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Completion Report for Imtermediate Aquifer Well R-47i

Los Alamos
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Prepared by the Environmental Programs Directorate

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EXECUTIVE SUMMARY

This completion report summarizes the drilling, installation, development, and aquifer testing of intermediate-perched zone well R-47i. Well R-47i was installed at Technical Area 14 (TA-14) at Los Alamos National Laboratory in Los Alamos County, New Mexico. This report was written in accordance with Section IV.A.3.e.iv of the Compliance Order on Consent. Well R-47i was installed at the direction of the New Mexico Environment Department (NMED).

The original plan for this location was to drill and install a regional well to be called R-47 that would augment the TA-16 monitoring well network by providing a regional monitoring well northeast of the 260 Outfall. However, as a result of problems encountered during construction of the regional well, the regional well was abandoned and an intermediate-perched zone well, R-47i, was installed instead.

The intermediate well R-47i was installed with a single 20-ft screen within the perched zone between 840.0 to 860.6 ft below ground surface (bgs) in the upper Puye Formation. The depth to water after well installation and well development was 832.2 ft bgs, as measured on November 18, 2009. During drilling for the originally planned deep regional well, the regional aquifer was encountered at approximately 1242 ft bgs within the Puye Formation fanglomerate.

The borehole was drilled using dual-rotary fluid-assisted and standard air-rotary drilling methods. Drilling fluid additives included potable water and AQF-2 foaming agent. The original borehole was advanced to a total depth of 1350.5 ft bgs using a combination of dual rotary and open-hole drilling methods.

The well was completed in accordance with the NMED-approved well design. Hydrogeologic testing indicated that the well is productive and will perform effectively to meet planned objectives. Groundwater sampling at R-47i will be performed as part of the interim facility-wide groundwater monitoring program.

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Acronyms and Abbreviations

amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
DOE	Department of Energy (U.S.)
DTW	depth to water
EES-14	Earth and Environmental Sciences Group 14
Eh	oxidation-reduction potential
ENV	environmental
EP	Environmental Programs Directorate
EPA	Environmental Protection Agency (U.S.)
gpd	gallons per day
gpm	gallons per minute
HE	high explosives
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine

ICPMS	inductively coupled plasma mass spectrometry
ICPOES	inductively coupled plasma optical emission spectroscopy
ID	identification
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MDA	material disposal area
µS/cm	microsiemens per centimeter
mV	millivolt
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
NWI	North Wind, Inc.
O.D.	outside diameter
ORP	oxidation-reduction potential
PETN	pentaerythritol tetranitrate
pH	potential of hydrogen
PVC	polyvinyl chloride
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member of the Bandelier Tuff
Qct	Cerro Toledo interval
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RPF	Records Processing Facility
SOP	standard operating procedure
TA	technical area
TD	total depth
TOC	total organic carbon
Tpf	Puye Formation
TU	tritium unit
VOC	volatile organic compound
WCSF	waste characterization strategy form
wt%	weight percent
WES-EDA	Waste and Environmental Services Division–Environmental Data and Analysis

1.0 INTRODUCTION

This completion report summarizes site preparation, borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for intermediate-perched groundwater monitoring well R-47i. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the Compliance Order on Consent (the Consent Order). The R-47i monitoring well was drilled, constructed, and tested from June 11 to December 6, 2009, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

Well R-47i was installed on the north rim of Cañon de Valle at Technical Area 14 (TA-14) in Los Alamos County, New Mexico (Figure 1.0-1). The purpose of the R-47i well is to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the Groundwater Protection Program for the Laboratory, the Consent Order, and the New Mexico Environment Department (NMED) approved work plan.

Originally planned as a single-completion well in the regional aquifer, borehole R-47 was drilled to a total depth (TD) of 1350.5 ft below ground surface (bgs). The regional aquifer was encountered at 1245.3 ft bgs. The permanent casing and well screen were installed. Installation of annular seals and filter pack resulted in bentonite intrusion into the screen, and the decision was made by the Laboratory, NMED, and the U.S. Department of Energy (DOE) to abandon the lower portion of the borehole and to complete the well in the intermediate zone as well R-47i. The borehole was backfilled, and a 20-ft screen was placed between 840.0 and 860.6 ft bgs. The depth to water (DTW) after well installation was 832.2 ft bgs on November 18, 2009. During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to the original borehole depth of 1350.5 ft bgs.

Postinstallation activities included well development, aquifer testing, surface completion, geodetic surveying, and dedicated sampling system installation. Future activities will include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory’s Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendices completed to date associated with the R-47i project. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the NMED in accordance with DOE policy.

2.0 PRELIMINARY ACTIVITIES

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

2.1 Administrative Preparation

The following documents helped guide the implementation of the scope of work for R-47/R-47i:

- “Work Plan for Redrilling Well R-47” (LANL 2009, 107505)
- R-47 Drill Plan, Rev. 2 (North Wind Inc. 2009, 109101)

- “Integrated Work Document for Regional and Intermediate Aquifer Well Drilling” (LANL 2007, 100972)
- “Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan” (LANL 2006, 092600)
- “Waste Characterization Strategy Form for Five Spring Wells” (LANL 2009, 104230)
- “Revised Well Design for R-47i” (Dale 2009, 108127)

2.2 Site Preparation

Site preparation was performed by Laboratory personnel before the rig was mobilized. The dual-rotary drill rig, air compressors, trailers, and support vehicles were mobilized to the drill site from June 12 to 14, 2009. Alternative drilling tools and construction materials were staged near the drill site per Laboratory approval.

The Northwind, Inc. (NWI) office trailer, generators, and general field equipment were moved on-site after mobilization of the drilling equipment. The Laboratory’s fire hydrant 535 was designated as the source for potable water to be transported to the drill site with a water truck. Safety barriers and signs were installed around the cuttings containment pit and along the perimeter of the work area.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and approach, and provides a chronological summary of field activities conducted at the R-47 borehole and R-47i well location.

3.1 Drilling Approach

The R-47i borehole was drilled using a Schramm, Inc., T130XD Rotadrill dual-rotary drilling rig with casing rotator. The dual-rotary system allows for advancement of casing with the casing rotator while drilling with conventional air/mist/foam methods with the drill string. The Schramm T130XD drill rig was originally equipped with conventional 4-in. drill pipe, tricone bits, downhole-hammer bits, and general drilling equipment. Following segregation of the 4-in. drill pipe, 5.5-in. dual wall drill pipe was used. Auxiliary equipment included two Ingersoll Rand 1170 ft^3/min trailer-mounted air compressors and one Ingersoll Rand 1070 ft^3/min trailer-mounted air compressor. Three sizes of drill casing were used: 18-in., 12-in., and 10-in. A53 grade B flush-welded mild carbon-steel casing. The dual-rotary technique used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole. In addition, the casing sizes selected ensured that the required 2-in. minimum annular thickness of the filter pack around a 5.56-in.-outside diameter (O.D.) well, as required by the Consent Order (Section X.C.3), would be met.

Drilling additives were used, as needed, between ground surface and 1175 ft bgs (100 ft above the anticipated top of the regional aquifer). The fluids were used to cool the bit and help lift cuttings from the borehole. Only potable water and approved Baroid AQF-2 foaming agent were used during drilling and well completion. Potable water was also used during borehole jetting and cleaning activities before the intermediate well was constructed. Total amounts of drilling fluids introduced into the borehole and those recovered are presented in Table 3.1-1.

3.2 Chronological Drilling Activities

Required drilling equipment and supplies were mobilized to the drill site from June 12 to 14, 2009. Drill rig set-up, final rig inspection, and preparation for drilling occurred from June 15 to 23, 2009. Drilling activities commenced at 1133 h on June 23, 2009. The borehole was advanced from ground surface to 55 ft bgs using a 17 7/8-in. button-tooth, tricone bit and 18-in.-inside diameter (I.D.) casing.

On June 24, the borehole was advanced from 55 to 63.4 ft bgs. When the casing became difficult to rotate at 63.6 ft bgs, preparations began to advance the borehole using the 17-in. hammer bit via open-hole drilling methods with foam injection.

On June 25, preparations to drill open-hole using the 17-in. hammer bit continued. The borehole depth was tagged through casing at 61.4 ft bgs.

On June 26, the borehole was advanced from 61.4 to 101 ft bgs. After a new connection was made to advance past 101 ft bgs, the hammer would not fire, and the decision was made to trip the drill string out of the borehole. During the trip-out, the pin on the second joint of pipe from the top of the string broke, leaving 82.6 ft of tooling in the hole. Fishing tools were brought on-site and decontaminated; the remaining tooling was captured and the trip out of the hole began. The trip-out was completed on the morning of June 27, and the drill pipe and collars were moved to the staging area for decontamination before inspection. Inspections of the drill pipe, collars, and subs began in the afternoon.

On June 28, the inspection of the drilling tools was completed. All drill pipe, collars and subs that had been inspected were decontaminated again. The borehole was advanced from 100.8 to 241.0 ft bgs in the afternoon.

On June 29, the drillers expressed concern that the bottom hole assembly was of insufficient weight and was causing up-hole vibration through the drill string. As a result, it was decided that drilling would not continue until additional collars could be brought on-site. The casing rotator was taken off-site for repair and maintenance. The site was secured on June 30 for days off.

Work resumed on July 7 with the reinstallation of the drill string, and conventional rotary drilling began on July 8. The borehole was advanced from 241.0 to 248.0 ft bgs. At that depth, the lower pin on the double-pin sub on the drill rig’s quill sheared and the sub required replacement. The drill string was tripped out of the hole, inspected for damage, and then tripped back in. Drilling resumed and the borehole was advanced to 328 ft bgs.

Between July 9 and 10, the borehole was advanced from 328 to 748 ft bgs. At that depth, the drill string was tripped out of the hole and 12-in. casing was installed to 731 ft bgs between July 11 and 14 in anticipation of potential borehole stability problems within the Guaje Pumice Bed.

On July 15, preparations were made to resume drilling via dual-rotary drilling methods, including reinstalling the casing rotator. Preparations were completed on the morning of July 16, and the 13-in. bit, hammer, and drill string were tripped in to the borehole. The borehole was advanced from 748 to 795 ft bgs in the afternoon.

On July 17, the borehole was advanced from 795 to 840 ft bgs. While the drill crew attempted to advance past 840 ft bgs, the pin on the top joint of drill pipe sheared and the tools were left in the borehole. Although the top joint of drill pipe was approximately at ground level, an overshot tool was required to capture the pipe because the sheared pin was stuck in the box of the next joint of pipe.

On July 18, the drill string was captured and tripped out of the borehole. At this point, all 4-in. drill pipe was loaded and transported to the staging area, where it was off-loaded and taken out of service.

Between July 19 and July 20, preparations were made to resume drilling using 5.5-in. drill pipe. The DTW was tagged at 826.6 ft bgs. The site was then secured for days off.

On the morning of July 28, DTW was tagged in the open borehole at 826.6 ft bgs. The 5.5-in. bit, hammer, collars, and drill pipe were tripped into the borehole.

On July 29, the drill string was tripped in, and the borehole was advanced from 840 to 875 ft bgs.

Between July 30 and August 2, the borehole was advanced from 875 to 1034 ft bgs. It became difficult to pull the bit back into the casing while the lowermost 4 ft was drilled; in addition, the drill bit could not be pulled into the casing at the end of the shift.

The borehole was advanced only 1 ft, to 1035 ft bgs, on August 3. Another attempt was made to retract the drill bit into the casing. Because the bit could not be retracted, the decision was made to trip both the casing and drill strings out of the hole. One joint of drill pipe and 20 ft of casing were tripped out and laid down.

Between August 4 and 6, the remaining casing and drill tools were tripped out of the borehole. Upon laying down the lowermost joint of 12-in. casing, it was discovered the casing shoe was missing and the leading edge of the casing was fractured and bent, thus preventing the bit from retracting into the casing. The Laboratory’s borehole video camera was run into the open borehole to 872 ft bgs. The borehole was noted to be wet at 835 ft bgs, and water was observed flowing into the borehole at 842 ft bgs. The Laboratory’s gamma and induction logging tools were also run in the open borehole. The DTW was tagged at 857.4 ft bgs.

On August 7, all 5.5-in. drill pipe used to drill to 1035 ft bgs was moved to the staging area to be inspected.

On August 8, inspection of the pipe was completed. During the inspection, the drill crew began running 12-in. casing back into the borehole. Between the afternoon of August 8 and 11, 12-in. casing was run to a depth of 833.8 ft bgs.

In the morning of August 12, a water sample was collected from the open borehole with a bailer at a depth of 910 ft bgs. The 12-in. casing was installed in the borehole to a depth of 925.7 ft bgs, at which depth further progress was impeded. The casing was pulled up to 913.9 ft bgs and secured to end the shift.

On August 13, a bail down and recovery test was conducted. Preparations began to trip in the drill string to underream ahead of the 12-in. casing.

On August 14 and 15, the drill tools were tripped in and the 12-in. casing was advanced from 925.6 ft bgs to roughly 1028 ft bgs, at which time the borehole was airlifted until dry. An attempt was made to measure the DTW after airlifting operations but the hole remained dry.

In the morning of August 16, the water level had recovered, and a second water sample was collected from 1025 ft bgs via airlifting. Bentonite slurry was then pumped via tremie into the bottom of the borehole from 1035 ft bgs to 1024 ft bgs in an attempt to prevent perched water higher in the hole from entering the borehole. The 12-in. casing was landed in the bentonite, and the borehole was advanced via open-hole drilling methods to 1043 ft bgs. The drill string was tripped out of the hole on August 17 to allow inspection of the bit.

Between August 18 and 19, the drill string and bit were tripped back in and the borehole was advanced open-hole to 1200 ft bgs. The drill string was tripped out to run a video log of the borehole. The Laboratory's borehole video camera was run downhole, and water coming in around the casing shoe at 1035 ft bgs and standing water in the hole at 1164.0 ft bgs were noted.

Between the afternoon of August 18 and the morning of August 20, no drilling was conducted while the drill crew waited for an approved path forward from NWI and Laboratory personnel. It was decided to backfill the borehole to 1050 ft bgs with sand, trip in an inflatable packer to the bottom of the 12-in. casing, and pump bentonite grout into the borehole above the packer in an attempt to seal off the lower 10 ft of annular space around the outside of the casing. The afternoon of August 20 was spent off-loading pallets of sand and decontaminating tremie pipe.

Between August 21 and the morning of August 22, sand was poured into the open borehole from 1164 to 1051 ft bgs. Bentonite chips were poured from 1051 to 1050 ft bgs and preparations were made to trip in the inflatable packer on 5.5-in. drill pipe.

On the morning of August 23, the packer was tripped in to 1020 ft bgs inside the 12-in. casing and inflated to 200 psi. The borehole was grouted below the packer with 6000 gal. of water and 96 bags of Halliburton Quik Grout. The packer was left inflated overnight to allow the grout to set up and infiltrate the formation at the base of the 12-in. casing at 1035 ft bgs and prevent it from rising inside the 12-in. casing.

On August 24, the packer was deflated and tripped out of the borehole. The drill string was tripped-in to 1020 ft bgs, and the borehole was air lifted to evacuate standing water. Unsuccessful attempts were made in the afternoon to measure DTW.

On the morning of August 25, it was confirmed that no water was in the borehole, and the Laboratory approved cleaning the borehole of backfill materials and resuming drilling. The backfill materials were drilled out, and the borehole was advanced from 1200 to 1280 ft bgs via open-hole drilling methods.

On August 26, the borehole continuously caved to roughly 1272 ft bgs following attempts in the morning to clean and resume drilling. The decision was made to trip the drill string out of the hole and begin preparations to install 10-in. casing to 1280 ft. The DTW was measured in the afternoon at 1242.1 ft bgs.

Between August 27 and September 1, 10-in. casing was installed in the hole to 1269.3 ft bgs. Between the afternoon of September 1 and the morning of September 3, the drill string was tripped in, the casing rotator was installed, and preparations were made to resume advancing the borehole past 1280 ft bgs.

Between September 3 and September 4, the borehole was advanced via dual-rotary methods to TD of 1350.5 ft bgs. On September 5, the drill string was tripped out of the hole and Schlumberger ran cased-hole geophysical logs (Appendix D).

During drilling and well construction activities, field crews generally worked one 12 h shift per day, 7 d per wk.

4.0 SAMPLING ACTIVITIES

The following sections describe the cuttings and groundwater sampling activities conducted during the drilling of the deep borehole and completion of monitoring well R-47i. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the borehole at 5-ft intervals from 5 to 1350 ft bgs. At each interval, approximately 500 mL of bulk cuttings was collected by the site geologist from the discharge cyclone, placed in Ziploc plastic bags, labeled, and archived in core boxes. Portions of the bulk samples collected from ground surface to TD were sieved (>#10 and >#35 mesh) and placed in chip trays along with unsieved (whole rock) cuttings. Overall recovery of the borehole cuttings samples was good, with 96% of the borehole interval recovered. Intervals with no recovery were 0–5 ft bgs, 80–95 ft bgs, 445–455 ft bgs, 465–470 ft bgs, 520–525 ft bgs, 565–570 ft bgs, 745–750 ft bgs and 985–990 ft bgs.

Lithologic descriptions of the cuttings were used to prepare the lithologic log for R-47i (Appendix A). Section 5.1 presents a summary of the borehole stratigraphy.

Radiation control technicians screened cuttings before they were submitted to the Laboratory for archiving. All screening measurements were within the range of background values. The core boxes and chip trays were delivered to the Laboratory’s archive at the conclusion of drilling activities.

4.2 Water Sampling

Water samples were collected during borehole drilling at depths of 910 and 1025 ft bgs. The upper sample was collected using a bailer on August 12 and may have included a component of supplied municipal water used during drilling activities. The lower sample, collected August 16, was air lifted after borehole was allowed to dry. Perched zone screening samples were analyzed for metals, anions (including perchlorate), high explosives (HE), and volatile organic compounds (VOCs). Groundwater sample numbers, as well as the required analyses, are listed in Table 4.2-1.

At the Laboratory’s direction, no regional groundwater samples were collected. One sample (GW47-10-1975) was collected via airlifting from the open borehole at 1272 ft bgs to check for the presence of bentonite. During well development of the completed perched-intermediate well, five samples were collected for total organic carbon (TOC) screening at the end of each shift. Analytical results for all samples are presented in Appendix B.

Further groundwater characterization sampling will be conducted from completed well R-47i in accordance with the Consent Order. For the first year, the samples will be analyzed for the full suite of constituents, including radioactive elements; anions/cations; general inorganic chemicals; VOCs and semivolatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sample frequency will be evaluated and presented in the annual interim facility-wide groundwater monitoring plan.

5.0 GEOLOGY AND HYDROGEOLOGY

The following sections present a brief description of the geologic and hydrogeologic features penetrated at R-47i. The Laboratory’s geology task leader and site geologists examined cuttings to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, and water-level measurements were used to characterize groundwater occurrences.

5.1 Stratigraphy

The stratigraphic sequence observed in the R-47i borehole is based on lithologic descriptions of cuttings samples collected from the discharge cyclone and borehole geophysical logs. Figure 5.1-1 illustrates the stratigraphy encountered at during drilling to the original TD of 1350.5 ft bgs. A detailed lithologic log based on analysis of drill cuttings is presented in Appendix A.

