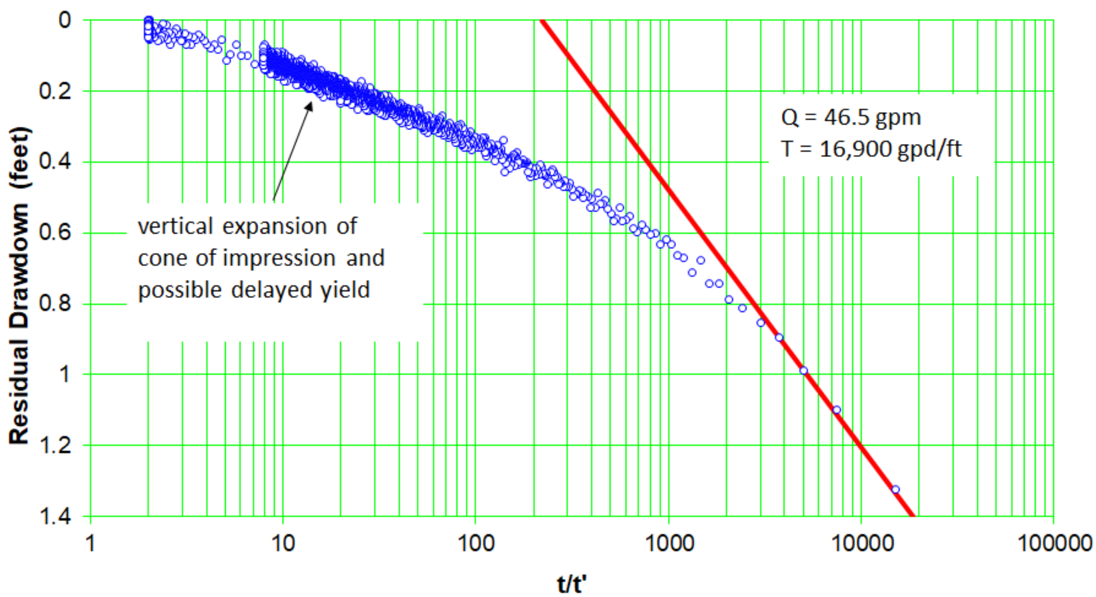

Figure E-8.3-1 Well R-70 screen 2 trial recovery

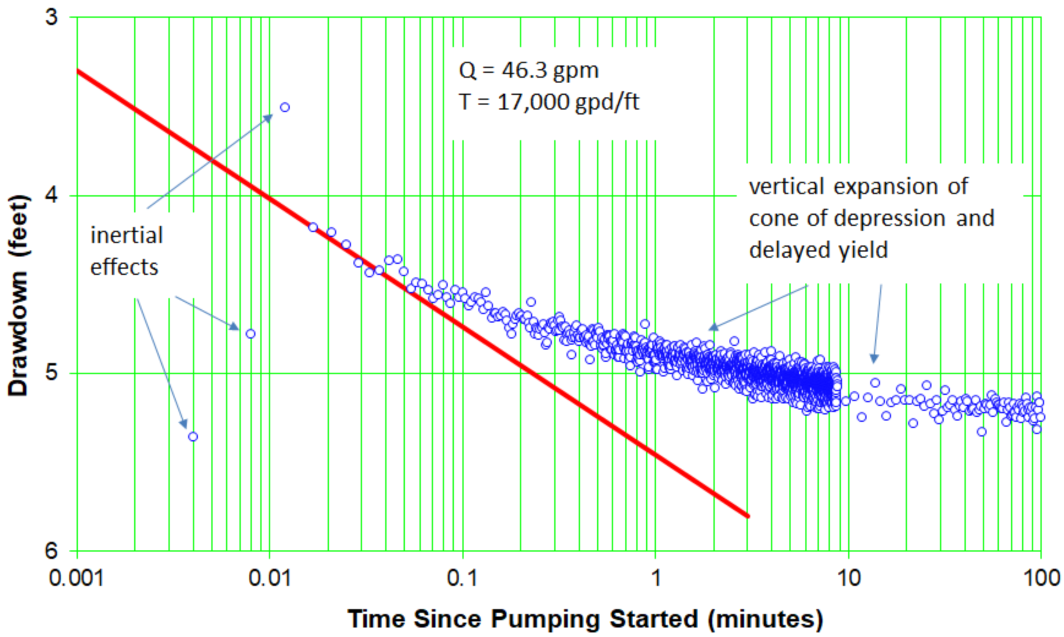

Figure E-8.3-2 Well R-70 screen 2 trial drawdown

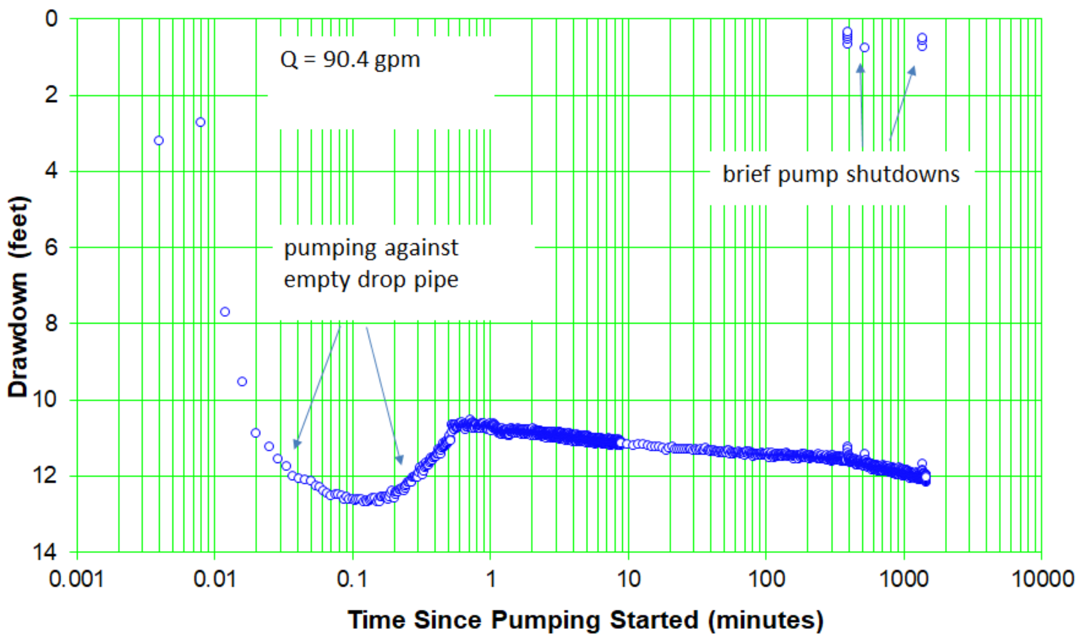

Figure E-8.4-1 Well R-70 screen 2 drawdown

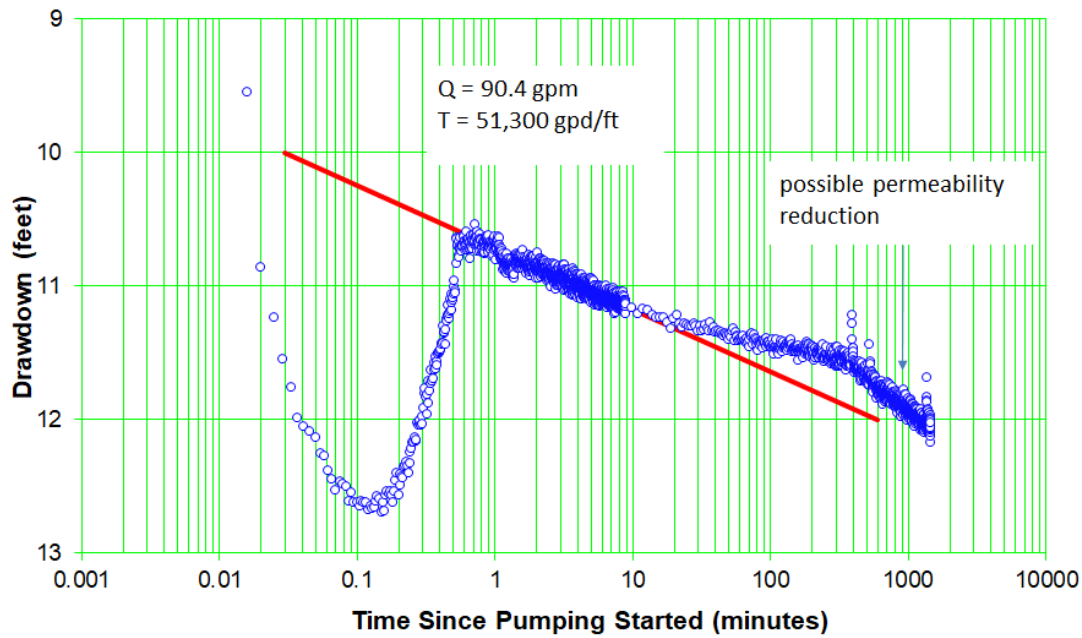