Artificial Fill (0–5 ft bgs)

Artificial fill consisting of base course gravel was present at R-47i from ground surface to 5 ft bgs.

Unit 4, Tshirege Member of the Bandelier Tuff (5–20 ft bgs)

Unit 4 of the Tshirege Member of the Bandelier Tuff was present from 5 ft to 20 ft bgs. Unit 4 consisted of weakly welded or weathered tuffs that were orange-pink in color.

Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (20–155 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff was present from 20 ft to 155 ft bgs. Unit 3 was a nonwelded to partly welded, vapor-phase altered tuff that was pale orange to grayish orange in color, except from 95 ft to 105 ft bgs, where it was light brown to pale brown.

Unit 2, Tshirege Member of the Bandelier Tuff, Qbt 2 (155–260 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff was present from 155 ft to 260 ft bgs. Unit 2 was a weakly to moderately welded, crystal rich tuff ranging from light brown to pale red in color with 2%–5% iron-oxide-stained volcanic lithic fragments.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (260–309 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff was present from 260 ft to 309 ft bgs. Unit 1v was a moderate orange pink, weakly welded, devitrified, crystal rich volcanic tuff.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (309–347 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was present from 309 ft to 347 ft bgs. Unit 1g was a very pale orange to grayish orange, weakly welded tuff. The interval from 310 ft to 320 ft bgs was very pale orange to pale yellowish orange, and weakly welded.

Cerro Toledo Interval, Qct (347–583 ft bgs)

Tephra and volcaniclastic rocks of the Cerro Toledo interval were present from 347 ft to 583 ft bgs. The Cerro Toledo interval consisted of tuffaceous sedimentary deposits that were deposited between the Tshirege and Otowi Members of the Bandelier Tuff. The deposits predominantly consisted of reworked tuff with some sands, gravels, and cobbles derived from Tshicoma dacites in the Jemez Mountains west of the Pajarito Plateau.

Otowi Member of the Bandelier Tuff, Qbo (583–761 ft bgs)

The Otowi Member of the Bandelier Tuff was present from 583 ft to 761 ft bgs. The Otowi Member was a glassy, lithic-bearing, pumiceous, poorly-welded ash-flow tuff. It contained pale orange to grayish orange pink, subangular to subrounded, intermediate composition volcanic rocks up to 0.4-in. in diameter. Vitric pale orange to white pumice lapilli contained conspicuous phenocrysts of quartz and sanidine.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (761–769 ft bgs)

The Guaje Pumice Bed was present from 761 ft to 769 ft bgs and contained abundant pumice fragments (up to 90%) with subordinate amounts of volcanic lithics, quartz and sanidine phenocrysts, and trace amounts of vitrophyre (obsidian) fragments.

Puye Formation (Tpf) (769–1350.5 ft bgs)

Puye Formation was present from 769 ft to 1350.5 ft bgs, and consisted of a sequence of fluvial and lacustrine sedimentary deposits. The deposits ranged from poorly graded to well-graded gravels with angular to subrounded sands, containing up to 100% porphyritic and aphyric intermediate volcanics (up to 1.2-in. in diameter).

5.2 Groundwater

The perched-intermediate zone at around 830 ft bgs was first penetrated during drilling on July 17, 2009, although no indication of formation water was noted from the discharge.

Perched groundwater was first recognized in the borehole during video logging on August 6, 2009. Moisture was first noted along the borehole wall at approximately 834 ft to 835 ft bgs within the Puye Formation. The borehole was 1034.0 ft deep, and the DTW was 896.0 ft bgs, provided excellent imaging of the perched interval. The video log showed a wet borehole wall from 834 ft to 835 ft bgs, with water dripping along one quadrant of the wall. Strong flow of water on the borehole wall was observed at 842 ft, and by 857 ft the flow was continuous around the full diameter of the borehole.

Observations from the borehole video log and cuttings indicated a possible increase in matrix fines and clay content in rocks below approximately 873 ft bgs; induction logging indicated the occurrence of discrete electrically conductive layers that were several feet thick below 873 ft bgs. These layers may represent perching horizons containing nearly saturated matrix fines.

During subsequent development of the perched-intermediate zone, flow rates of approximately 1.5 gpm were observed. During the 24-h constant rate pump test, a flow rate of 0.9 gpm was maintained, and the average hydraulic conductivity of 0.21 ft/d was calculated for the perched-intermediate zone. After the well was installed, the DTW on November 18, 2009, was 832.2 ft bgs.

The top of the regional aquifer, at an approximate depth of 1242 ft bgs on the basis of geophysical logging, was first penetrated during drilling on August 25, 2009. However, no indication of groundwater was noted from the discharge. On September 26, 2009, before well construction, the DTW of the regional aquifer stabilized at 1245.3 ft bgs.

6.0 BOREHOLE LOGGING

The following sections describe the video and geophysical logging conducted at borehole R-47 and well R-47i. A summary detail of all logs conducted is provided in Table 6.0-1.

6.1 Video Logging

Laboratory personnel ran video logs in the open or partially cased borehole on August 6 and 19, 2009, on October 8 and 30, twice on October 31, and on November 2 and 5. A video log within the well casing was completed on October 3. Table 6.0-1 presents a summary of video logging runs. Four representative video logs are included on DVDs in Appendix C.

6.2 Geophysical Logging

Laboratory personnel ran natural gamma and array induction logs in the R-47i borehole on August 6, 2009. Laboratory personnel attempted to run additional gamma logs on October 5 and 6, 2009; however, the gamma logging tool was inoperable on both days. Table 6.0-1 presents a summary of geophysical logging runs.

Additionally, a suite of Schlumberger geophysical logs was run inside the temporary 10-in.-I.D. casing from ground surface to 1348 ft bgs on September 5, 2009. These geophysical logs consisted of Schlumberger's cased hole suite, including the Accelerator Porosity Sonde, Triple Detector Lithodensity, Elemental Capture Spectroscopy, Hostile Natural Gamma Spectroscopy and Gamma Ray logs. Interpretation and details of the logging are presented in the geophysical logging report and accompanying CD included in Appendix D.

7.0 WELL INSTALLATION

Attempts to install the originally planned regional well were conducted between September 26 and October 21, 2009. However, because problems were encountered during well construction (discussed below), the decision was made to abandon the lower portion of the borehole and complete the well as R-47i in the intermediate zone at approximately 850 ft bgs. Subsequently, the borehole was backfilled to below the intermediate zone between October 22 and November 6. The well casing, screen, and annular fill for intermediate well R-47i were installed between November 7 and 16.

7.1 Well Design

Well R-47i was designed in accordance with the Consent Order. NMED approved the specific well design for R-47i before it was installed (Dale 2009, 108127). The well was designed with a single screened interval between 840.0 ft and 860.0 ft bgs to monitor perched groundwater quality and water levels in the upper part of the Puye Formation.

7.2 Well Construction

Well-construction materials consisted of 5.0-in.-I.D./5.6-in.-O.D., type A304 passivated stainless-steel threaded casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The screened section used two 10-ft lengths of 5.0-in.-I.D. rod-based, 0.020-in. slot, wire-wrapped well screen. Compatible external stainless-steel couplings (also type A304 stainless-steel fabricated to ASTM A312 standards) were used to join all individual casing and screen sections. The coupled unions between threaded sections were approximately 0.7 ft long. All casing, couplings, and screen were steam and pressure-washed on-site before installation. A string of 2-in.-I.D. threaded/coupled steel tremie pipe (decontaminated before use) was used to deliver backfill and annular fill materials downhole during well construction.

The Schramm T130XD rig was used for well construction. Initially the annular and backfill materials were installed via the tremie pipe, after which the temporary drill casing was retracted, followed by raising the tremie pipe. The permanent well casing was hung on a wireline while the drill casing was supported by a ring and slips. During this part of the process, the cut sections of drill casing were picked up by a second wireline, laid down, and staged away from the drill rig.

The following sections provide a chronological summary of activities during attempts to construct the R-47 regional aquifer well and the successful construction of the R-47i well. Table 7.2-1 provides volumes of well annular fill materials use during the construction of R-47i, and Figure 7.2-1 shows the backfilled borehole and completed well design of R-47i.

7.2.1 Regional Aquifer Well R-47 Construction (September 6–October 21, 2009)

The original R-47 well design was for a single-completion well in the Puye Formation. The 20-ft-long screened interval was to be set from 1257.0 ft to 1277.0 ft bgs, with a nominal 20-ft stainless-steel sump below the well screen.

Well construction materials were mobilized to the drill site between September 6 and 10. Preparations, including decontamination of the stainless-steel well casing and screen, took place during this time. From September 10 to 14, the borehole was backfilled from the original TD of 1350.5 ft to 1306.3 ft bgs with bentonite 3/8-in. chips.

From September 26 to October 1, the 5-in. stainless steel well casing was installed in the borehole to a depth of 1299.5 ft bgs with the screen interval between 1277.6 ft and 1257.0 ft bgs. The borehole was backfilled from 1306.3 to 1282.7 ft bgs with a bentonite-sand mixture. A filter pack of 10/20 sand was placed from 1282.7 to 1252.0 and swabbed to promote settlement. A transition zone of 20/40 sand was placed from 1252.0 to 1249.0 ft bgs.

On October 2, the top of the 20/40 sand transition zone was tagged at 1250.0 ft bgs. The 10-in. drill casing was retracted about 60 ft from 1249.6 ft to 1194 ft bgs, and the first lift of bentonite (30 bags of 3/8-in. chips) was placed from 1250.0 ft to 1238.0 ft bgs. The second lift of bentonite (25 bags of 3/8-in. chips) was placed in the afternoon, and left to hydrate overnight to get a solid tag of the elevation before proceeding further.

On October 3, before the day’s activities began, the top of the bentonite was tagged at 1240.5 ft bgs. The third lift of bentonite (30 bags of 3/8-in. chips) was placed down the hole and tagged at 1234.5 ft bgs. An additional 50 bags of bentonite were placed downhole, but a reliable tag could not be obtained because the tagger appeared to be caught in a plugged section of the tremie pipe. Fifty feet of tremie pipe was tripped out of the hole, and two 20-ft sections of the 10-in. casing were retracted and cut off, leaving the bottom of the 10-in. casing at a depth of 1160.0 ft bgs. While the third section of drill casing was being pulled, the well casing was lifted approximately 1.5 ft. Laboratory personnel were notified and the downhole camera was brought on-site. Water was pumped down the tremie pipe and the borehole annulus, and at 1320 h, the 10-in. casing could be rotated freely without any apparent movement to the well string. A 20-ft section of 10-in. casing was retracted and cut off, leaving the bottom of the 10-in. casing at 1140.1 ft bgs. The top of the bentonite in the borehole was tagged at 1188.0 ft bgs. An attempt to tag the bottom depth of the 5-in. well string was unsuccessful. At 1600 h, the Laboratory’s video camera detected bentonite in the top of the screen at approximately 1262 ft bgs, indicating the sand filter pack had collapsed and allowed bentonite to flow downward into the well screen.

On October 4, the top of the bentonite in the annular space was tagged at 1175 ft bgs before the day’s activities began. The tremie pipe was lowered inside the 5-in. well casing in an attempt to clean the screen. Two attempts were made to run a gamma log, but both failed because the tools were not operating. On the afternoon of October 6, the Laboratory directed the drill crew to pull the well casing.

The 5-in. well casing was pulled and decontaminated on October 7 and 8. The well screen was cleaned and examined and showed no visible damage. On October 8, a Laboratory video camera attempt to examine the borehole below the 10-in. casing failed because of high turbidity of standing water at 962.2 ft bgs.

From October 10 to 20, attempts to clean the borehole consisted of air-lifting and jetting the borehole walls to remove bentonite, and advancing and underreaming the 10-in. casing. The 10-in. casing was repeatedly advanced and retracted between the depths of 1270.0 and 1293.2 ft bgs in an attempt to clean bentonite from the water-bearing zone in the borehole. A water sample was air lifted from 1272.0 ft bgs on October 15 to screen for bentonite.

On October 21, direction was received from the Laboratory to abandon further attempts to rebuild the regional aquifer well, and to install an intermediate zone well instead. The well designation was changed to R-47i, and the proposed design was for one screen in the intermediate perched zone in the Puye Formation.

7.2.2 Intermediate Well R-47i Construction (October 22–November 16, 2009)

Between October 22 and November 3, the borehole was backfilled to a depth of 900.7 ft bgs. Backfill materials consisted of bentonite, sand, and formational slough. A 140-ft section of 12-in. steel casing was left in this section between 900.0 and 1040 ft bgs as a measure to further stabilize this lower portion of the borehole. Four Laboratory video camera runs were made in this time frame: October 30 after cutting and removal of the 12-in. casing, twice on October 31, and again on November 2. Details of these runs are provided in Table 6.0-1.

On November 4, the borehole was pressure-jetted with water from 560.0 ft to 895.4 ft bgs to remove bentonite from the walls. A Laboratory video camera run conducted on November 5 confirmed the absence of bentonite in this interval.

An NMED-approved well design was received on November 6, and construction of the intermediate well took place from November 6 through November 16. One screened interval was specified for the R-47i well design. The nominal 20-ft-long screened interval was set from 840.0 ft to 860.6 ft bgs. A 4.9-ft stainless-steel sump was placed below the bottom of the well screen.

On November 6, the borehole depth was tagged at 894.6 ft bgs, indicating some formational material accumulation between 900.7 ft and 894.6 ft bgs, most likely from pressure-jetting of the borehole. The borehole was backfilled from 894.6 ft to 881.0 ft bgs with bentonite chips. On November 7, the stainless-steel 5-in. well casing was installed to a depth of 865.5 ft bgs, and the remainder of the bentonite bottom seal was placed from 881.0 to 866 ft bgs (total of 32.2 ft^3 3/8-in. bentonite chips). A 10/20 silica sand filter pack was installed from 866 to 835 ft bgs and surged to promote compaction (total 10/20 sand: 50.0 ft^3). A short 20/40 silica sand transition collar on top of the filter pack was placed from 835.0 to 832.0 ft bgs (total 20/40 sand: 4.0 ft^3).

The well's upper bentonite seal (3/8-in. chips) was installed from November 8 to 12, from 832.0 to 73.0 ft bgs using a total of 1027.4 ft^3 of bentonite. The upper surface seal, a dry mix of 98 wt% Portland cement with 2 wt% Baroid IDP-381 additive was placed above the upper bentonite seal from 73.0 to 3.0 ft bgs using a total of 231.5 ft^3 of cement grout. The actual volume differed from the calculated volume (108.6 ft^3) by 113%. This difference was most probably because of borehole diameter variances as well as actual grout formula calculations closer to 57% than the preferred 45%. On November 16, well construction was deemed NMED complete. Table 7.2-1 itemizes volumes of all materials used during well construction.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation at R-47i, the well was developed, and an aquifer test was performed. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system has been installed. Site-restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees.

8.1 Well Development

The well was developed between November 16 and 24, 2009. A total of 2607 gal. was removed during development. Initially, the screened interval was bailed to remove formation fines in the filter pack and sump. Bailing continued until water clarity visibly improved. A swabbing technique was used to facilitate removal of formation fines. Final development was accomplished using a submersible pump.

The bailing tool used was a stainless steel bailer with a capacity of 5.6 gal. The tool was lowered by wireline using a Semco S15000 pulling unit and repeatedly filled, withdrawn from hole and dumped into the cuttings pit. A total of 585 gal. was bailed between November 16 and the morning of November 17. The screened interval was swabbed for 65 min on November 17, and an additional 305 gal. was bailed.

A 10-hp, 4-in. Grundfos submersible pump was set at a depth of 857.0 ft bgs and pumped at a rate of 1.5 gpm from November 22 to 24. The well was pumped for almost 24 h and produced 1717 gal. during this period. The volumes of water removed during each phase of development are presented in Table B-1.2-1 of Appendix B.

8.1.1 Well Development Field Parameters

Field parameters of turbidity, temperature, potential of hydrogen (pH), dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance parameters were monitored at R-47i during the pumping stage of well development. In addition, water samples were collected for TOC analysis. The required values for TOC and turbidity to determine adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTU), respectively.

Field parameters were monitored by collecting aliquots of groundwater from the discharge pipe during well development without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This exposure may have caused a slight variation in the measured values for temperature, pH, ORP, and DO.

During development, measurements of pH varied from 6.47 to 9.09; temperature varied from 9.41°C to 19.50°C; DO varied from 0.20 to 7.72 mg/L; and specific conductance varied from 159 to 442 microsiemens per centimeter (µS/cm). Corrected oxidation-reduction potential or Eh values varied from 115.2 to 371.8 mV. Turbidity ranged from 16.6 to 2213.0 NTU for the nonfiltered groundwater samples, with one anomalously high value of 4000 NTU measured directly after swabbing of the screened interval.

Field parameter measurements upon completion of well development at R-47i were as follows: pH was 7.7, temperature was 14.42°C, specific conductance was 176 µS/cm, and turbidity was 17.6 NTU. The final TOC concentration was 0.95 mg/l. Table B-1.2-1 of Appendix B presents field parameters and discharge volumes recorded during development.

8.2 Aquifer Testing

Preliminary step-tests and a 24-h aquifer test of R-47i were conducted between December 2 to December 6, 2009 by David Schafer and Associates. Several short duration pumping intervals with short duration recovery intervals (step-tests) were conducted on December 2, 2009. The objective of the step-tests was to assess the behavior of the system and determine the optimal pumping rate for the 24-h test. A 24-h aquifer test was completed from December 4 to 6, 2009. A 10-hp, 4-in.-diameter Grundfos submersible pump was used to perform the aquifer tests. Approximately 1381 gal. of groundwater was purged during aquifer testing activities, as shown in Table B-1.2-1 of Appendix B. The results of the R-47i aquifer testing are presented in Appendix E.

8.3 Dedicated Sampling System Installation

The dedicated sampling system was installed between December 17 and 18, 2009. A 4-in. Grundfos pump with a Franklin Electric motor and passivated 1-in. stainless-steel pipe were installed with a pump intake depth of 860.3 ft bgs. Two 1-in. polyvinyl chloride (PVC) sounder tubes with 1.7-ft screened intervals were installed alongside of the pump assembly. One PVC tube allows access for manual water-level measurements, and the other PVC tube is for installation of the dedicated transducer used to collect water-level data over time. Details of the dedicated sampling system are presented in Figures 8.3-1a and 8.3-1b.

8.4 Wellhead Completion

A reinforced concrete pad, 10 ft ×10 ft × 6.0 in. thick, was installed at the R-47i wellhead. The pad was slightly elevated above ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass survey pin imprinted with well identification information was embedded in the northwest corner of the pad. A 16.75-in.-O.D. steel protective casing was installed around the well casing to a depth of 3.0 ft bgs and cemented in place. The protective casing was covered with a mushroom cap with locking bar. A 0.5-in. weep hole was drilled near the base of the protective casing to prevent water accumulation inside the protective casing. A total of four removable bollards, painted bright yellow for visibility, were set approximately 1-ft from each of the pad edges to protect the well from accidental vehicle damage. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on January 27, 2010 (Table 8.5-1 and Appendix F). The survey data collected conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in ft 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 (Table 8.5-1).