Figure E-8.4-2 Well R-70 screen 2 drawdown – expanded scale

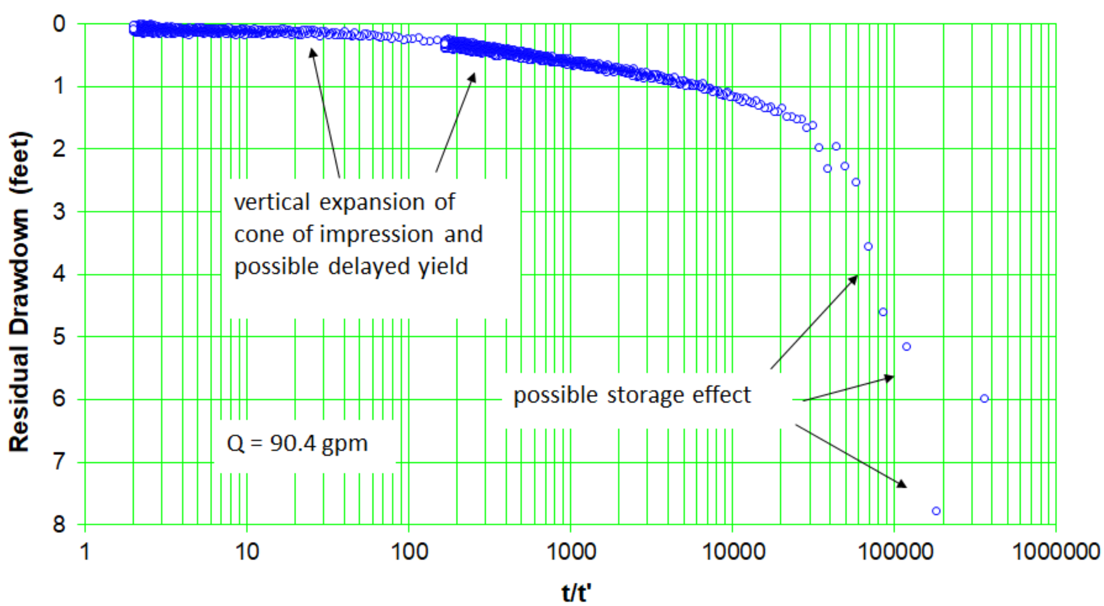

Figure E-8.4-3 Well R-70 screen 2 recovery

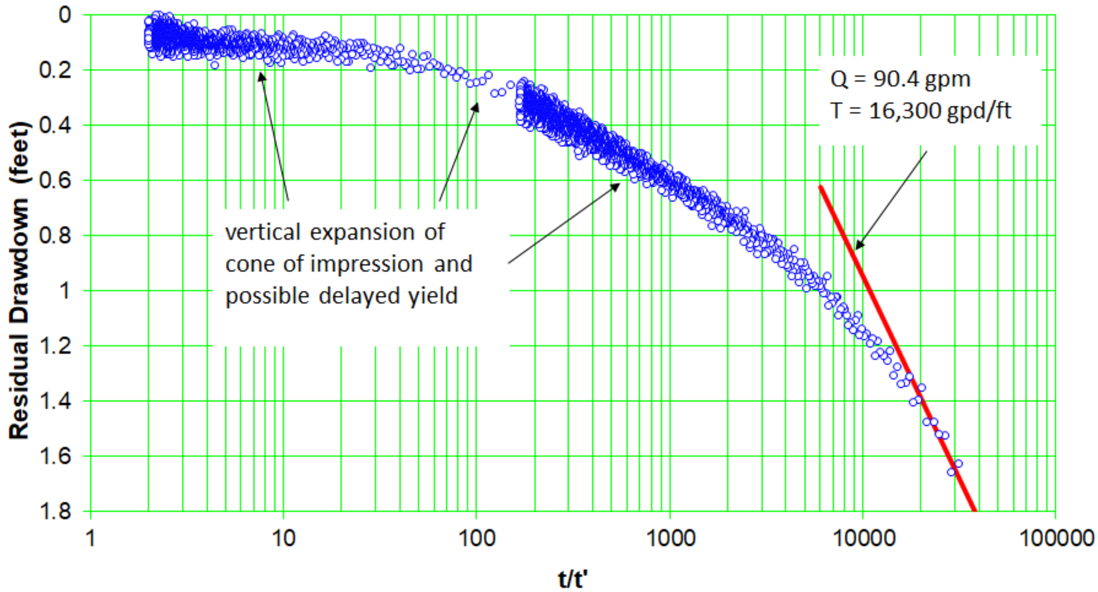

Figure E-8.4-4 Well R-70 screen 2 recovery – expanded scale

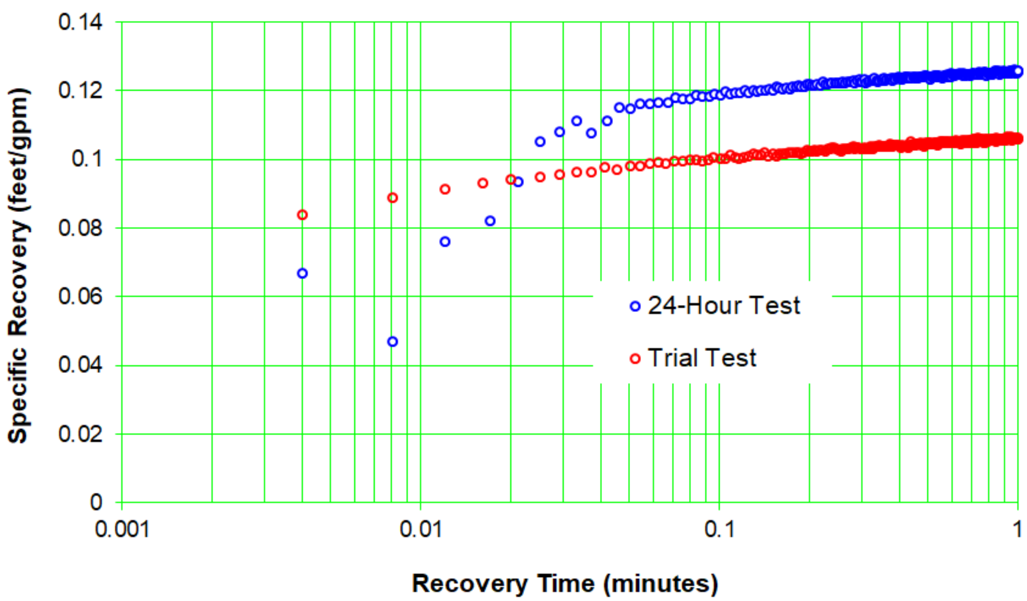

Figure E-8.4-5 Well R-70 screen 2 specific recovery comparison