8.6 Waste Management and Site Restoration

Waste generated from the R-47i project included contact waste, drill cuttings, drilling fluids, petroleum-contaminated soil, and purged groundwater. All waste streams produced during drilling and development activities were sampled in accordance with “Waste Characterization Strategy Form for Five Spring Wells”

(LANL 2009, 104230). A list of the waste characterization samples collected from R-47i is presented in Table 8.6-1.

Fluids produced during drilling and well development currently are staged in pits and frac tanks. These fluids are expected to be disposed through land-application after a review of associated analytical results per the waste characterization strategy form (WCSF) and ENV-RCRA-SOP-010.0, Land Application of Groundwater. If it is determined that these fluids cannot be land applied, they will be transferred into containers, placed in an accumulation area appropriate to the waste type, and managed accordingly.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA SOP-011.0, Land Application of Drill Cuttings. If the drill cuttings cannot be land applied, they will be excavated from the cuttings pit, containerized, placed in an accumulation area appropriate to the waste type, and managed accordingly.

Site-restoration activities will include removal of drilling fluids and cuttings from the pit and managing them in accordance with applicable SOPs. In addition, site-restoration activities will include the removal of the polyethylene liner, removal of the containment area berms, and backfilling and regrading the containment area, as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Before drilling, sampling, and well construction activities began at R-47i, a site-specific drill plan for R-47 was prepared (North Wind 2009, 109101). Deviations from the above-referenced drill plan occurred during the course of field activities and are summarized below.

On October 2 or 3, 2009, the well screen for the originally planned deep regional well R-47 was lifted approximately 1.5 ft as the drill casing was raised during well construction. The sand filter pack within the screened interval may have collapsed, thus allowing bentonite chips to flow downward and enter the well screen.

As a result, direction was given by the Laboratory on October 21 to begin backfilling the deep borehole in preparation for installing an intermediate-perched zone well with the screened interval between 840 ft and 860 ft bgs. The well name was changed to R-47i.

10.0 ACKNOWLEDGMENTS

Lane Christensen drilled the deep borehole and installed the R-47i monitoring well.

Pat Longmire provided the write-up for Appendix B, Groundwater Analytical Results.

Laboratory personnel ran downhole video equipment.

Schlumberger Water Services performed geophysical logging of the borehole and Ned Clayton provided the write-up and data for Appendix D, Schlumberger Geophysical Logging Report

David Schafer and Associates performed the aquifer testing and provided the write-up and data for Appendix E, Aquifer Testing Report.

Precision Surveys, Inc. conducted the geodetic survey and provide the survey report in Appendix F.

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

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

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

Dale, M., November 6, 2009. RE: Perched Intermediate Well R-47i Well Design [and attachment]. E-mail message to D. Broxton (LANL) from M. Dale (NMED), Santa Fe, New Mexico. (Dale 2009, 108127)

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

LANL (Los Alamos National Laboratory), October 4, 2007. "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (Mobilization, Site Preparation and Setup Stages)," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2007, 100972)

LANL (Los Alamos National Laboratory), January 28, 2009. "Waste Characterization Strategy Form for the Five Spring Wells (TA-53 [53-1(i)], TA-54 [PCI-1 and PCI-2], TA-16 [CdV-16-3(i)], TA-15 [CdV-R-15-1]) Regional and Intermediate Groundwater Well Installation," Los Alamos, New Mexico. (LANL 2009, 104230)

LANL (Los Alamos National Laboratory), November 2009. "Work Plan for Redrilling Well R-47," Los Alamos National Laboratory document LA-UR-09-7269, Los Alamos, New Mexico. (LANL 2009, 107505)

North Wind Inc., May 14, 2009. "R-47 Drill Plan, Installation of Well R-47, TA 14, Los Alamos National Laboratory, Revision 2," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (North Wind, Inc., 2009, 109101)

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; 19 March 2008.

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

Coarse Scale Drainage Arcs; Los Alamos National Laboratory, Water Quality and Hydrology Group of the Risk Reduction and Environmental Stewardship Program; as published 03 June 2003.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 19 March 2008; as published 04 January 2008.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 19 March 2008; as published 04 January 2008.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 19 March 2008; as published 04 January 2008

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning and Project Initiation Group, Infrastructure Planning Division; 19 September 2007.

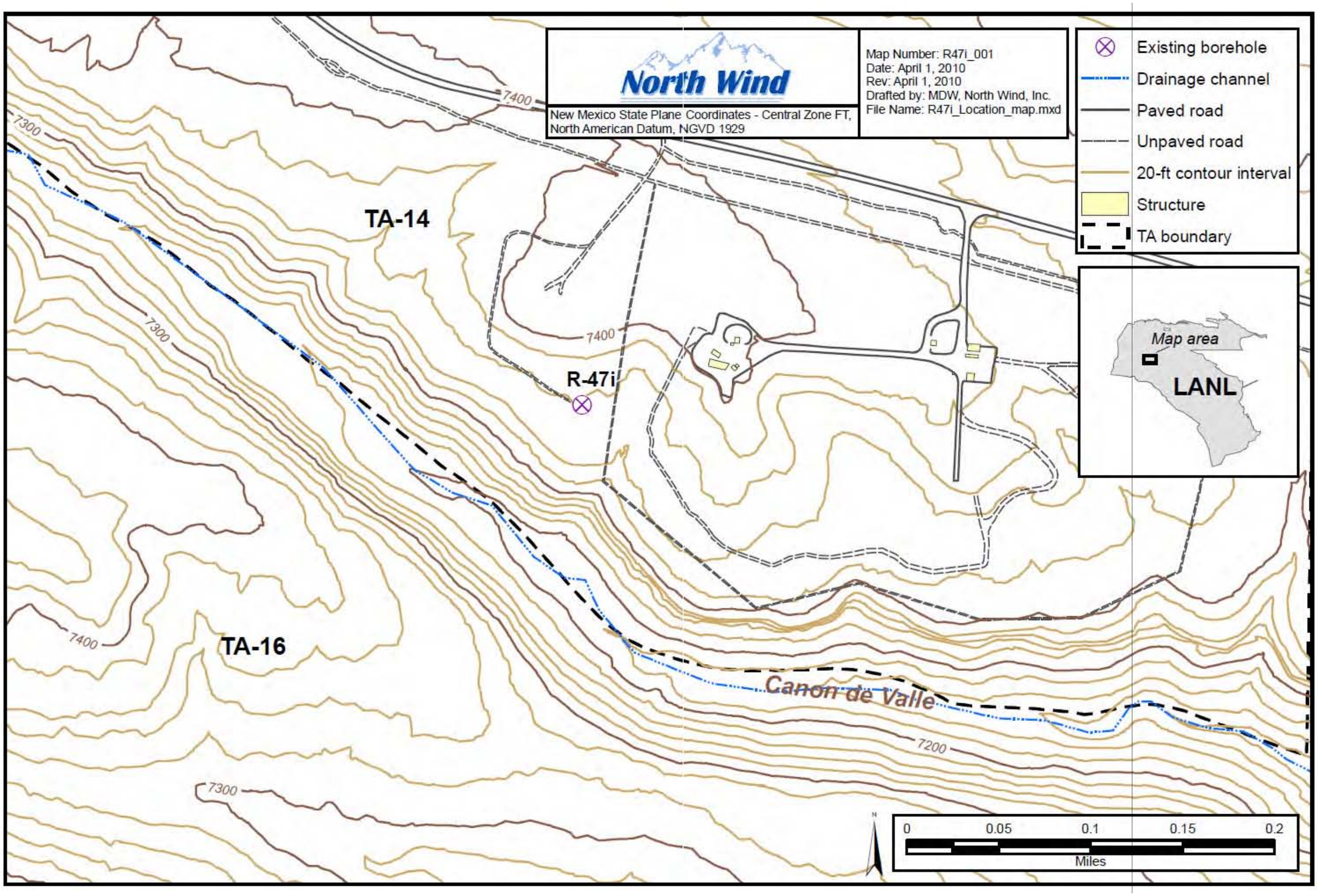
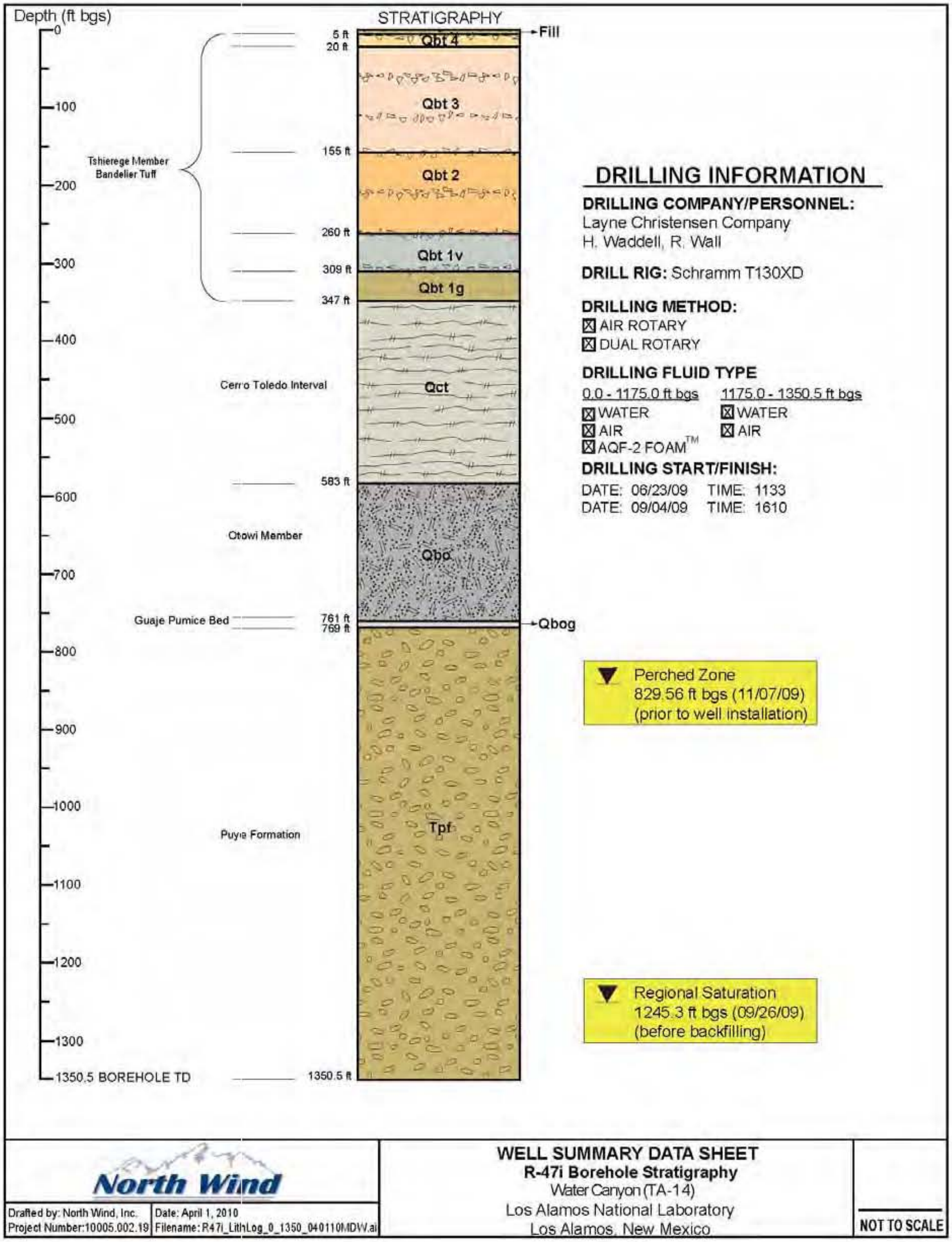


Figure 1.0-1 Location of monitoring well R-47i



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL:
Layne Christensen Company
H. Waddell, R. Wall

DRILL RIG: Schramm T130XD

DRILLING METHOD:
☒ AIR ROTARY
☒ DUAL ROTARY

DRILLING FLUID TYPE

0.0 - 1175.0 ft bgs	1175.0 - 1350.5 ft bgs
☒ WATER	☒ WATER
☒ AIR	☒ AIR
☒ AQF-2 FOAM™	

DRILLING START/FINISH:
DATE: 06/23/09 TIME: 1133
DATE: 09/04/09 TIME: 1610

Perched Zone
829.56 ft bgs (11/07/09)
(prior to well installation)

Regional Saturation
1245.3 ft bgs (09/26/09)
(before backfilling)

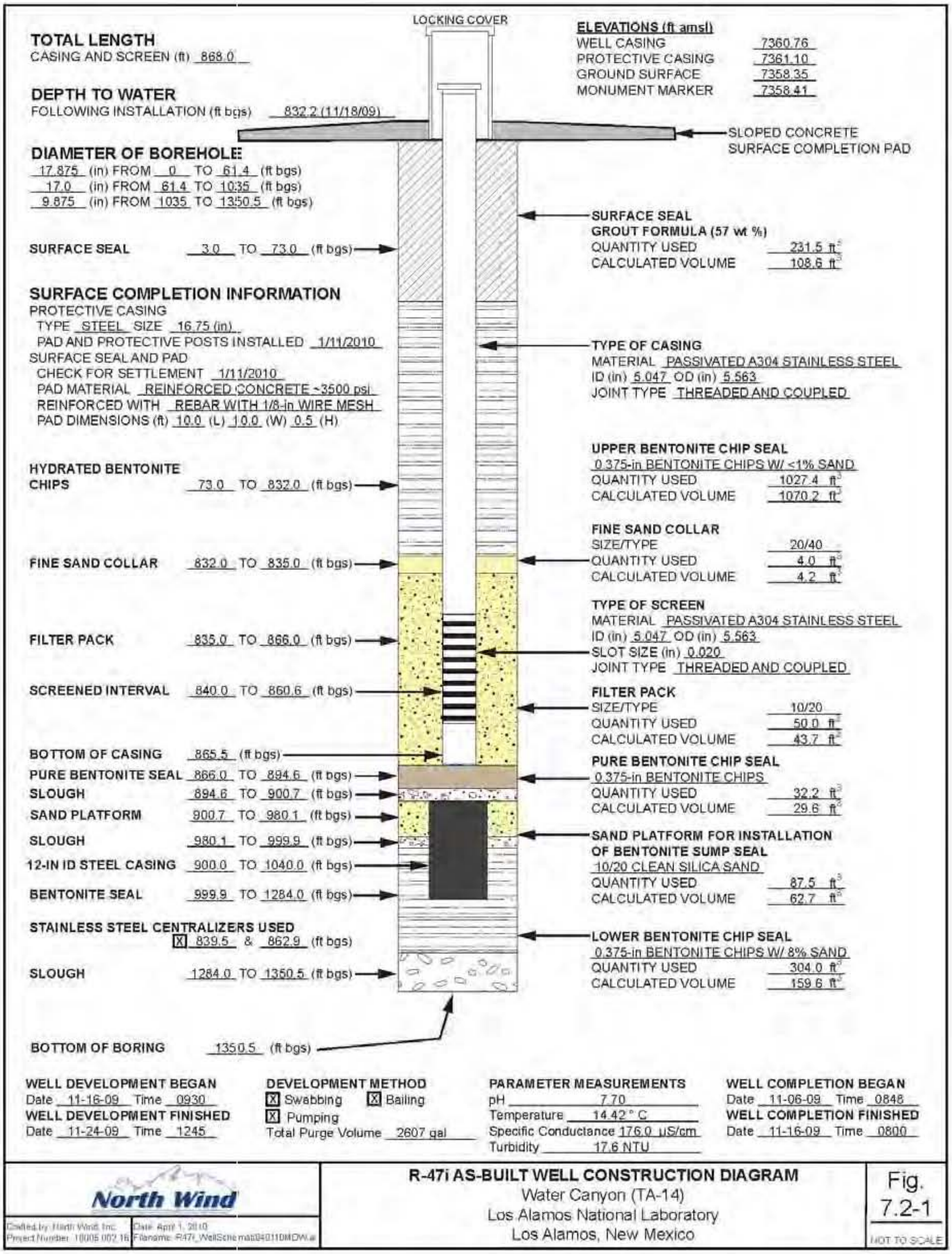
North Wind

Drafted by: North Wind, Inc. | Date: April 1, 2010
Project Number:10005.002.19 | Filename: R47i_LithLog_0_1350_040110MDW.ai

WELL SUMMARY DATA SHEET
R-47i Borehole Stratigraphy
Water Canyon (TA-14)
Los Alamos National Laboratory
Los Alamos, New Mexico

NOT TO SCALE

Figure 5.1-1 Monitoring well R-47i borehole stratigraphy



TOTAL LENGTH
CASING AND SCREEN (ft) 868.0

DEPTH TO WATER
FOLLOWING INSTALLATION (ft bgs) 832.2 (11/18/09)

DIAMETER OF BOREHOLE
17.875 (in) FROM 0 TO 61.4 (ft bgs)
17.0 (in) FROM 61.4 TO 1035 (ft bgs)
9.875 (in) FROM 1035 TO 1350.5 (ft bgs)

SURFACE SEAL 3.0 TO 73.0 (ft bgs)

SURFACE COMPLETION INFORMATION
PROTECTIVE CASING
TYPE STEEL SIZE 16.75 (in)
PAD AND PROTECTIVE POSTS INSTALLED 1/11/2010
SURFACE SEAL AND PAD
CHECK FOR SETTLEMENT 1/11/2010
PAD MATERIAL REINFORCED CONCRETE ~3500 psi
REINFORCED WITH REBAR WITH 1/8-in WIRE MESH
PAD DIMENSIONS (ft) 10.0 (L) 10.0 (W) 0.5 (H)

HYDRATED BENTONITE CHIPS 73.0 TO 832.0 (ft bgs)
FINE SAND COLLAR 832.0 TO 835.0 (ft bgs)
FILTER PACK 835.0 TO 866.0 (ft bgs)
SCREENED INTERVAL 840.0 TO 860.6 (ft bgs)
BOTTOM OF CASING 865.5 (ft bgs)
PURE BENTONITE SEAL 866.0 TO 894.6 (ft bgs)
SLOUGH 894.6 TO 900.7 (ft bgs)
SAND PLATFORM 900.7 TO 980.1 (ft bgs)
SLOUGH 980.1 TO 999.9 (ft bgs)
12-IN ID STEEL CASING 900.0 TO 1040.0 (ft bgs)
BENTONITE SEAL 999.9 TO 1284.0 (ft bgs)
STAINLESS STEEL CENTRALIZERS USED
☒ 839.5 & 862.9 (ft bgs)
SLOUGH 1284.0 TO 1350.5 (ft bgs)

BOTTOM OF BORING 1350.5 (ft bgs)

ELEVATIONS (ft amsl)