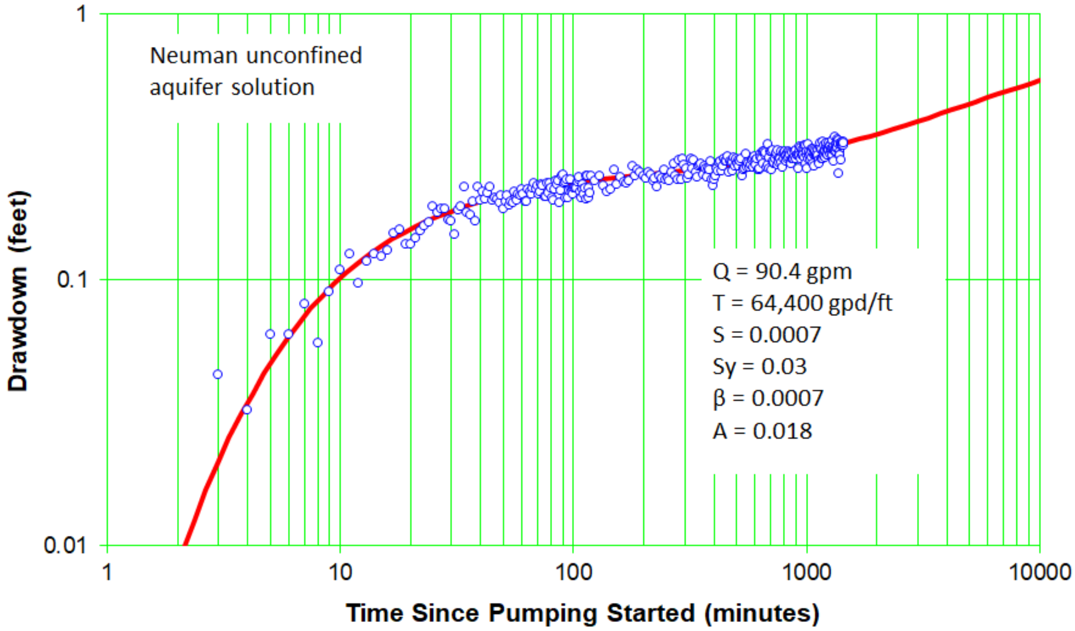

Figure E-8.4-6 Well R-70 screen 1 drawdown response to pumping screen 2

Table E-6.0-1
Estimated Thickness of Upper Regional Aquifer

Well	Water Table (ft)	Comments	Thickness (ft)
R-8	711	Top of screen 2 at 822 ft	<111
R-13	839	Bottom of screen at 1019 ft	>180
R-14	1183	Bottom of screen at 1293 ft	>110
R-33	983	Top of screen 2 at 1112 ft	<129
R-35a	795	Top of screen at 1013 ft	<218
R-42	920	Bottom of boring at 1048 ft	>128
R-43	894	Bottom of screen 2 at 979 ft	>85
R-43 boring	894	Bottom of boring at 1006 ft	>112
R-44	879	Bottom of screen 2 at 995 ft	>116
R-44 boring	879	Bottom of boring at 1094 ft	>215
R-45	868	Bottom of screen 2 at 995 ft	>127
R-45 boring	868	Bottom of boring at 1057 ft	>189
R-50	1067	Bottom of screen 2 at 1206 ft	>139
R-50 boring	1067	Bottom of boring at 1225 ft	>158
R-61	1101	Bottom of screen 2 at 1241 ft	>140
R-61 boring	1101	Bottom of boring at 1266 ft	>165

Table E-8.5-1
Upper-Bound Aquifer Parameters for Screen 1

Test	Screen Interval T (gpd/ft)	K (gpd/ft^2)	K (ft/day)
Trial recovery	12,700	310	41.4
Trial pumping	12,600	320	42.7
24-hr pumping*	16,700	408	54.5
24-hr recovery	13,300	325	43.4
Average	13,030	318	42.5

* Excluded from average.

Table E-8.5-2
Upper-Bound Aquifer Parameters for Screen 2

Test	Screen Interval T (gpd/ft)	K (gpd/ft^2)	K (ft/day)
Trial recovery	16,900	825	110
Trial pumping	17,000	830	111
24-hr pumping*	51,300	2504	335
24-hr Recovery	16,300	796	106
Average	16,730	817	109

* Excluded from average.

Table E-8.5-3
Results of Neuman Analysis

Pumped	Observed	T (gpd/ft)	K (gpd/ft^2)	K (ft/day)	S	S_y	A
Screen 1	Screen 2	56,400	353	47.1	0.0007	0.05	0.018
Screen 2	Screen 1	64,400	403	53.8	0.0007	0.03	0.018
Both	Both	60,400	378	50.5	0.0007	0.04	0.018

Appendix F

Sampling System Test Report for Well R-70

F-1.0 INTRODUCTION

The R-70 Baski dual-valve submersible pump sampling system installation was completed over the course of three separate periods of fieldwork. In September, the Baski sampling system was delivered to the well site, measured, and inspected. As a result of that inspection, parts of the system were returned to the manufacturer and replacement parts were fabricated. In mid-October, the sampling system was returned to the well site and installation was attempted. During that attempt, the system became stuck within the upper screen and had to be removed. During late October and early November the sampling system was successfully installed and tested.

Table F-1.0-1 shows the details of the R-70 well and sampling components. The system is installed with the top of the pump shroud set a couple of feet beneath screen 1, 1009.58 ft measured distance (MD) down the well casing. A weep valve is located at 8.0 ft MD to prevent freezing. After the sampling system was installed, the packer was inflated to 214 pounds per square inch (psi) on October 31, 2019. After installation, 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 wire was correct and to fill the drop pipe.

F-2.0 SAMPLING SYSTEM INSTALLATION HISTORY

The dedicated sampling system was delivered and inspected at the site from September 24 through September 27, 2019. The inspection revealed suspect welding on several parts of the sampling system, which was rejected. Replacement parts were fabricated in Los Alamos by a certified welder.

On October 12 and 13, 2019, the Baski sampling system was remobilized to the R-70 well site and various components were tested. Leaks detected in the tubing coupling, the packers, and in the regulator/cylinder connection were repaired. During installation of the sampling system on October 15, 2019, the system became stuck on a flange in the upper screen at 983.5 ft MD. The sampling system was pulled from the well on October 16 and 17, 2019, and a video log was run on October 18, 2019, to observe the interior of the well bore for damage. An attempt to run a caliper log into the well on October 18, 2019, failed because the caliper did not work accurately in the well slanted at 25° from the vertical. Measurements of the centralizer below the packer indicated that it was too large to pass through the nominal inside diameter of the screen weld rings. Both the centralizers above and below the packer were sent to a machine shop and turned down to allow passage through the potential weld bead restrictions.

On October 28, 2019, the temporary packer was removed in preparation to reinstall the Baski sampling system into the R-70 well. The lower access port valve, the packer, and centralizers were assembled, lowered into the well, and successfully tested. On October 29, 2019, the upper access port valve was assembled, lowered into the well, and successfully tested. On October 30, 2019, the entire sampling system was lowered into the well. Once the system was in place on October 31, 2019, the packer and upper and lower APVs were successfully tested.