WELL CASING	7360.76
PROTECTIVE CASING	7361.10
GROUND SURFACE	7358.35
MONUMENT MARKER	7358.41

SURFACE SEAL
GROUT FORMULA (57 wt %)
QUANTITY USED 231.5 ft^3
CALCULATED VOLUME 108.6 ft^3

TYPE OF CASING
MATERIAL PASSIVATED A304 STAINLESS STEEL
ID (in) 5.047 OD (in) 5.563
JOINT TYPE THREADED AND COUPLED

UPPER BENTONITE CHIP SEAL
0.375-in BENTONITE CHIPS W/ <1% SAND
QUANTITY USED 1027.4 ft^3
CALCULATED VOLUME 1070.2 ft^3

FINE SAND COLLAR
SIZE/TYPE 20/40
QUANTITY USED 4.0 ft^3
CALCULATED VOLUME 4.2 ft^3

TYPE OF SCREEN
MATERIAL PASSIVATED A304 STAINLESS STEEL
ID (in) 5.047 OD (in) 5.563
SLOT SIZE (in) 0.020
JOINT TYPE THREADED AND COUPLED

FILTER PACK
SIZE/TYPE 10/20
QUANTITY USED 50.0 ft^3
CALCULATED VOLUME 43.7 ft^3

PURE BENTONITE CHIP SEAL
0.375-in BENTONITE CHIPS
QUANTITY USED 32.2 ft^3
CALCULATED VOLUME 29.6 ft^3

SAND PLATFORM FOR INSTALLATION OF BENTONITE SUMP SEAL
10/20 CLEAN SILICA SAND
QUANTITY USED 87.5 ft^3
CALCULATED VOLUME 62.7 ft^3

LOWER BENTONITE CHIP SEAL
0.375-in BENTONITE CHIPS W/ 8% SAND
QUANTITY USED 304.0 ft^3
CALCULATED VOLUME 159.6 ft^3

WELL DEVELOPMENT BEGAN
Date 11-16-09 Time 0930
WELL DEVELOPMENT FINISHED
Date 11-24-09 Time 1245

DEVELOPMENT METHOD
☒ Swabbing ☒ Bailing
☒ Pumping
Total Purge Volume 2607 gal

PARAMETER MEASUREMENTS
pH 7.70
Temperature 14.42 ° C
Specific Conductance 176.0 µS/cm
Turbidity 17.6 NTU

WELL COMPLETION BEGAN
Date 11-06-09 Time 0848
WELL COMPLETION FINISHED
Date 11-16-09 Time 0800

North Wind
Drafted by: North Wind, Inc.
Project Number: 10005.002.16
Date: April 1, 2010
Filename: R47i_WellSchematic040110MDW.ai

R-47i AS-BUILT WELL CONSTRUCTION DIAGRAM
Water Canyon (TA-14)
Los Alamos National Laboratory
Los Alamos, New Mexico

Fig. 7.2-1
NOT TO SCALE

Figure 7.2-1 Monitoring well R-47i as-built well construction diagram

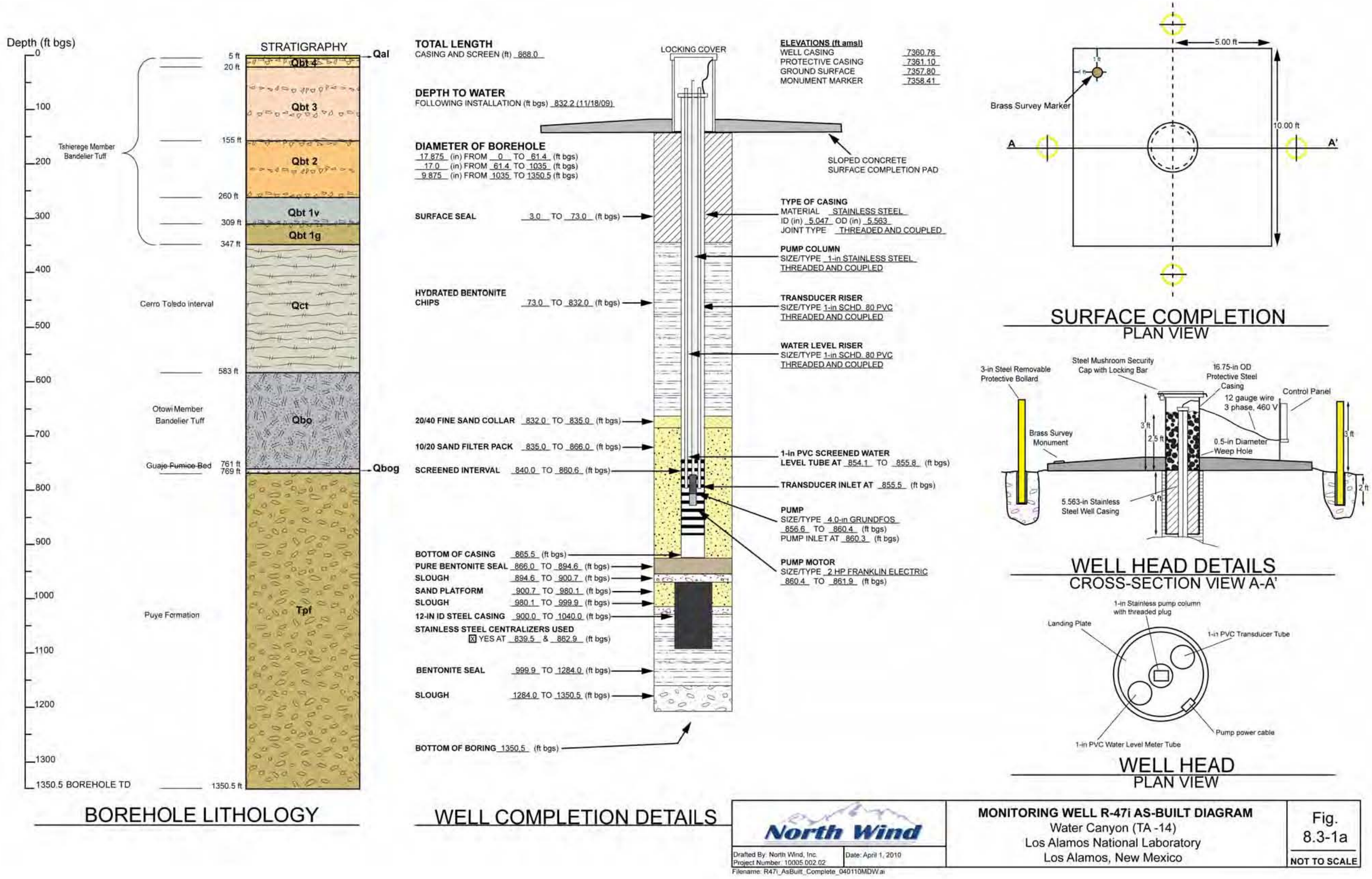
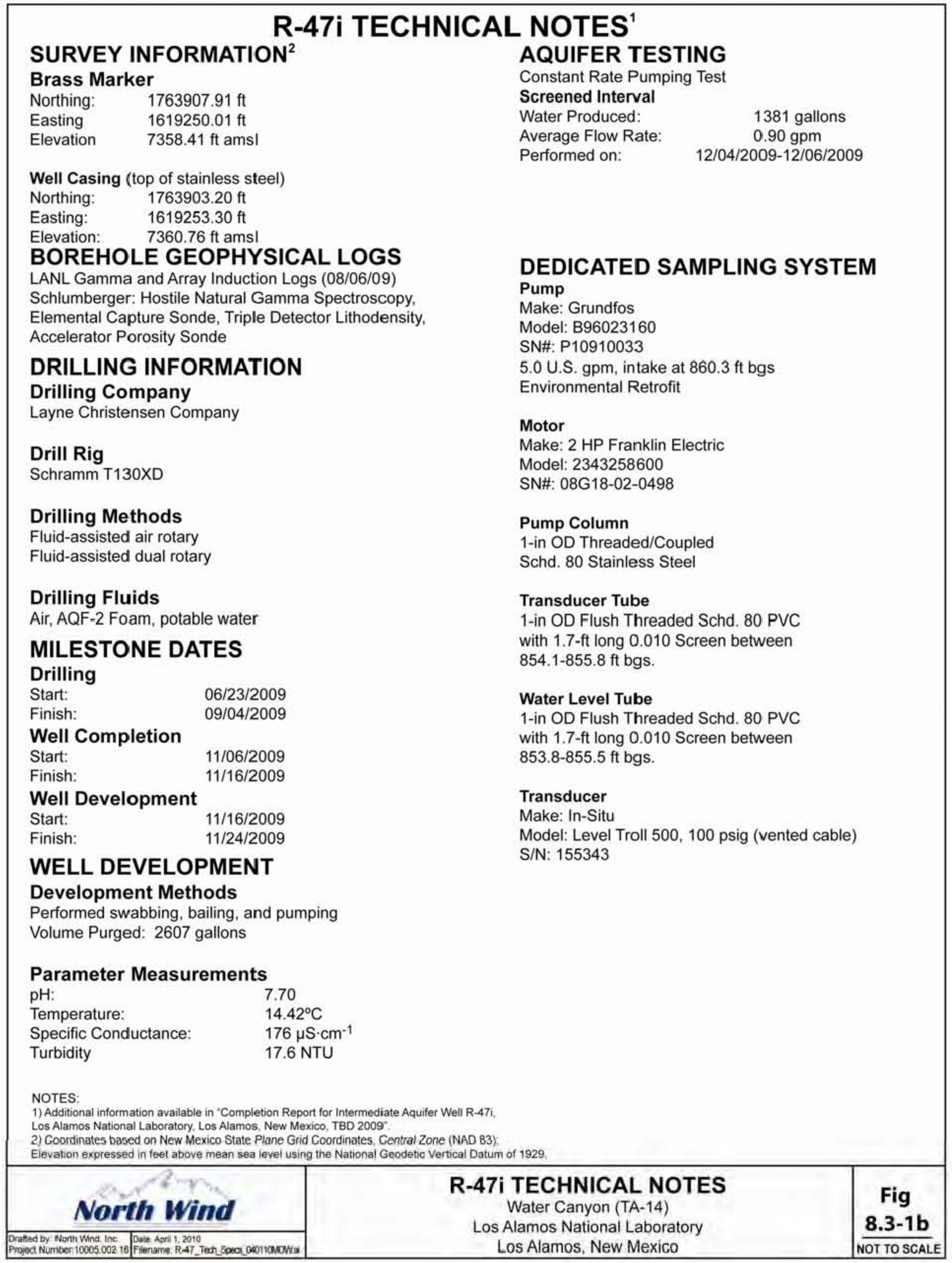


Figure 8.3-1a **As-built schematic for intermediate monitoring well R-47i**



R-47i TECHNICAL NOTES[1]

SURVEY INFORMATION[2]

Brass Marker

Northing:	1763907.91 ft
Easting	1619250.01 ft
Elevation	7358.41 ft amsl

Well Casing (top of stainless steel)

Northing:	1763903.20 ft
Easting:	1619253.30 ft
Elevation:	7360.76 ft amsl

BOREHOLE GEOPHYSICAL LOGS

LANL Gamma and Array Induction Logs (08/06/09)
Schlumberger: Hostile Natural Gamma Spectroscopy, Elemental Capture Sonde, Triple Detector Lithodensity, Accelerator Porosity Sonde

DRILLING INFORMATION

Drilling Company
Layne Christensen Company

Drill Rig
Schramm T130XD

Drilling Methods
Fluid-assisted air rotary
Fluid-assisted dual rotary

Drilling Fluids
Air, AQF-2 Foam, potable water

MILESTONE DATES

Drilling

Start:	06/23/2009
Finish:	09/04/2009

Well Completion

Start:	11/06/2009
Finish:	11/16/2009

Well Development

Start:	11/16/2009
Finish:	11/24/2009

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Volume Purged: 2607 gallons

Parameter Measurements

pH:	7.70
Temperature:	14.42ºC
Specific Conductance:	176 µS·cm^{-1}
Turbidity	17.6 NTU

AQUIFER TESTING

Constant Rate Pumping Test
Screened Interval

Water Produced:	1381 gallons
Average Flow Rate:	0.90 gpm
Performed on:	12/04/2009-12/06/2009

DEDICATED SAMPLING SYSTEM

Pump
Make: Grundfos
Model: B96023160
SN#: P10910033
5.0 U.S. gpm, intake at 860.3 ft bgs
Environmental Retrofit

Motor
Make: 2 HP Franklin Electric
Model: 2343258600
SN#: 08G18-02-0498

Pump Column
1-in OD Threaded/Coupled
Schd. 80 Stainless Steel

Transducer Tube
1-in OD Flush Threaded Schd. 80 PVC with 1.7-ft long 0.010 Screen between 854.1-855.8 ft bgs.

Water Level Tube
1-in OD Flush Threaded Schd. 80 PVC with 1.7-ft long 0.010 Screen between 853.8-855.5 ft bgs.

Transducer
Make: In-Situ
Model: Level Troll 500, 100 psig (vented cable)
S/N: 155343

NOTES:
1) Additional information available in "Completion Report for Intermediate Aquifer Well R-47i, Los Alamos National Laboratory, Los Alamos, New Mexico, TBD 2009".
2) Coordinates based on New Mexico State *Plane Grid Coordinates, Central Zone* (NAD 83); Elevation expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

North Wind
Drafted by: North Wind, Inc.
Project Number: 10005.002.16
Date: April 1, 2010
Filename: R-47_Tech_Specs_040110MDW.ai

R-47i TECHNICAL NOTES
Water Canyon (TA-14)
Los Alamos National Laboratory
Los Alamos, New Mexico

Fig 8.3-1b
NOT TO SCALE

Figure 8.3-1b As-built technical notes for monitoring well R-47i

Table 3.1-1
Fluid Quantities Used during R-47i Drilling and Well Construction

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
Drilling					
06/23/09	1000	1,000	n/a[a]	n/a	nm[b]
06/24/09	1000	2,000	n/a	n/a	nm
06/26/09	40	2,040	n/a	n/a	nm
06/28/09	5000	7,040	n/a	n/a	nm
07/08/09	2500	9,540	30	30	nm
07/09/09	7500	17,040	55	85	nm
07/10/09	6500	23,540	30	115	nm
07/16/09	1000	24,540	6	121	nm
07/29/09	6000	30,540	30	151	nm
07/30/09	3000	33,540	20	171	nm
07/31/09	4000	37,540	20	191	nm
08/01/09	2700	40,240	15	206	nm
08/02/09	3000	43,240	25	231	nm
08/03/09	2500	45,740	8	239	nm
08/16/09	2000	47,740	10	249	nm
08/18/09	4000	51,740	30	279	nm
08/19/09	6000	57,740	20	299	nm
08/21/09	40	57,780	n/a	n/a	nm
08/22/09	40	57,820	n/a	n/a	nm
08/23/09b	6000	63,820	n/a	n/a	nm
Borehole Cleaning (Intermediate Zone)					
11/04/09	11,350	75,170	n/a	n/a	nm
11/05/09	450	75,620	n/a	n/a	~155,000[c]
Well Construction					
11/06/09	1500	77,120	n/a	n/a	n/a
11/07/09	1500	78,620	n/a	n/a	n/a
11/08/09	2500	81,120	n/a	n/a	n/a
11/09/09	12,000	93,120	n/a	n/a	n/a
11/10/09	26,000	119,120	n/a	n/a	n/a
11/11/09	30,000	149,120	n/a	n/a	n/a

Table 3.1-1 (continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
11/12/09	42,000	191,120	n/a	n/a	n/a
11/14/09	413	191,533	n/a	n/a	n/a
11/14/09	350	191,883	n/a	n/a	n/a
Total Water Volume (gal.)					
R-47i	191,883				

[a] n/a = Not applicable.

[b] nm = Not measured.

[c] Cumulative volume based on pit dimensions and observed water depth at end of drilling and borehole cleaning activities. Includes estimated evaporation losses.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Drilling and Well Development of Well R-47i

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-47i	GW47-09-11454	08/12/09	910	Groundwater (bailed)	Metals/anions (including perchlorate) HE, VOCs
R-47i	GW47-09-11453	08/16/09	1025	Groundwater (air lifted)	Metals/anions (including perchlorate) HE, VOCs
R-47i	GW47-10-1975	10/15/09	1272	Groundwater (air lifted)	Metals/anions (including perchlorate) TOC
Well Development					
R-47i	GW47-10-6940	11/16/09	860	Groundwater (bailed)	TOC
R-47i	GW47-10-6941	11/17/09	860	Groundwater (bailed)	TOC
R-47i	GW47-10-6942	11/22/09	857	Groundwater (pump intake)	TOC
R-47i	GW47-10-6943	11/23/09	857	Groundwater (pump intake)	TOC
R-47i	GW47-10-6944	11/24/09	857	Groundwater (pump intake)	TOC

Table 6.0-1
R-47i Video and Geophysical Logging Runs

Date	Depth (ft bgs)	Description
08/06/09	0–896	LANL video log run in open borehole to inspect borehole after damaged casing string tripped out. Standing water in borehole at 896 ft bgs.
08/06/09	0–896	LANL natural gamma and array induction log.
08/19/09	0–1164	LANL video log run in partially cased borehole to inspect open interval below cased zone to determine presence/absence of water in borehole. Standing water in borehole at 1164 ft bgs.
09/05/09	0–1348	Schlumberger cased hole logs: array induction, triple detector lithodensity, elemental capture spectroscopy, natural and spectral gamma, and accelerator porosity sonde.
10/03/09	0–1261	LANL video log run inside stainless well casing to determine cause of obstruction inside well at ~1262 ft bgs. Discovered bentonite intruding into regional aquifer screened zone at ~1262 ft bgs.
10/05/09	0–0	Attempted LANL gamma tool run. Gamma tool was inoperable; no gamma log from this attempt.
10/06/09	0–0	Attempted LANL gamma tool run. Gamma tool was inoperable; no gamma log from this attempt.
10/08/09	0–1139	LANL video log run in partially cased borehole to inspect bottom of 10-in. casing. Water turbidity precluded inspection of bottom of casing.
10/30/09	0–890	LANL video log run in partially cased borehole to determine perched zone static water level. Standing water in borehole at 832 ft bgs; water turbidity precluded visibility below top of standing water.
10/31/09	0–874	LANL video log run in partially cased borehole to determine perched zone recharge rate after blowing hole dry through air lifting methods. Water tagged multiple times at 874 ft bgs, 864 ft bgs, and 842 ft bgs as perched zone water was recharging borehole. Camera retracted after tagging water at 842 ft bgs.
10/31/09	0–842	LANL video log run in partially cased borehole to determine perched zone recharge rate after blowing hole dry through air lifting methods and retracting 100.09 ft of 10-in. casing. Water level tagged at 842 ft bgs before retracting camera.
11/02/09	0–837	LANL video log run in partially cased borehole to determine depth to water and to inspect borehole walls to determine whether or not to pressure jet borehole to remove bentonite/grout. Standing water in borehole at 837 ft bgs.
11/05/09	0–832	LANL video log run in partially cased borehole to determine depth to water and to inspect borehole walls after pressure jetting. Walls free of bentonite to top of standing water at 832 ft bgs. Top of Puye Formation noted at 770 ft bgs.

Table 7.2-1
R-47i Monitoring Well Annular Fill Materials

Annular Fill Type	Purpose	Volume (ft^3)
Portland Cement w/ IDP 381	Surface seal	231.5
0.375-in. bentonite chips	Upper bentonite seal	1027.4
20/40 silica sand	Transition sand collar	4.0
10/20 silica sand	Primary filter pack	50.0
0.375-in. bentonite chips	Bentonite seal	32.2
10/20 silica sand	Sand platform for installation of bentonite seal	87.5
0.375-in. bentonite chips with 8 wt% 10/20 sand	Lower bentonite/sand seal	304.0

Table 8.5-1
R-47i Survey Coordinates

Identification	Northing	Easting	Elevation
R-47i brass pin embedded in pad	1619250.01	1763907.91	7358.41
R-47i ground surface near pad	1619244.76	1763913.41	7358.35
R-47i top of 16-in. protective casing	1619253.18	1763903.12	7361.10
R-47i top of stainless-steel well casing	1619253.30	1763903.20	7360.76

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

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-47i

Sample ID/Event ID	Date, Time Collected	Description	Sample Type
GW47-09-11059/908	6/30/2009, 1053	Decon Water	Liquid
GW47-09-11060/908	6/30/2009, 1053	Trip Blank	Liquid
GW47-09-9349/2167	7/28/2009, 0930	Decon Water	Liquid
GW47-09-9350/2167	7/28/2009, 0930	Trip Blank	Liquid
GW47-09-12377/2221	8/26/2009, 1620	Decon Water	Liquid
GW47-09-12915/2241	9/4/2009, 1305	Decon Water	Liquid
GW47-09-12916/2241	9/4/2009, 1000	Decon Water	Liquid
GW47-09-12917/2241	9/5/2009, 1637	Decon Water	Liquid
GW47-09-12918/2241	9/5/2009, 1400	Decon Water	Liquid
GW47-09-12920/2241	9/4/2009, 1156	Decon Water	Liquid
GW47-09-13300/2256	9/22/2009, 1230	Decon Water	Liquid
GW47-09-13301/2256	9/22/2009, 1235	Decon Water	Liquid
GW47-09-13302/2257	9/22/2009, 1145	Decon Water	Liquid
GW47-09-13303/2257	9/22/2009, 1215	Decon Water	Liquid
GW47-09-13304/2257	9/22/2009, 1215	Trip Blank	Liquid
WSTR47-10-551/2300	10/13/2009, 1630	Decon Water	Liquid
WSTR47-10-552/2300	10/13/2009, 1400	Decon Water	Liquid
WSTR47-10-553/2300	10/13/2009, 1630	Trip Blank	Liquid
WSTR47-10-2777/2300	10/21/2009, 1400	Trip Blank	Liquid
WSTR47-10-5341/2441	11/24/2009, 1353	Decon Water	Liquid
WSTR47-10-5342/2441	11/24/2009, 1353	Trip Blank	Liquid
WSTR47-10-7144/2475	11/24/2009, 1410	Trip Blank	Liquid
WSTR47-10-7145/2475	11/24/2009, 1435	Trip Blank	Liquid
WSTR47-10-7146/2475	11/24/2009, 1459	Trip Blank	Liquid
WSTR47-10-7147/2475	11/24/2009, 1524	Trip Blank	Liquid
WSTR47-10-7148/2475	11/24/2009, 1410	Decon Water	Liquid
WSTR47-10-7149/2475	11/24/2009, 1435	Decon Water	Liquid
WSTR47-10-7150/2475	11/24/2009, 1459	Decon Water	Liquid
WSTR47-10-7151/2475	11/24/2009, 1524	Decon Water	Liquid
WSTR47-10-8862/2531	12/21/2009, 1415	Trip Blank	Liquid
WSTR47-10-8863/2531	12/21/2009, 1415	Waste Water	Liquid

Appendix A

R-47i Borehole Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

Borehole Identification (ID): R-47i	**Technical Area (TA):** 14		**Page:** 1 of 16
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 6/23/09: 1133		**End Date/Time:** 9/4/09:1610
Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD		**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl			**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
0–5	**CONSTRUCTION FILL:** No samples collected in this interval (base course and fill).		Artificial fill from 0-5 ft bgs.
5–15	**UNIT 4 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Fill and base course plus unconsolidated tuff, moderate orange pink (5YR 8/4), weakly welded or weathered. +10F (i.e. sample fraction retained by the No. 10 sieve): composed of 85-90% base course and fill, 10-15% welded tuff fragments, trace quartz and sanidine crystals. +35F: 70-75% quartz and sanidine crystals, 15-20% base coarse fragments, 5-15% welded tuff fragments.	**Qbt4**	Unit 4 of the Tshirege Member of the Bandelier Tuff, encountered from 5-20 ft bgs.
15–20	Unconsolidated tuff, moderate orange pink (5YR 8/4), weakly welded or weathered. +10F: composed of 55-60% welded tuff fragments, 30-40% quartz and sanidine crystals, 5-10% lithic fragments (base course and fill plus intermediate composition volcanics).	**Qbt4**	
20–35	**UNIT 3 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, very pale orange (10YR 8/2) to grayish orange pink (5YR 7/2), weakly welded. +10F: 70-75% welded tuff fragments, 25-30% quartz and sanidine crystals. +35F: 50-55% quartz and sanidine crystals (bipyramidal quartz crystals noted), 40-45% welded tuff fragments, and trace to 5% volcanic lithics and base course (influence from up-hole).	**Qbt3**	Unit 3 of the Tshirege Member of the Bandelier Tuff, encountered from 20-155 ft bgs.
35–65	Tuff as above, base course absent.	**Qbt3**	

Borehole Identification (ID): R-47i
Technical Area (TA): 14
Page: 2 of 16
Drilling Company: Layne Christensen Co.
Start Date/Time: 6/23/09: 1133
End Date/Time: 9/4/09:1610
Drilling Method: Dual Rotary
MACHINE: Schramm T130XD
Sampling Method: Grab
Ground Elevation: 7358.35 ft amsl
Total Depth: 1350.5 ft bgs
Driller: H. Waddell/R. Wall
Site Geologists: D. Osbourne, B. Lucero, G. Kinsman, S. Thomas

65–80	Tuff, grayish orange (10YR 7/4), weakly welded. +10F: 95-100% welded tuff fragments, trace-5% intermediate composition volcanic lithics, trace quartz and sanidine crystals. +35F: 55-60% quartz and sanidine crystals (bipyramidal quartz crystals noted), 40-45% welded tuff fragments, and trace volcanic lithic fragments. +60F: 70-75% quartz and sanidine crystals, 20-25% welded tuff fragments, 5% volcanic lithics.	**Qbt3**	
80–95	No samples collected in this interval (no cuttings returned while drilling).		
95–105	Tuff, light brown (5YR 6/4) to pale brown (5YR 5/2), weakly welded. +10F: 60 – 65% welded tuff fragments, 20-25% intermediate composition volcanic lithics, 10-20% quartz and sanidine crystals (clear quartz crystals, trace smokey to rosey, trace bipyramidal crystals noted). +35F: 90-95% quartz and sanidine crystals, 5-10% welded tuff fragments, trace volcanic lithics.	**Qbt3**	
105–110	Tuff as above, insufficient recovery to sieve +10F and +35F fractions.	**Qbt3**	
110–155	Tuff, very pale orange (10YR 8/2) to grayish orange (10YR 7/4), weakly welded. +10F: No samples of this fraction size were retained. +35F: 85 – 90% quartz and sanidine crystals (clear quartz crystals, trace smokey to rosey, trace bipyramidal crystals noted), 5-10% welded tuff fragments, and trace volcanic lithic fragments. Phenocryst size is generally larger than above. +60F: 90-95% quartz and sanidine crystals, 5-10% welded tuff fragments, trace volcanic lithics.	**Qbt3**	
155–160	**UNIT 2 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, moderate orange pink (10R 7/4) to pale red (10R 6/2), potential weathering surface (brick red discharge while drilling) or weakly welded. WR: sandy texture. +10F: No samples of this fraction size were retained. +35F: no ash matrix observed, 95-100% quartz and sanidine crystals with trace intermediate composition lithic fragments (dacite).	**Qbt2**	Unit 2 of the Tshirege Member of the Bandelier Tuff, encountered from 155-260 ft bgs.

Borehole Identification (ID): R-47i

Technical Area (TA): 14

Page: 3 of 16

Drilling Company: Layne Christensen Co.

Start Date/Time: 6/23/09: 1133

End Date/Time: 9/4/09:1610

Drilling Method: Dual Rotary

MACHINE: Schramm T130XD

Sampling Method: Grab

Ground Elevation: 7358.35 ft amsl

Total Depth: 1350.5 ft bgs

Driller: H. Waddell/R. Wall

Site Geologists: D. Osbourne, B. Lucero, G. Kinsman, S. Thomas

160–170	Tuff, pale red (10R 6/2) to pale yellowish brown (10YR 6/2), weakly to moderately welded. Insufficient recovery to sieve +10F and +35F fractions.	**Qbt2**	
170–200	Tuff, light brown (5YR 6/4) to pale yellowish brown (10YR 6/2), moderately welded, crystal-rich. +10F: 100% welded tuff fragments with 20-30% quartz and sanidine crystals, and 2-5% Fe-oxide-stained volcanic lithic fragments, with trace intermediate composition volcanic lithics. +35F: 90% tuff fragments, 10% quartz and sanidine crystals (white inclusions noted in quartz crystals).	**Qbt2**	
200–205	Tuff, light brown (5YR 6/4) to pale yellowish brown (10YR 6/2), weakly welded, crystal-rich. +10F: No samples of this fraction size were retained. +35F: 50% welded tuff fragments with 20-30% quartz and sanidine crystals, and 2-5% Fe-oxide-stained volcanic lithic fragments, 50% quartz and sanidine crystals. +60F: 85% quartz and sanidine crystals, 10% tuff fragments, 5% volcanic lithics.	**Qbt2**	
205–240	Tuff, pale red (10R 6/2), moderately welded, crystal-rich. WR: composed dominantly of welded tuff fragments with 20-30% quartz and sanidine crystals, and 2-5% Fe-oxide-stained volcanic lithic fragments. +35F: 50% quartz and sanidine crystals and 50% tuff fragments.	**Qbt2**	Sample from 225-245 ft is borehole cleanout collected at end of joint.
240–265	Tuff as above, weakly to moderately welded, crystal-rich. WR: silty texture with 65-70% quartz and sanidine crystals, 20-25% welded tuff fragments with 20-30% quartz and sanidine crystals, and 2-5% Fe-oxide-stained volcanic lithic fragments.	**Qbt2**	Sample from 245-265 ft is borehole cleanout collected at end of joint.

Borehole Identification (ID): R-47i	**Technical Area (TA):** 14	**Page:** 4 of 16
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 6/23/09: 1133	**End Date/Time:** 9/4/09:1610
Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl		**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas	

265–310	**UNIT 1V OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, moderate orange pink (5YR 8/4), weakly welded, crystal-rich. WR: silty to sandy texture. +10F: 90-95% quartz and sanidine crystals (bypyramidal quartz and “wormy” inclusions in quartz noted), 5-10% intermediate composition lithic fragments, trace weakly welded tuff fragments. +35F: 75-80% quartz and sanidine crystals, 10-15% weakly welded tuff fragments, 10-15% intermediate composition and Fe-oxide-stained volcanic lithic fragments.	**Qbt1v**	Lithology based on borehole-cleanout samples from 265-285 ft bgs and 285-305 ft bgs. Based on LANL borehole video (11/05/09), Qbt1v extends from 260-309 ft bgs.
310–320	**UNIT 1G OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Vitric tuff, very pale orange (10YR 8/2) to pale yellowish orange (10YR 8/6), weakly welded. +10F: composed of 70-75% quartz and sanidine crystals and 20-25% intermediate composition volcanic lithic fragments (up to 5 mm), 2-3% vitric pumice and tuff fragments. +35F: 95-98% quartz and sanidine crystals and 2-5% tuff fragments.	**Qbt1g**	Unit 1g of the Tshirege Member of the Bandelier Tuff, encountered from 309-347 ft bgs.
320–360	**CERRO TOLEDO INTERVAL:** Vitric tuff, very pale orange (10YR 8/2) to grayish orange (10YR 7/4), weakly welded. WR: sandy texture. +10F: No samples of this fraction size were retained. +35F: 55-60% intermediate composition volcanic lithic fragments, up to 3-4 mm, 30-40% quartz and sanidine crystals (smoky quartz and trace “wormy inclusions” noted), 5-10% tuff and white vitric pumice fragments. +60F: 50% quartz and sanidine crystals, 35-40% tuff and white vitric pumice fragments, 10-15% intermediate composition volcanic lithic fragments, trace vitrophyre (obsidian) fragments noted.	**Qct**	Based on video (performed 11/05/09), gamma, and induction logs, the contact between Qbt1g and Qct is at 347 ft bgs. Cerro Toledo interval was encountered from 347-583 ft bgs.

Borehole Identification (ID): R-47i	**Technical Area (TA):** 14	**Page:** 5 of 16
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 6/23/09: 1133	**End Date/Time:** 9/4/09:1610
Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl		**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas	

360–365	Volcaniclastic sediments, very pale orange (10YR 8/2), poorly graded gravel with sand (GP), fine to coarse sand, grains angular to subrounded. +10F: detrital constituents (up to 5 mm) composed of 95-98% varied intermediate composition volcanic lithics, and 2-5% white vitric pumice. +35F: 90% varied intermediate composition volcanic lithics, 7-8% quartz and sanidine crystals, and 2-3% white vitric pumice.	**Qct**	
365–400	Volcaniclastic sediments, very pale orange (10YR 8/2) to pale yellowish orange (10YR 8/6), well-graded gravel (GW), angular to subrounded. WR: silty to sandy texture. +10F: detrital constituents (up to 8 mm) composed of 90-95% varied intermediate composition volcanic lithics, 5-10% white vitric pumice and moderate orange tuff fragments. +35F: 65-70% varied intermediate composition volcanic lithics, 25-30% quartz and sanidine crystals (light to dark smokey quartz noted), and 5-10% white vitric pumice and moderate orange tuff fragments.	**Qct**	Insufficient recovery to sieve +10F and +35F between 370-375 ft bgs, 385-400 ft bgs.
400–435	Volcaniclastic sediments as above, general increase in tuff and pumice fragments.	**Qct**	
435–445	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded gravel (GW), angular to subrounded. WR: silty to sandy texture. +10F: detrital constituents (up to 8 mm) composed of 100% varied intermediate composition volcanic lithics. +35F: 80-85% varied intermediate composition volcanic lithics, 5-10% quartz and sanidine crystals (light to dark smokey quartz noted), and 5-10% white vitric pumice and moderate orange tuff fragments.	**Qct**	Insufficient recovery to sieve +10F and +35F between 435-440 ft bgs.
445–455	No samples collected in this interval (no cuttings returned while drilling).		

Borehole Identification (ID): R-47i	**Technical Area (TA):** 14	**Page:** 6 of 16
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 6/23/09: 1133	**End Date/Time:** 9/4/09:1610
Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl		**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas	

455–465	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded gravel (GW), angular to subrounded. WR: silty to sandy texture. +10F: detrital constituents (up to 8 mm) composed of 100% varied intermediate composition volcanic lithics. +35F: 80-85% varied intermediate composition volcanic lithics, 5-10% quartz and sanidine crystals (light to dark smokey quartz noted), and 5-10% white vitric pumice and moderate orange tuff fragments.	**Qct**	
465–470	No samples collected in this interval (no cuttings returned while drilling).	**Qct**	
470–480	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded gravel with sand (GW), angular to subrounded. WR: silty to sandy texture, detrital constituents (up to 8 mm) composed of nearly 100% varied intermediate composition volcanic lithics, with trace quartz and sanidine crystals, and trace white vitric pumice fragments.	**Qct**	Insufficient recovery to sieve +10F and +35F between 470-480 ft bgs.
480–485	Volcaniclastic sediments, very pale orange (10YR 8/2) to grayish orange (10YR 7/4), well-graded gravel with silt and sand (GW-GM), angular to subrounded. WR: silty to sandy texture, increase in silt and sand. +10F: detrital constituents (up to 6 mm) composed of nearly 100% varied intermediate composition volcanic lithics, with trace quartz and sanidine crystals, and trace white vitric pumice fragments and moderate orange pink tuff fragments. +35F: No samples of this fraction size were retained.	**Qct**	
485–495	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded gravel with sand (GW), angular to subrounded. WR: silty texture (coating gravel), decrease in silt/sand from above, detrital constituents (up to 12 mm) composed of nearly 100% varied intermediate composition volcanic lithics, with trace white to moderate orange pink pumice and tuff fragments.	**Qct**	Insufficient recovery to sieve +10F and +35F between 485-495 ft bgs.

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Drilling Method: Dual Rotary
MACHINE: Schramm T130XD
Sampling Method: Grab
Ground Elevation: 7358.35 ft amsl
Total Depth: 1350.5 ft bgs
Driller: H. Waddell/R. Wall
Site Geologists: D. Osbourne, B. Lucero, G. Kinsman, S. Thomas

495–500	Volcaniclastic sediments, very pale orange (10YR 8/2), poorly graded gravel with sand (GP), angular to subrounded. WR: silty texture (coating gravel). +10F: detrital constituents (up to 8 mm) composed of nearly 100% varied intermediate composition volcanic lithics (angular to subangular) with trace white tuff fragments. +35F: No samples of this fraction size were retained.	**Qct**	
500–515	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded gravel with sand (GW), angular to subrounded. WR: silty texture (coating gravel). +10F: detrital constituents (up to 6 mm) composed of nearly 100% Fe-oxide-stained varied intermediate composition volcanic lithics (angular to subangular) with trace grayish orange to light brown tuff fragments. +35F: Similar composition to +10F (No samples of this fraction size were retained between 510-515 ft bgs).	**Qct**	Insufficient recovery to sieve +10F and +35F between 505-510 ft bgs.
515–520	Volcaniclastic sediments as above, increase in quartz and sanidine crystals in +35F fraction to 10-15%.	**Qct**	
520–525	No samples collected in this interval (no cuttings returned while drilling).		
525–540	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded gravel with sand (GW), angular to subrounded. WR: silty to sandy texture (coating gravel). +10F: detrital constituents (up to 6 mm) composed of nearly 100% varied intermediate composition volcanic lithics (angular to subangular) with trace quartz and sanidine crystals and trace grayish orange to light brown tuff and pumice fragments. +35F: Similar composition to +10F.	**Qct**	
540–565	Volcaniclastic sediments as above, increase in percentage of quartz and sanidine crystals and tuff and pumice fragments, with depth, to 10% quartz/sanidine and 10% tuff and pumice.	**Qct**	Insufficient recovery to sieve +35F between 535-540 ft bgs and 545-550 ft bgs.