F-3.0 PACKER INFORMATION

The packer in R-70 is located from 1032.27 to 1035.61 ft MD, which is 25.1 ft MD below the bottom of screen 1 and 2.98 ft MD above the top of screen 2. The packer inflation tubing uses 0.25-in. stainless-steel tubing from the surface to the packer and to the closed side of the APVs. The APV control tubing is also 0.25-in. stainless-steel tubing.

The packer was initially inflated on October 31, 2019, at 1:00 p.m. to a pressure of 214 psi. The shut-in packer pressure at 10:30 a.m. on November 1, 2019, was steady at 215 psi, indicating that the packer and associated tubing appeared to be holding pressure. The packer had been holding pressure for 19.5 hr before the system test began, so any initial pressure fluctuations associated with expansion and seating of the packer should have been complete. After the initial packer inflation on October 31, the APVs were operated to ascertain that there were no leaks in the control lines. An 8-day packer pressure test was conducted from November 1 through 8, 2019. The dates and packer pressures recorded are shown in Table F-3.0-1

F-4.0 R-70 PUMP SYSTEM FUNCTION TESTING

On November 6, 2019, a pump system function test was conducted. The lower APV was pressurized to 373.95 psi at 2:46 p.m. At that time the packer pressure jumped to 216 psi. At 3:00 p.m., the leads were switched, the lower APV was repressurized, and the pump was switched on. Water was pumped to the surface in 8 min and flowed at 7.72 gallons per minute (gpm). The test was completed at 3:21 p.m. with a final flow rate of 8.11 gpm and a total of 91.74 gal. pumped.

On November 7, 2019, the upper APV was pressurized to 374 psi and the pump was turned on at 10:40 a.m. Water was pumped to the surface in 13 min, at a flow rate of 8.22 gpm (measured by flow-meter). At 12:14 p.m. the APV pressure was 374.65 psi. Purge water pumping was complete by 12:48 p.m., with a total of 2026 gal. purged, 91.74 gal. pumped, and 60 gal. pumped for groundwater samples. Groundwater quality parameters stabilized during the last 65 min of the pumping test. Groundwater samples were collected under stable water quality parameters from 12:23 to 12:48 p.m.

On November 8, 2019, the packer pressure was stable at 214 psi at 9:45 a.m. The lower APV was pressurized to 373.80 psi and the packer pressure rose to 217 psi at 9:57 a.m. The pump was turned on at 9:59 a.m., with an initial flow meter reading of 2076.62 gal. Water was pumped to the surface in 14 min. Initially, the water pumped to the surface had a yellowish tinge but cleared up shortly thereafter. The pump was turned off at 12:11 p.m. with a final flow meter reading of 4056.10 and a total of 1979.49 gal pumped from the lower screen during this test. The packer pressure increased to 218 psi, which was the actual target pressure for the packer.

Table F-4.0-1 shows the groundwater volumes generated during the pump system function testing.

F-5.0 ACCESS PORT VALVE OPERATION

With the packer inflated, each APV 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-70 is stainless-steel tubing. The pressure applied to open the APVs was in excess of 370 psi. When the APVs were actuated, the packer pressure increased by a couple of psi in response to the movement of the valve, indicating that the valve had opened. The APVs typically opened less than a minute after the nitrogen gas was applied and closed less than half a minute after the gas pressure was released. However, the 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 wellhead 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 2:46 p.m. on November 6, 2019. Shortly thereafter, the packer pressure increased by 2 psi, confirming that the lower APV had opened. At 5:21 p.m. the lower APV was depressurized, the valve closed, and groundwater flow into the screen 2 APV ceased.

The upper APV was pressurized initially at 10:40 p.m. on November 7, 2019, at a pressure of 374 psi. At 2:48 p.m. the upper APV was depressurized, the valve closed, and groundwater flow into the screen 1 APV ceased.

The lower APV was pressurized initially at 9:57 a.m. on November 8, 2019, at a pressure of 373.80 psi. Shortly thereafter, the packer pressure increased by 3 psi, confirming that the lower APV had opened. At 2:11 p.m. the lower APV was depressurized, the valve closed, and groundwater flow into the screen 2 APV ceased. Once the lower APV was depressurized, the packer pressure decreased by 3 psi, returning to 214 psi.

F-6.0 PUMPING SCREEN 1

After the lower APV was actuated at 10:40 a.m. on November 7, 2019, pumping began at screen 1 at 10:40 a.m. An open sampling valve at the wellhead was watched closely for water in order to confirm that water had reached the surface. After 13 min, water was observed at the surface. Pumping continued at screen 1 until 2:48 p.m. The discharge rate during pumping was 8.78 gpm. After pumping for 4 hr, 8 min, 2177.74 gal of water had been pumped from screen 1. Groundwater was sampled at the end of this pumping test.

F-7.0 PUMPING SCREEN 2

After the lower APV was actuated at 9:57 a.m. on November 8, 2019, pumping began at screen 2 at 9:59 a.m. An open sampling valve at the wellhead was watched closely for water in order to confirm that water had reached the surface. After 14 min, water was observed at the surface. Pumping continued at screen 2 until 2:10 p.m. The discharge rate during pumping was 7.89 gpm. After pumping for 4 hr, 11 min, 1979.49 gal of water had been pumped from screen 2, long enough to simulate a sampling event.

F-8.0 SUMMARY

- The packer was set to the midrange pressure level of 214 psi at 1:00 p.m. on October 31, 2019.
- The packer, pump, pump shroud, and APVs appeared to function normally during testing.
- The 0.25-in. stainless-steel screen 2 transfer tube appeared to be functioning well, allowing rapid water-level response in the screen.
- The pumping rate at screen 1 was 8.22 gpm.
- The pumping rate at screen 2 ranged from 7.72 to 8.81 gpm.

Table F-1.0-1
R-70 Sampling System Completion Details

System Component	Depth (ft MD)	Elevation (ft amsl)
Weep Valve	8.0	6685.24
Top of TDU[a] screen	987.26	5797.73
Bottom of TDU screen	1007.17	5779.68
TDU PVC[b] riser end cap	1007.30	5779.79
Top of pump shroud	1009.58	5777.59
Bottom of pump shroud	1017.69	5770.15
Top of upper APV screen	1020.56	5767.55
Bottom of upper APV screen	1020.88	5767.83
Top of LIC[c]	1022.45	5765.84
Bottom of LIC	1027.12	5761.60
Top of packer	1032.27	5756.94
Bottom of packer	1035.61	5753.91
Top of TDL[d] screen	1038.59	5751.21
Bottom of TDL screen	1039.58	5750.29
Top of lower APV screen	1042.63	5747.55
Bottom of lower APV screen	1042.95	5747.82
Bottom bullnose system	1043.57	5746.69

[a] TDU = Total depth upper.

[b] PVC = Polyvinyl chloride.

[c] LIC = Liquid inflation chamber.

[d] TDL = Total depth lower.

Table F-3.0-1
8-day Packer Test Results

Date	Pressure (psi)
11/1/2019	215
11/2/2019	214
11/3/2019	214
11/4/2019	Not checked
11/5/2019	214
11/6/2019	214 (216 with upper APV open)
11/7/2019	Not recorded
11/8/2019	214 (217 with lower APV open)

Table F-4.0-1
Groundwater Volumes Pumped for the Pump System Function Testing

	11/6/2019	11/7/2019	11/8/2019	Total Groundwater Purged
Screen 1	n/a*	2177.74 gal.	n/a	2177.74 gal.
Screen 2	91.74 gal.	n/a	1979.49 gal.	2071.23 gal.

* n/a = Not applicable.