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Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl		**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas	

565–570	No samples collected in this interval (no cuttings returned while drilling).		
570–580	Volcaniclastic sediments, very pale orange (10YR 8/2), well-graded sand with gravel (SW), angular to subrounded. WR: silty coating on gravel. +10F: detrital constituents (up to 6 mm) composed of 95-98% varied intermediate composition volcanic lithics with trace Fe-oxide staining, with 2-5% grayish orange to moderate orange pink tuff fragments and white pumice fragments. +35F: 50% varied intermediate composition volcanic lithics with trace Fe-oxide staining, 40-45% grayish orange to moderate orange pink tuff fragments and white pumice fragments, 5-10% quartz and sanidine crystals.	**Qct**	Insufficient recovery to sieve +35F between 575-580 ft bgs.
580–590	**OTOWI MEMBER OF THE BANDELIER TUFF:** Volcaniclastic sediments, generally very pale orange (10YR 8/2), well-graded gravel with sand (GW), angular to subrounded. WR: fine to coarse sand, silty coating on gravel. +10F: detrital constituents (up to 6 mm) composed of 95-98% varied intermediate composition volcanic lithics with trace Fe-oxide staining, with 2-5% grayish orange to moderate orange pink tuff fragments and white pumice fragments. +35F: 50% varied intermediate composition volcanic lithics with trace Fe-oxide staining, 40-45% grayish orange to moderate orange pink tuff fragments and white pumice fragments, 5-10% quartz and sanidine crystals.	**Qbo**	Insufficient recovery to sieve +10F and +35F between 585-590 ft bgs. Based on LANL borehole video (11/05/09), contact between Qct and Qbo appears to be at 589 ft bgs. However, the gamma log indicates that the contact between Qct and Qbo is at 583 ft bgs, and that depth is called as the Qct-Qbo contact.

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Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD	**Sampling Method:** Grab	
Ground Elevation: 7358.35 ft amsl		**Total Depth:** 1350.5 ft bgs	
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		
590–605	Tuff, grayish orange pink (5YR 7/2) to pale reddish brown (10R 5/4), weakly welded. WR: silty to sandy texture with very fine to coarse sand-size lithics and crystals. +10F: No samples of this fraction size were retained. +35F: composed of 85-95% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 6 mm) including andesite and dacite, 10-15% pinkish and white, fibrous vitric pumices. +60F: 60% quartz and sanidine crystals, 20-25% pumice, 20-25% volcanic lithics (trace vitrophyre (obsidian) noted).	**Qbo**	
605–625	Tuff, moderate orange pink (5YR 8/4) to grayish orange (10YR 7/4), weakly welded. WR: pale reddish brown to light brown, silty to sandy texture with very fine to coarse sand-size lithics and crystals. +10F: 75-80% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 6 mm) including andesite and dacite, 20-25% very pale orange to light brown tuff and fibrous vitric pumice fragments (Note: +10F fraction only retained in 620-625 ft bgs sample). +35F: composed of 85-95% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 6 mm) including andesite and dacite, 10-15% pinkish and white, fibrous vitric pumices. +60F: 50% tuff and pumice fragments, 35-40% quartz and sanidine crystals, 10-15% volcanic lithics.	**Qbo**	
625–670	Tuff, very pale orange (10YR 8/2) to grayish orange pink (5YR 7/2), weakly welded. WR: fine to medium sand-sized tuff and quartz/sanidine fragments. +10F: 75-80% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 6 mm) including andesite and dacite with trace Fe-oxide staining, 20-25% very pale orange to light brown tuff and fibrous vitric pumice fragments with trace Fe-oxide staining. +35F: 50% tuff and pumice fragments, 35-40% volcanic lithics, 10-15% quartz and sanidine crystals (trace rosey quartz noted).	**Qbo**	

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Drilling Company: Layne Christensen Co.	**Start Date/Time:** 6/23/09: 1133		**End Date/Time:** 9/4/09:1610
Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD		**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl			**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		
670–710	Tuff, very pale orange (10YR 8/2), weakly welded. WR: fine to medium sand-sized tuff and quartz/sanidine fragments lend sandy texture. +10F: 50-60% very pale orange to light brown tuff and fibrous vitric pumice fragments with trace Fe-oxide staining, 40-50% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 6 mm) including andesite and dacite with trace Fe-oxide staining. +35F: 60-65% tuff and pumice fragments, 15-20% quartz and sanidine crystals (trace rosey quartz noted), 15-20% volcanic lithics.	**Qbo**	Insufficient recovery to sieve +10F and +35F between 685-690 ft bgs.
710–725	Tuff, very pale orange (10YR 8/2), weakly welded. WR: fine to medium sand-sized tuff and quartz/sanidine fragments lend sandy texture. +10F: 65-70% white to very pale orange tuff and fibrous vitric pumice fragments with trace Fe-oxide staining, 30-35% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 4 mm) including andesite and dacite with trace Fe-oxide staining. +35F: 70-75% tuff and pumice fragments, 15-20% quartz and sanidine crystals (trace rosey quartz noted), 5-10% volcanic lithics.	**Qbo**	
725–730	Tuff, very pale orange (10YR 8/2) to grayish orange pink (5YR 7/2), weakly welded. WR: fine to medium sand-sized tuff and quartz/sanidine fragments lend sandy texture. +10F: 75-80% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 3 mm) including andesite and dacite with trace Fe-oxide staining, 10-55% white to very pale orange tuff and fibrous vitric pumice fragments with trace Fe-oxide staining, 5-10% quartz and sanidine crystals. +35F: 55-60% quartz and sanidine crystals (trace smokey and trace bipyramidal quartz crystals noted), 20-25% tuff and pumice fragments, 15-25% volcanic lithics.	**Qbo**	

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MACHINE: Schramm T130XD
Sampling Method: Grab
Ground Elevation: 7358.35 ft amsl
Total Depth: 1350.5 ft bgs
Driller: H. Waddell/R. Wall
Site Geologists: D. Osbourne, B. Lucero, G. Kinsman, S. Thomas

730–740	Tuff, very pale orange (10YR 8/2), weakly welded. WR: fine to medium sand-sized tuff and quartz/sanidine fragments lend sandy texture. +10F: 50% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 10 mm) including andesite and dacite, 50% white to very pale orange tuff and fibrous vitric pumice fragments. +35F: 70-75% quartz and sanidine crystals (smokey, rosey and bypyramidal quartz noted), 15-20% varieties of intermediate volcanic lithics, 5-15% tuff and pumice fragments, trace vitrophyre (obsidian) fragments.	**Qbo**	
740–745	Tuff, very pale orange (10YR 8/2), weakly welded. WR: fine to medium sand-sized tuff and quartz/sanidine fragments lend sandy texture. +10F: 50% varieties of aphanitic and porphyritic intermediate volcanic lithics (up to 10 mm) including andesite and dacite, 50% white to very pale orange tuff and fibrous vitric pumice fragments. +35F: 70-75% quartz and sanidine crystals (smokey, rosey and bypyramidal quartz noted), 15-20% varieties of intermediate volcanic lithics, 5-15% tuff and pumice fragments, trace vitrophyre (obsidian) fragments.	**Qbo**	
745–750	No samples collected in this interval (brief loss of circulation while drilling).	**Qbo**	
750–755	Tuff, very pale orange (10YR 8/2), weakly welded. WR: silty to sandy texture. +10F: 50-60% very pale orange to grayish orange pink tuff fragments and white to grayish orange pink vitric pumice fragments, 40-50% varieties of aphanitic and porphyritic intermediate volcanic lithics including andesite and dacite, trace quartz and sanidine crystals. +35F: 85-90% tuff and pumice fragments, 10-15% volcanic lithics, trace quartz and sanidine crystals.	**Qbo**	

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Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD		**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl			**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		
755–770	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Pumice, white (N9) to very pale orange (10YR 8/2), unwelded. WR: contains pumice fragments up to 10 mm. +10F: 80-90% white to very pale orange pumice fragments, 10-20% intermediate composition volcanic lithics. +35F: similar composition to +10F fraction.	**Qbog**	However, video log indicates that the top of Qbog is at 761 ft bgs. Based on LANL borehole video performed 11/05/09, the basal contact between Qbog and Tpf is at 769 ft bgs.
770–775	**PUYE FORMATION:** Pumice (and volcaniclastic sediments), white (N9) to very pale orange (10YR 8/2), unwelded. WR: contains pumice fragments up to 5 mm. +10F: 70-75% white to very pale orange pumice fragments, 20-25% intermediate composition volcanic lithics. +35F: 70-75% pumice fragments, 20% quartz and sanidine crystals, 5-10% volcanic lithics, including trace vitrophyre (obsidian).	**Tpf**	Puye Formation encountered from 769-1350.5 ft bgs.
775–780	Volcaniclastic sediments, well-graded gravel with sand (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: composed of 90% porphyritic and aphyric intermediate volcanics (up to 24 mm), 10% white pumice. +35F: 70-75% pumice, 15-20% volcanic lithics, 5-15% quartz and sanidine crystals.	**Tpf**	
780–785	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 24 mm), trace white pumice. +35F: No samples of this fraction size were retained.	**Tpf**	
785–905	Volcaniclastic sediments, well graded gravel with minor sand (GW), very pale orange (10YR 8/2) silty coating on some gravel, angular to subrounded. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 30 mm). +35F: 100% intermediate volcanic lithics. Trace quartzite fragments noted above 820 ft bgs.	**Tpf**	

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Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD		**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl			**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		
905–910	Volcaniclastic sediments as above, poorly graded gravel with sand (GP), trace very pale orange (10YR 8/2) to moderate orange pink (5YR 8/4) silty coating on gravel, angular to subrounded. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 10 mm). +35F: 100% intermediate volcanic lithics, trace tuff/pumice fragments. Trace quartzite fragments noted.	**Tpf**	
910–920	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 2 cm), trace white pumice. +35F: No samples of this fraction size were retained.	**Tpf**	
920–930	Volcaniclastic sediments as above, poorly graded gravel with sand (GP), angular to subrounded, trace very pale orange (10YR 8/2) to moderate orange pink (5YR 8/4) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 12 mm). +35F: 100% intermediate volcanic lithics, trace tuff/pumice fragments.	**Tpf**	
930–935	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 2 cm), trace white pumice. +35F: No samples of this fraction size were retained.	**Tpf**	
935–940	Volcaniclastic sediments, poorly graded gravel with sand (GP), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 1 cm). +35F: 100% intermediate volcanic lithics.	**Tpf**	
940–945	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 2 cm). +35F: No samples of this fraction size were retained.	**Tpf**	

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Drilling Method: Dual Rotary	**MACHINE:** Schramm T130XD	**Sampling Method:** Grab	
Ground Elevation: 7358.35 ft amsl		**Total Depth:** 1350.5 ft bgs	
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		
940–945	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 2 cm). +35F: No samples of this fraction size were retained.	**Tpf**	
945–950	Volcaniclastic sediments, poorly graded gravel with sand (GP), angular to subrounded, trace very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 8 mm). +35F: 95-98% intermediate volcanic lithics, 2-5% quartz and sanidine crystals.	**Tpf**	
950–975	Volcaniclastic sediments, poorly graded gravel with silt and sand (GP-GM), angular to subrounded, very pale orange (10YR 8/2) to pale yellowish orange (10YR 8/6) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 2 cm). +35F: 100% intermediate volcanic lithics, trace quartz and sanidine crystals.	**Tpf**	
975–985	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, no fine-grained material upon which to base general color. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 3 cm). +35F: No samples of this fraction size were retained.	**Tpf**	
985–990	No samples collected in this interval (no cuttings returned while drilling).		
990–1010	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 3 cm). +35F: 100% intermediate volcanic lithics.	**Tpf**	
1010–1025	Volcaniclastic sediments, well-graded gravel with silt and sand (GW-GM), angular to subrounded, very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 2 cm). +35F: 100% intermediate volcanic lithics.	**Tpf**	

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End Date/Time: 9/4/09:1610

Drilling Method: Dual Rotary

MACHINE: Schramm T130XD

Sampling Method: Grab

Ground Elevation: 7358.35 ft amsl

Total Depth: 1350.5 ft bgs

Driller: H. Waddell/R. Wall

Site Geologists: D. Osbourne, B. Lucero, G. Kinsman, S. Thomas

1025–1035	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 3 cm). +35F: No samples of this fraction size were retained.	**Tpf**	
1035–1185	Volcaniclastic sediments, well-graded gravel (GW), angular to subrounded, very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 1 cm). +35F: 100% intermediate volcanic lithics.	**Tpf**	
1185–1200	Volcaniclastic sediments, well-graded gravel with sand (GW), angular to subrounded, trace to minor very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 35 mm). +35F: 95-98% intermediate volcanic lithics, 2-5% quartz and sanidine crystals.	**Tpf**	
1200–1210	Volcaniclastic sediments, poorly graded gravel with sand (GP), angular to subrounded, trace very pale orange (10YR 8/2) silty coating on gravel. +10F: 98% porphyritic and aphyric intermediate volcanics (up to 8 mm), 2% quartz and quartzite fragments and pebbles. +35F: 65% intermediate volcanic lithics, 35% quartz and quartzite.	**Tpf**	
1210–1240	Volcaniclastic sediments, poorly graded gravel with sand (GP), angular to subrounded, trace very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 20 mm), trace quartz and quartzite fragments and pebbles. +35F: 100% intermediate volcanic lithics, trace quartz and quartzite.	**Tpf**	
1240–1295	Volcaniclastic sediments, well-graded gravel with silty sand and clay (GW-GC), angular to subrounded, trace very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 20 mm), trace quartz and quartzite fragments and pebbles. +35F: 100% intermediate volcanic lithics, trace quartz and quartzite.	**Tpf**	

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Drilling Method: Dual Rotary		**MACHINE:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7358.35 ft amsl			**Total Depth:** 1350.5 ft bgs
Driller: H. Waddell/R. Wall	**Site Geologists:** D. Osbourne, B. Lucero, G. Kinsman, S. Thomas		
1295–1350.5	Volcaniclastic sediments, well-graded gravel with sand (GW), angular to subrounded, trace very pale orange (10YR 8/2) silty coating on gravel. +10F: 100% porphyritic and aphyric intermediate volcanics (up to 20 mm), trace quartz and quartzite fragments and pebbles. +35F: 100% intermediate volcanic lithics, trace quartz and quartzite.	**Tpf**	

End of borehole = 1350.5 ft bgs

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-47i

A total of eight groundwater-screening samples were collected during drilling, well construction, and development at well R-47i. Two groundwater-screening samples, GW47-09-11454 and GW47-09-11453, were collected during drilling from the open borehole at 910 ft and 1025 ft below ground surface (bgs), respectively. Sample GW47-09-11454 was collected from standing water in the borehole, with a measured depth to water of 857 ft bgs and a borehole depth of approximately 1035 ft bgs. The two samples were submitted to an external analytical laboratory for analyses of volatile organic compounds (VOCs), high explosive compounds (HE), metals and anions (including perchlorate); and were sent to the Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14) laboratory for analyses of cations, anions, perchlorate and metals.

A third sample, GW47-10-1975, was collected during the original attempt at the R-47 regional monitoring well construction from the screened interval at approximately 1272 ft bgs. It was collected to determine if bentonite was present within the screened interval and was submitted for off-site analyses of metals, anions and total organic carbon (TOC).

Five groundwater-screening samples (GW47-10-6940, GW47-10-6941, GW47-10-6942, GW47-10-6943, and GW-10-6944) were collected from well R-47i during development and analyzed by EES-14 for TOC concentrations. These five samples were collected from the screened interval of the completed well at a depth between 840.0 to 860.6 ft bgs.

B-1.1 Analytical Techniques

Chemical analyses of groundwater-screening samples collected from R-47i were performed at LANL's EES-14. Groundwater samples were filtered (0.45-µm membranes) before preservation and chemical analyses. Samples were acidified at the EES-14 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (EPA Method 300, Rev. 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Instrument detection limits for perchlorate were 0.002 and 0.005 ppm (EPA Method 314.0, Rev. 1) for the R-47i screening samples. Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) (EPA Method 200.7, Rev. 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, iron, lithium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved antimony, arsenic, beryllium, cadmium, cesium, chromium, cobalt, copper, lead, lithium, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS) (EPA Method 200.8, Rev. 5.4). The precision limits (analytical error) for major ions and trace elements were generally less than ±7% using ICPOES and ICPMS. Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques. TOC analyses were performed on unfiltered groundwater-screening samples following EPA Method 415.1. Charge balance errors for total cations and anions were less than ±5% for complete analyses of the above inorganic chemicals in the borehole screening samples. The negative cation-anion charge balance values indicate excess anions for the filtered borehole samples.

B-1.2 Field Parameters

B-1.2.1 Well Development

Table B-1.2-1 presents a summary of field parameter measurements and water volumes purged during development of well R-47i. Measurements of pH ranged from 6.47 to 9.09. Measurements of temperature varied from 9.41˚C to 19.50˚C during this phase. Concentrations of dissolved oxygen varied from 0.20 to 6.74 mg/L. Corrected oxidation-reduction potential values as Eh ranged from 115.2 to 371.8 millivolts (mV). Specific conductance varied from 159.0 to 442.0 µS/cm. Turbidity measurements on non-filtered samples containing suspended sediment ranged from 16.6 to 4000 nephelometric turbidity units (NTU). The final turbidity reading at the end of development was 17.6 NTU; however, it had decreased to approximately 7 NTU by the end of aquifer testing (Table B-1.2-1).

B-1.3 Analytical Results for Groundwater-Screening Samples

B-1.3.1 Off-site Laboratory Analytical Results for VOCs, HEs, Anions and Metals

Table B-1.3-1 presents a summary of the off-site analytical results reported for R-47i.

One of the two borehole screening samples collected during well drilling, GW47-09-11453, reported three VOCs: acetone, 2-butanone and naphthalene, at concentrations of 16.6, 5.67 and 0.56 µg/L, respectively. Acetone and naphthalene were validated as J or estimated values by a validation team external to the Laboratory. VOCs were not detected in sample GW47-09-11454.

Oxalate, likely representative of AQF-2 drilling foam, was detected in the sample collected from 910 ft bgs in standing borehole water, GW47-09-11454, at 1.24 mg/L, but was not detected in the other borehole water sample or the bentonite screening sample collected during well construction. Perchlorate was not detected in any of the three samples. The off-site analytical laboratory reported a TOC concentration of 12.27 mg/L for the bentonite screening sample collected during the original well construction; the two borehole screening samples were not analyzed for TOC.

High explosive compounds were not detected in the two borehole water samples, including tetryl; 2,4,6-trinitrotoluene; 2,4-dinitrotoluene; RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine); 4-amino-2,6-dinitrotoluene; HMX (1,3,5,7-tetranitro-1,3,5,7-tetrazocine); 2-amino-4,6-dinitrotoluene; 2,6-dinitrotoluene; PETN (pentaerythritol tetranitrate); 2-nitrotoluene; nitrobenzene; 3-nitrobenzene; 1,3,5-trinitrobenzene; 1,3-dinitrobenzene; and 4-nitrotoluene (Table B-1.3-1). GW-47-09-1875 was not analyzed for HE.

B-1.3.2 EES-14 Analytical Results from Drilling and Well Development Samples

Analytical results for groundwater-screening samples collected at well R-47i during drilling are provided in Table B-1.3-2. Chloride, nitrate, fluoride, and sulfate concentrations in GW47-09-11454 and GW47-0-11453 generally do not indicate any residual drilling fluid effects. Perchlorate was not detected in those two samples or in sample GW47-10-1975.

GW47-10-1975, collected to screen for bentonite, does show colloidal bentonite, disaggregated aquifer material, and groundwater. Analytical results for the fluid sample show elevated dissolved concentrations of aluminum (68 ppm), sodium (157 ppm), total carbonate alkalinity (187 mg$CaCO_3$/L), silica (1236 ppm), and sulfate (167 ppm) characteristic of bentonite used for well construction at the original well R-47. Elevated concentrations of copper (0.006 ppm), iron (27.90 ppm), lithium (0.16 ppm), manganese

(0.335 ppm), lead (0.0108 ppm), tin (0.006 ppm), titanium (0.571 ppm), and zinc (0.058 ppm) along with a basic pH of 8.97, strongly support the abundance of bentonite in sample GW47-10-1975 (Table B-1.3-2).

EES-14 analytical results for TOC measured in five groundwater-screening samples collected during development of well R-47i are provided in Table B-1.3-3. Concentrations of TOC decreased over development from 3.46 to 0.95 mgC/L, suggesting that any potential residual drilling fluid (AQF-2) used during drilling was successfully removed during development.

Table B-1.2-1
Well Development Volumes and Associated Field Water-Quality Parameters for R-47i

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP and Eh (mV)[a]	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development									
11/16/09	0931	7.93	18.12	7.72	121.0, 324.9	246	2213	6	6
	1639	7.9	18.30	6.71	142.3, 346.2	253	1499	439	445
11/17/09	0933	7.87	18.51	5.85	167.9, 371.8	258	1589	140	585
	1050	9.09	19.13	6.34	144.9, 348.8	442	4000[b]	6	591
	1630	8.21	19.50	6.74	165.0, 368.9	264	1706	299	890
11/22/09	0751	7.22	10.90	2.43	-2.1, 211.7	177	48.1	22	912
	0820	7.3	11.52	1.50	-34.5, 179.3	191	121	44	956
	0850	7.36	12.38	1.56	-40.4, 173.4	197	194	39	995
	1040	7.42	13.53	1.09	-70.6, 138.3	213	106.9	45	1040
	1110	7.39	14.16	0.84	-92.2, 116.7	214	46.8	42	1082
	1140	7.33	14.64	1.99	-68.5, 140.4	191	35.2	42	1124
	1210	7.36	15.31	1.44	-86.8, 122.1	206	33.5	45	1169
	1240	7.37	15.31	1.45	-90.8, 118.1	202	27.2	45	1214
	1310	7.4	15.50	1.56	-92.6, 116.3	200	27.1	45	1259
	1340	7.36	15.22	1.51	-93.1, 115.8	197	24.8	42	1301
	1410	7.37	15.52	1.53	-91.7, 117.2	196	28.7	42	1343
	1440	7.35	15.55	1.58	-89.8, 119.1	197	38.5	42	1385
	1510	7.34	15.17	1.55	-86.1, 122.8	195	45.2	39	1424
	1540	7.35	15.20	1.65	-89.0, 119.9	192	43.6	41	1465
	1610	7.3	14.71	1.72	-90.9, 118.0	190	39.1	42	1507
	1640	7.3	14.10	1.77	-81.7, 127.2	188	37.7	41	1548
11/23/09	0715	6.47	9.41	0.20	-54.8, 159.0	186	54.5	45	1593
	0745	7.51	9.80	0.85	-110.3, 103.5	175	49.4	41	1634
	0815	7.38	11.27	1.90	-77.3, 136.5	164	23.7	39	1673
	0845	7.33	11.90	1.63	-83.9, 129.9	179	24.9	39	1712
	0915	7.36	12.79	1.48	-93.7, 115.2	185	23.8	42	1754
	0945	7.37	13.25	1.41	-89.7, 119.2	185	22.1	42	1796
	1015	7.36	14.36	1.43	-89.7, 119.2	183	21.7	44	1840
	1045	7.36	14.90	1.44	-93.7, 115.2	183	20.3	42	1882
	1115	7.34	15.23	1.48	-90.5, 118.4	182	21.6	42	1924

Table B-1.2-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP and Eh (mV)[a]	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/23/09 (cont.)	1145	7.27	14.27	1.46	-78.9, 130.0	185	21.1	41	1965
	1215	7.28	15.32	1.46	-86.2, 122.7	186	23.6	41	2006
	1245	7.29	15.24	1.48	-86.6, 122.3	185	25.9	45	2051
	1315	7.28	15.02	1.50	-82.0, 126.9	184	30.9	45	2096
	1345	7.29	14.72	1.55	-83.9, 125.0	180	33.8	45	2141
	1415	7.28	14.93	1.54	-80.5, 128.4	179	34.2	45	2186
	1445	7.29	14.70	1.53	-78.6, 130.3	178	45.2	39	2225
	1515	7.3	14.31	1.88	-60.2, 148.7	174	53.9	30	2255
	1545	7.28	13.76	2.35	-41.0, 167.9	170	102	30	2285
	1615	7.27	13.22	2.30	-30.4, 178.5	169	135	30	2315
11/24/09	0815	6.68	9.73	3.75	26.3, 240.1	166	54.3	33	2348
	0845	7.16	10.26	3.80	-13.2, 200.6	162	61	3	2351
	0915	7.3	10.24	4.73	-27.1, 186.7	159	23.8	32	2383
	0945	7.56	11.37	5.43	-13.7, 200.1	171	18.7	32	2415
	1020	7.61	12.70	2.00	-18.7, 190.2	178	19.8	37	2452
	1050	7.62	12.42	3.65	-11.0, 202.8	176	18.8	32	2484
	1120	7.69	12.69	3.34	-14.0, 194.9	179	17.5	32	2516
	1150	7.64	13.90	2.91	-36.0, 172.9	177	16.6	32	2548
	1220	7.68	14.16	4.76	-14.5, 194.4	175	16.6	32	2580
	1245	7.7	14.42	3.08	-25.5, 183.4	176	17.6	27	2607
	1245	7.7	14.42	3.08	-25.5, 183.4	176	17.6	27	2607
	1245	7.7	14.42	3.08	-25.5, 183.4	176	17.6	27	2607
Aquifer Testing									
12/4/09	0940	8.19	10.37	6.65	-15.9, 197.9	131	frozen blank	n/r[c]	n/r
	1010	8.14	10.51	6.55	-9.1, 204.7	160	23.80	27	27
	1040	8.45	6.70	8.07	-12.0, 206.6	177	10.20	31	58
	1110	8.41	3.82	9.01	-1.8, 216.8	160	10.31	38	96
	1140	8.19	2.57	9.45	15.4, 234.0	163	9.18	21	117
	1210	7.98	13.23	1.64	-66.6, 142.3	173	8.47	37	154
	1240	7.94	13.20	1.58	-70.0, 138.9	173	8.48	29	183
	1310	7.90	13.36	1.90	-58.5, 150.4	171	5.98	33	216
	1340	7.88	13.49	1.93	-59.4, 149.5	170	6.79	32	248
	1410	7.86	13.54	1.85	-66.8, 142.1	169	6.91	30	278
	1440	7.84	13.18	1.86	-63.9, 145.0	169	8.33	30	308

Table B-1.2-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP and Eh (mV)[a]	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
12/4/09 (cont.)	1510	7.86	13.22	1.65	-73.9, 135.0	168	6.35	31	339
	1540	7.83	13.43	1.59	-74.0, 134.9	167	7.76	29	368
	1610	7.84	13.16	1.57	-74.1, 134.8	162	8.23	28	396
	1640	7.83	13.06	1.32	-69.8, 139.1	120	8.65	34	430
	1710	7.80	12.87	1.69	-67.6, 141.3	158	6.25	29	459
	1740	7.79	12.46	1.70	-61.9, 151.9	118	5.59	31	490
	1810	7.67	12.60	1.72	-59.1, 149.8	132	6.76	32	522
	1845	7.66	12.40	1.52	-61.9, 151.9	95	6.44	36	558
	1930	7.61	12.41	1.34	-59.9, 153.9	86	6.78	43	601
	2000	7.57	12.38	1.34	-57.9, 155.9	83	7.36	30	631
	2030	7.57	12.14	1.50	-53.3, 160.5	83	7.54	30	661
	2100	7.57	12.50	1.51	-61.6, 152.2	83	6.91	30	691
	2130	7.61	12.22	1.53	-62.8, 151.0	82	6.50	30	721
	2200	7.59	12.24	1.40	-60.4, 153.4	81	6.54	30	751
	2300	7.69	11.91	1.43	-59.0, 154.8	81	7.29	60	811
	2400	7.63	11.79	1.46	-53.0, 160.8	80	8.26	60	871
12/5/09	0130	7.64	12.13	1.52	-50.1, 163.7	80	8.02	60	931
	0200	7.66	11.63	1.58	-53.0, 160.8	79	8.04	60	991
	0300	7.57	11.91	1.69	-56.8, 157.0	80	7.4	60	1051
	0400	7.56	11.71	1.66	-56.6, 157.2	80	7.22	60	1111
	0500	7.57	11.90	1.64	-47.9, 165.9	79	7.43	60	1171
	0600	7.57	12.09	1.58	-48.3, 262.1	79	6.94	60	1231
	0700	7.57	11.86	1.59	-49.4, 164.4	79	6.26	60	1291
	0800	7.58	9.55	1.50	-42.7, 171.1	79	6.49	60	1351
	0830	7.76	12.05	1.65	-50.2, 163.6	78	7.16	30	1381

[a] Eh (mV) is calculated from a Ag/AgCl saturated KCl electrode filling solution at 5.0ºC, 10.0ºC, 15.0ºC, and 20ºC by adding temperature-sensitive correction factors of 218.6, 213.8, 208.9, and 203.9 mV, respectively.

[b] Sampled immediately following swabbing.

[c] n/r = Not recorded.

Table B-1.3-1
Off-site Analytical Laboratory Analytical Results

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11453	WET_CHEM	pH	7.69	SU	NQ[a]
GW47-09-11453	WET_CHEM	Alkalinity-CO3	0.80	mg/L	U[b]
GW47-09-11453	WET_CHEM	Alkalinity-CO3+HCO3	93.00	mg/L	NQ
GW47-09-11453	METALS	Arsenic	0.00	mg/L	NQ
GW47-09-11453	METALS	Boron	0.02	mg/L	NQ
GW47-09-11453	METALS	Barium	0.00	mg/L	NQ
GW47-09-11453	METALS	Beryllium	0.00	mg/L	U
GW47-09-11453	METALS	Calcium	9.69	mg/L	NQ
GW47-09-11453	METALS	Cadmium	0.00	mg/L	U
GW47-09-11453	METALS	Cobalt	0.00	mg/L	U
GW47-09-11453	METALS	Chromium	0.00	mg/L	NQ
GW47-09-11453	METALS	Cesium	0.00	mg/L	U
GW47-09-11453	METALS	Copper	0.00	mg/L	U
GW47-09-11453	METALS	Iron	0.01	mg/L	U
GW47-09-11453	METALS	Mercury	0.00	mg/L	U
GW47-09-11453	METALS	Potassium	0.34	mg/L	NQ
GW47-09-11453	METALS	Lithium	0.01	mg/L	NQ
GW47-09-11453	METALS	Magnesium	2.57	mg/L	NQ
GW47-09-11453	METALS	Manganese	0.02	mg/L	NQ
GW47-09-11453	METALS	Molybdenum	0.00	mg/L	U
GW47-09-11453	METALS	Sodium	10.94	mg/L	NQ
GW47-09-11453	METALS	Lead	0.00	mg/L	U
GW47-09-11453	METALS	Antimony	0.00	mg/L	U
GW47-09-11453	METALS	Selenium	0.00	mg/L	U
GW47-09-11453	METALS	Silicon Dioxide	64.88	mg/L	NQ
GW47-09-11453	METALS	Tin	0.00	mg/L	U
GW47-09-11453	METALS	Strontium	0.03	mg/L	NQ
GW47-09-11453	METALS	Titanium	0.00	mg/L	U
GW47-09-11453	METALS	Thallium	0.00	mg/L	U
GW47-09-11453	METALS	Uranium	0.00	mg/L	U
GW47-09-11453	METALS	Vanadium	0.00	mg/L	U
GW47-09-11453	METALS	Zinc	0.09	mg/L	NQ
GW47-09-11453	METALS	Silver	0.00	mg/L	U
GW47-09-11453	METALS	Nickel	0.00	mg/L	U
GW47-09-11453	METALS	Aluminum	0.00	mg/L	NQ
GW47-09-11453	ANION	Sulfate	7.33	mg/L	NQ

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11453	ANION	Nitrite	0.00	mg/L	U
GW47-09-11453	ANION	Bromide	0.04	mg/L	NQ
GW47-09-11453	ANION	Oxalate	1.24	mg/L	NQ
GW47-09-11453	ANION	Chloride	4.75	mg/L	NQ
GW47-09-11453	ANION	Perchlorate	0.01	mg/L	U
GW47-09-11453	ANION	Phosphorus, Orthophosphate (Expressed as PO4)	0.01	mg/L	U
GW47-09-11453	ANION	Nitrate	0.35	mg/L	NQ
GW47-09-11453	ANION	Fluoride	0.36	mg/L	NQ
GW47-09-11453	HE	Nitrobenzene	0.33	µg/L	UJ[c]
GW47-09-11453	HE	Nitrotoluene[3-]	0.33	µg/L	UJ
GW47-09-11453	HE	Trinitrobenzene[1,3,5-]	0.33	µg/L	UJ
GW47-09-11453	HE	Dinitrobenzene[1,3-]	0.33	µg/L	UJ
GW47-09-11453	HE	Amino-2,6-dinitrotoluene[4-]	0.33	µg/L	UJ
GW47-09-11453	HE	HMX	0.33	µg/L	UJ
GW47-09-11453	HE	TATB	1.30	µg/L	U
GW47-09-11453	HE	Amino-4,6-dinitrotoluene[2-]	0.33	µg/L	UJ
GW47-09-11453	HE	Tetryl	0.65	µg/L	UJ
GW47-09-11453	HE	Trinitrotoluene[2,4,6-]	0.33	µg/L	UJ
GW47-09-11453	HE	Dinitrotoluene[2,4-]	0.33	µg/L	UJ
GW47-09-11453	HE	RDX	0.33	µg/L	UJ
GW47-09-11453	HE	2,6-Diamino-4-nitrotoluene	1.30	µg/L	U
GW47-09-11453	HE	Dinitrotoluene[2,6-]	0.33	µg/L	UJ
GW47-09-11453	HE	3,5-Dinitroaniline	1.30	µg/L	U
GW47-09-11453	HE	Nitrotoluene[4-]	0.65	µg/L	UJ
GW47-09-11453	HE	Nitrotoluene[2-]	0.33	µg/L	UJ
GW47-09-11453	HE	PETN	1.30	µg/L	UJ
GW47-09-11453	HE	Tris (o-cresyl) phosphate	1.30	µg/L	UJ
GW47-09-11453	HE	2,4-Diamino-6-nitrotoluene	1.30	µg/L	U
GW47-09-11453	VOC	Ethylbenzene	1.00	µg/L	U
GW47-09-11453	VOC	Styrene	1.00	µg/L	U
GW47-09-11453	VOC	Dichloropropene[cis-1,3-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichloropropene[trans-1,3-]	1.00	µg/L	U
GW47-09-11453	VOC	Propylbenzene[1-]	1.00	µg/L	U
GW47-09-11453	VOC	Butylbenzene[n-]	1.00	µg/L	U
GW47-09-11453	VOC	Chlorotoluene[4-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichlorobenzene[1,4-]	1.00	µg/L	U
GW47-09-11453	VOC	Dibromoethane[1,2-]	1.00	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11453	VOC	Acrolein	5.00	µg/L	R[d]
GW47-09-11453	VOC	Chloro-1-propene[3-]	5.00	µg/L	U
GW47-09-11453	VOC	Dichloroethane[1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Propionitrile	5.00	µg/L	R
GW47-09-11453	VOC	Acrylonitrile	5.00	µg/L	U
GW47-09-11453	VOC	Vinyl acetate	5.00	µg/L	UJ
GW47-09-11453	VOC	Methyl-2-pentanone[4-]	5.00	µg/L	U
GW47-09-11453	VOC	Trimethylbenzene[1,3,5-]	1.00	µg/L	U
GW47-09-11453	VOC	Bromobenzene	1.00	µg/L	U
GW47-09-11453	VOC	Toluene	1.00	µg/L	U
GW47-09-11453	VOC	Chlorobenzene	1.00	µg/L	U
GW47-09-11453	VOC	Trichlorobenzene[1,2,4-]	1.00	µg/L	U
GW47-09-11453	VOC	Chlorodibromomethane	1.00	µg/L	U
GW47-09-11453	VOC	Methacrylonitrile	5.00	µg/L	U
GW47-09-11453	VOC	Chloro-1,3-butadiene[2-]	1.00	µg/L	U
GW47-09-11453	VOC	Tetrachloroethene	1.00	µg/L	U
GW47-09-11453	VOC	Butylbenzene[sec-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichloropropane[1,3-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichloroethene[cis-1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichloroethene[trans-1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Methyl tert-Butyl Ether	1.00	µg/L	U
GW47-09-11453	VOC	Dichlorobenzene[1,3-]	1.00	µg/L	U
GW47-09-11453	VOC	Carbon Tetrachloride	1.00	µg/L	U
GW47-09-11453	VOC	Dichloropropene[1,1-]	1.00	µg/L	U
GW47-09-11453	VOC	Hexanone[2-]	5.00	µg/L	U
GW47-09-11453	VOC	Dichloropropane[2,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Diethyl Ether	1.00	µg/L	U
GW47-09-11453	VOC	Acetone	16.60	µg/L	J[e]
GW47-09-11453	VOC	Chloroform	1.00	µg/L	U
GW47-09-11453	VOC	Butanol[1-]	50.00	µg/L	U
GW47-09-11453	VOC	Benzene	1.00	µg/L	U
GW47-09-11453	VOC	Trichloroethane[1,1,1-]	1.00	µg/L	U
GW47-09-11453	VOC	Bromomethane	1.00	µg/L	U
GW47-09-11453	VOC	Chloromethane	1.00	µg/L	U
GW47-09-11453	VOC	Iodomethane	5.00	µg/L	U
GW47-09-11453	VOC	Dibromomethane	1.00	µg/L	U
GW47-09-11453	VOC	Bromochloromethane	1.00	µg/L	U
GW47-09-11453	VOC	Chloroethane	1.00	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11453	VOC	Vinyl Chloride	1.00	µg/L	U
GW47-09-11453	VOC	Acetonitrile	25.00	µg/L	R
GW47-09-11453	VOC	Methylene Chloride	10.00	µg/L	U
GW47-09-11453	VOC	Carbon Disulfide	5.00	µg/L	U
GW47-09-11453	VOC	Bromoform	1.00	µg/L	U
GW47-09-11453	VOC	Bromodichloromethane	1.00	µg/L	U
GW47-09-11453	VOC	Dichloroethane[1,1-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichloroethene[1,1-]	1.00	µg/L	U
GW47-09-11453	VOC	Trichlorofluoromethane	1.00	µg/L	U
GW47-09-11453	VOC	Dichlorodifluoromethane	1.00	µg/L	U
GW47-09-11453	VOC	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5.00	µg/L	U
GW47-09-11453	VOC	Isobutyl alcohol	50.00	µg/L	R
GW47-09-11453	VOC	Dichloropropane[1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Butanone[2-]	5.67	µg/L	NQ
GW47-09-11453	VOC	Trichloroethane[1,1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Trichloroethene	1.00	µg/L	U
GW47-09-11453	VOC	Tetrachloroethane[1,1,2,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Methyl Methacrylate	5.00	µg/L	U
GW47-09-11453	VOC	Trichlorobenzene[1,2,3-]	1.00	µg/L	U
GW47-09-11453	VOC	Hexachlorobutadiene	1.00	µg/L	U
GW47-09-11453	VOC	Naphthalene	0.56	µg/L	J
GW47-09-11453	VOC	Xylene[1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Chlorotoluene[2-]	1.00	µg/L	U
GW47-09-11453	VOC	Dichlorobenzene[1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Trimethylbenzene[1,2,4-]	1.00	µg/L	U
GW47-09-11453	VOC	Dibromo-3-Chloropropane[1,2-]	1.00	µg/L	U
GW47-09-11453	VOC	Trichloropropane[1,2,3-]	1.00	µg/L	U
GW47-09-11453	VOC	Ethyl Methacrylate	5.00	µg/L	U
GW47-09-11453	VOC	Butylbenzene[tert-]	1.00	µg/L	U
GW47-09-11453	VOC	Isopropylbenzene	1.00	µg/L	UJ
GW47-09-11454	WET_CHEM	Alkalinity-CO3	0.80	mg/L	U
GW47-09-11454	WET_CHEM	Alkalinity-CO3+HCO3	65.66	mg/L	NQ
GW47-09-11454	WET_CHEM	pH	7.34	SU	NQ
GW47-09-11454	METALS	Aluminum	0.03	mg/L	NQ
GW47-09-11454	METALS	Arsenic	0.00	mg/L	NQ
GW47-09-11454	METALS	Boron	0.02	mg/L	NQ
GW47-09-11454	METALS	Barium	0.01	mg/L	NQ

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11454	METALS	Beryllium	0.00	mg/L	U
GW47-09-11454	METALS	Calcium	11.67	mg/L	NQ
GW47-09-11454	METALS	Cadmium	0.00	mg/L	U
GW47-09-11454	METALS	Cobalt	0.00	mg/L	U
GW47-09-11454	METALS	Chromium	0.00	mg/L	NQ
GW47-09-11454	METALS	Cesium	0.00	mg/L	U
GW47-09-11454	METALS	Copper	0.00	mg/L	NQ
GW47-09-11454	METALS	Iron	0.12	mg/L	NQ
GW47-09-11454	METALS	Mercury	0.00	mg/L	NQ
GW47-09-11454	METALS	Potassium	1.29	mg/L	NQ
GW47-09-11454	METALS	Lithium	0.09	mg/L	NQ
GW47-09-11454	METALS	Magnesium	2.84	mg/L	NQ
GW47-09-11454	METALS	Manganese	0.36	mg/L	NQ
GW47-09-11454	METALS	Molybdenum	0.01	mg/L	NQ
GW47-09-11454	METALS	Sodium	21.21	mg/L	NQ
GW47-09-11454	METALS	Nickel	0.00	mg/L	NQ
GW47-09-11454	METALS	Lead	0.00	mg/L	U
GW47-09-11454	METALS	Antimony	0.00	mg/L	U
GW47-09-11454	METALS	Selenium	0.00	mg/L	U
GW47-09-11454	METALS	Silicon Dioxide	26.63	mg/L	NQ
GW47-09-11454	METALS	Tin	0.00	mg/L	U
GW47-09-11454	METALS	Strontium	0.03	mg/L	NQ
GW47-09-11454	METALS	Titanium	0.00	mg/L	U
GW47-09-11454	METALS	Thallium	0.00	mg/L	U
GW47-09-11454	METALS	Uranium	0.00	mg/L	NQ
GW47-09-11454	METALS	Vanadium	0.00	mg/L	U
GW47-09-11454	METALS	Zinc	0.01	mg/L	NQ
GW47-09-11454	ANION	Phosphorus, Orthophosphate (Expressed as PO4)	0.06	mg/L	NQ
GW47-09-11454	ANION	Nitrite	0.00	mg/L	U
GW47-09-11454	ANION	Nitrate	0.39	mg/L	NQ
GW47-09-11454	ANION	Fluoride	0.18	mg/L	NQ
GW47-09-11454	ANION	Chloride	3.55	mg/L	NQ
GW47-09-11454	ANION	Perchlorate	0.00	mg/L	U
GW47-09-11454	ANION	Bromide	0.05	mg/L	NQ
GW47-09-11454	ANION	Oxalate	0.01	mg/L	U
GW47-09-11454	ANION	Sulfate	3.76	mg/L	NQ
GW47-09-11454	HE	Nitrobenzene	0.33	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11454	HE	Nitrotoluene[3-]	0.33	µg/L	U
GW47-09-11454	HE	Trinitrobenzene[1,3,5-]	0.33	µg/L	U
GW47-09-11454	HE	Dinitrobenzene[1,3-]	0.33	µg/L	U
GW47-09-11454	HE	Amino-2,6-dinitrotoluene[4-]	0.33	µg/L	U
GW47-09-11454	HE	TATB	1.30	µg/L	U
GW47-09-11454	HE	Amino-4,6-dinitrotoluene[2-]	0.33	µg/L	U
GW47-09-11454	HE	Tetryl	0.65	µg/L	UJ
GW47-09-11454	HE	2,6-Diamino-4-nitrotoluene	1.30	µg/L	U
GW47-09-11454	HE	Trinitrotoluene[2,4,6-]	0.33	µg/L	U
GW47-09-11454	HE	Dinitrotoluene[2,4-]	0.33	µg/L	U
GW47-09-11454	HE	RDX	0.33	µg/L	U
GW47-09-11454	HE	HMX	0.33	µg/L	U
GW47-09-11454	HE	Dinitrotoluene[2,6-]	0.33	µg/L	U
GW47-09-11454	HE	3,5-Dinitroaniline	1.30	µg/L	U
GW47-09-11454	HE	2,4-Diamino-6-nitrotoluene	1.30	µg/L	U
GW47-09-11454	HE	PETN	1.30	µg/L	U
GW47-09-11454	HE	Tris (o-cresyl) phosphate	1.30	µg/L	U
GW47-09-11454	HE	Nitrotoluene[4-]	0.65	µg/L	U
GW47-09-11454	HE	Nitrotoluene[2-]	0.33	µg/L	U
GW47-09-11454	VOC	Ethylbenzene	1.00	µg/L	U
GW47-09-11454	VOC	Styrene	1.00	µg/L	U
GW47-09-11454	VOC	Dichloropropene[cis-1,3-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichloropropene[trans-1,3-]	1.00	µg/L	U
GW47-09-11454	VOC	Propylbenzene[1-]	1.00	µg/L	U
GW47-09-11454	VOC	Butylbenzene[n-]	1.00	µg/L	U
GW47-09-11454	VOC	Chlorotoluene[4-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichlorobenzene[1,4-]	1.00	µg/L	U
GW47-09-11454	VOC	Dibromoethane[1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Acrolein	5.00	µg/L	R
GW47-09-11454	VOC	Chloro-1-propene[3-]	5.00	µg/L	U
GW47-09-11454	VOC	Dichloroethane[1,2-]	1.00	µg/L	UJ
GW47-09-11454	VOC	Propionitrile	5.00	µg/L	R
GW47-09-11454	VOC	Acrylonitrile	5.00	µg/L	U
GW47-09-11454	VOC	Vinyl acetate	5.00	µg/L	U
GW47-09-11454	VOC	Methyl-2-pentanone[4-]	5.00	µg/L	U
GW47-09-11454	VOC	Trimethylbenzene[1,3,5-]	1.00	µg/L	U
GW47-09-11454	VOC	Bromobenzene	1.00	µg/L	U
GW47-09-11454	VOC	Toluene	1.00	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11454	VOC	Chlorobenzene	1.00	µg/L	U
GW47-09-11454	VOC	Trichlorobenzene[1,2,4-]	1.00	µg/L	U
GW47-09-11454	VOC	Chlorodibromomethane	1.00	µg/L	U
GW47-09-11454	VOC	Methacrylonitrile	5.00	µg/L	U
GW47-09-11454	VOC	Chloro-1,3-butadiene[2-]	1.00	µg/L	U
GW47-09-11454	VOC	Tetrachloroethene	1.00	µg/L	U
GW47-09-11454	VOC	Butylbenzene[sec-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichloropropane[1,3-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichloroethene[cis-1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichloroethene[trans-1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Methyl tert-Butyl Ether	1.00	µg/L	U
GW47-09-11454	VOC	Dichlorobenzene[1,3-]	1.00	µg/L	U
GW47-09-11454	VOC	Carbon Tetrachloride	1.00	µg/L	U
GW47-09-11454	VOC	Dichloropropene[1,1-]	1.00	µg/L	U
GW47-09-11454	VOC	Hexanone[2-]	5.00	µg/L	UJ
GW47-09-11454	VOC	Dichloropropane[2,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Diethyl Ether	1.00	µg/L	U
GW47-09-11454	VOC	Tetrachloroethane[1,1,1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Acetone	10.00	µg/L	UJ
GW47-09-11454	VOC	Chloroform	1.00	µg/L	U
GW47-09-11454	VOC	Butanol[1-]	50.00	µg/L	R
GW47-09-11454	VOC	Benzene	1.00	µg/L	U
GW47-09-11454	VOC	Trichloroethane[1,1,1-]	1.00	µg/L	U
GW47-09-11454	VOC	Bromomethane	1.00	µg/L	U
GW47-09-11454	VOC	Chloromethane	1.00	µg/L	U
GW47-09-11454	VOC	Iodomethane	5.00	µg/L	U
GW47-09-11454	VOC	Dibromomethane	1.00	µg/L	UJ
GW47-09-11454	VOC	Bromochloromethane	1.00	µg/L	UJ
GW47-09-11454	VOC	Chloroethane	1.00	µg/L	U
GW47-09-11454	VOC	Vinyl Chloride	1.00	µg/L	U
GW47-09-11454	VOC	Acetonitrile	25.00	µg/L	R
GW47-09-11454	VOC	Methylene Chloride	10.00	µg/L	U
GW47-09-11454	VOC	Carbon Disulfide	5.00	µg/L	U
GW47-09-11454	VOC	Bromoform	1.00	µg/L	U
GW47-09-11454	VOC	Bromodichloromethane	1.00	µg/L	U
GW47-09-11454	VOC	Dichloroethane[1,1-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichloroethene[1,1-]	1.00	µg/L	U
GW47-09-11454	VOC	Trichlorofluoromethane	1.00	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-09-11454	VOC	Dichlorodifluoromethane	1.00	µg/L	UJ
GW47-09-11454	VOC	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5.00	µg/L	U
GW47-09-11454	VOC	Isobutyl alcohol	50.00	µg/L	R
GW47-09-11454	VOC	Dichloropropane[1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Butanone[2-]	5.00	µg/L	UJ
GW47-09-11454	VOC	Trichloroethane[1,1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Trichloroethene	1.00	µg/L	U
GW47-09-11454	VOC	Tetrachloroethane[1,1,2,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Methyl Methacrylate	1.88	µg/L	U
GW47-09-11454	VOC	Trichlorobenzene[1,2,3-]	1.00	µg/L	U
GW47-09-11454	VOC	Hexachlorobutadiene	1.00	µg/L	U
GW47-09-11454	VOC	Naphthalene	1.00	µg/L	U
GW47-09-11454	VOC	Xylene[1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Chlorotoluene[2-]	1.00	µg/L	U
GW47-09-11454	VOC	Dichlorobenzene[1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Trimethylbenzene[1,2,4-]	1.00	µg/L	U
GW47-09-11454	VOC	Dibromo-3-Chloropropane[1,2-]	1.00	µg/L	U
GW47-09-11454	VOC	Trichloropropane[1,2,3-]	1.00	µg/L	U
GW47-09-11454	VOC	Ethyl Methacrylate	5.00	µg/L	U
GW47-09-11454	VOC	Butylbenzene[tert-]	1.00	µg/L	U
GW47-09-11454	VOC	Isopropylbenzene	1.00	µg/L	U
GW47-09-11454	VOC	Isopropyltoluene[4-]	1.00	µg/L	U
GW47-09-11454	VOC	Xylene[1,3-]+Xylene[1,4-]	2.00	µg/L	U
GW47-10-1975	WET_CHEM	Alkalinity-CO3	13.37	mg/L	NQ
GW47-10-1975	WET_CHEM	Alkalinity-CO3+HCO3	187.00	mg/L	NQ
GW47-10-1975	WET_CHEM	Total Organic Carbon	12.27	mg/L	NQ
GW47-10-1975	WET_CHEM	pH	8.97	SU	NQ
GW47-10-1975	METALS	Arsenic	0.00	mg/L	NQ
GW47-10-1975	METALS	Boron	0.06	mg/L	NQ
GW47-10-1975	METALS	Barium	0.03	mg/L	NQ
GW47-10-1975	METALS	Beryllium	0.00	mg/L	U
GW47-10-1975	METALS	Silver	0.00	mg/L	U
GW47-10-1975	METALS	Aluminum	67.58	mg/L	NQ
GW47-10-1975	METALS	Calcium	5.98	mg/L	NQ
GW47-10-1975	METALS	Cadmium	0.00	mg/L	NQ
GW47-10-1975	METALS	Cobalt	0.00	mg/L	NQ
GW47-10-1975	METALS	Chromium	0.00	mg/L	NQ

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analyte Description	Lab Result	Units	Validation Qualifier Code
GW47-10-1975	METALS	Cesium	0.00	mg/L	U
GW47-10-1975	METALS	Copper	0.01	mg/L	NQ
GW47-10-1975	METALS	Iron	27.90	mg/L	NQ
GW47-10-1975	METALS	Mercury	0.00	mg/L	NQ
GW47-10-1975	METALS	Potassium	1.70	mg/L	NQ
GW47-10-1975	METALS	Lithium	0.11	mg/L	NQ
GW47-10-1975	METALS	Magnesium	15.42	mg/L	NQ
GW47-10-1975	METALS	Manganese	0.34	mg/L	NQ
GW47-10-1975	METALS	Molybdenum	0.01	mg/L	NQ
GW47-10-1975	METALS	Sodium	157.15	mg/L	NQ
GW47-10-1975	METALS	Nickel	0.01	mg/L	NQ
GW47-10-1975	METALS	Lead	0.01	mg/L	NQ
GW47-10-1975	METALS	Antimony	0.00	mg/L	U
GW47-10-1975	METALS	Selenium	0.00	mg/L	NQ
GW47-10-1975	METALS	Silicon Dioxide	1235.88	mg/L	NQ
GW47-10-1975	METALS	Tin	0.01	mg/L	NQ
GW47-10-1975	METALS	Strontium	0.07	mg/L	NQ
GW47-10-1975	METALS	Titanium	0.57	mg/L	NQ
GW47-10-1975	METALS	Thallium	0.00	mg/L	U
GW47-10-1975	METALS	Uranium	0.00	mg/L	NQ
GW47-10-1975	METALS	Zinc	0.06	mg/L	NQ
GW47-10-1975	METALS	Vanadium	0.00	mg/L	NQ
GW47-10-1975	ANION	Chloride	6.65	mg/L	NQ
GW47-10-1975	ANION	Perchlorate	0.01	mg/L	U
GW47-10-1975	ANION	Bromide	0.01	mg/L	U
GW47-10-1975	ANION	Fluoride	0.36	mg/L	NQ
GW47-10-1975	ANION	Sulfate	167.00	mg/L	NQ
GW47-10-1975	ANION	Phosphorus, Orthophosphate (Expressed as PO4)	0.01	mg/L	U
GW47-10-1975	ANION	Nitrite	0.15	mg/L	NQ
GW47-10-1975	ANION	Nitrate	0.90	mg/L	NQ
GW47-10-1975	ANION	Oxalate	0.01	mg/L	U

[a] NQ = no qualifiers were applied during validation; data are not useable.

[b] U = the analyte was analyzed for but not detected.

[c] UJ = the analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.

[d] R = the data are rejected as a result of major problems with quality assurance/quality control parameters.

[e] J = the analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.

Table B-1.3-2
Analytical Results for Groundwater-Screening Samples for R-47i

Sample ID	Date Received	Sample Type	Depth (ft)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)	Br(-) (ppm)	Br(-) (U)	TOC rslt (ppm)	C rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl(-) (ppm)	ClO4(-) (ppm)	ClO4(-) (U)	Co rslt (ppm)	stdev (Co)	Alk-CO3 rslt (ppm)
GW47-09-11454	8/12/2009	Borehole	910	0.001	U	0.004	0.000	0.0004	0.0000	0.018	0.000	0.003	0.000	0.001	U	0.05	0.01	NA	9.69	0.04	0.001	U	3.55	0.005	U	0.001	U	0
GW47-09-11453	8/17/2009	Borehole	1025	0.001	U	0.028	0.000	0.0002	0.0000	0.024	0.000	0.007	0.000	0.001	U	0.04	0.01	NA	11.67	0.02	0.001	U	4.75	0.002	U	0.001	U	0
GW47-10-1975	10/15/2009	Bentonite Screening Sample	1272	0.001	U	68	19	0.0011	0.0001	0.059	0.001	0.030	0.000	0.001	U	0.01	U	12.30	5.98	0.01	0.002	0.000	6.65	0.005	U	0.002	0.000	13

Note: U = Not detected; NA = Not analyzed.

Table B-1.3-2
Analytical Results for Groundwater-Screening Samples for R-47i

Sample ID	Date Received	Sample Type	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F(-) (ppm)	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)
GW47-09-11454	8/12/2009	Borehole	U	0.001	0.000	0.001	U	0.001	U	0.18	0.01	U	65.7	0.00005	U	0.34	0.00	0.010	0.000	2.57	0.01	0.017	0.000	0.001	U	10.94
GW47-09-11453	8/17/2009	Borehole	U	0.003	0.000	0.001	U	0.002	0.000	0.36	0.12	0.00	93.0	0.00021	0.00001	1.29	0.01	0.086	0.009	2.84	0.02	0.356	0.002	0.013	0.001	21.21
GW47-10-1975	10/15/2009	Bentonite Screening Sample	0.8	0.004	0.000	0.001	U	0.006	0.000	0.36	27.90	2.82	187.0	0.00007	0.00000	1.70	0.02	0.106	0.000	15.42	0.07	0.335	0.003	0.007	0.000	157.15

Note: U = Not detected; NA = Not analyzed.

Table B-1.3-2
Analytical Results for Groundwater-Screening Samples for R-47i

Sample ID	Date Received	Sample Type	stdev (Na)	Ni rslt (ppm)	stdev (Ni)	NO2 (ppm)	NO2-N rslt	NO2-N (U)	NO3 (ppm)	NO3-N rslt	C2O4 rslt (ppm)	C2O4 (U)	Pb rslt (ppm)	stdev (Pb)	pH	PO4(-3) rslt (ppm)	PO4(-3) (U)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)	Si rslt (ppm)	stdev (Si)	SiO2 rslt (ppm)	stdev (SiO2)
GW47-09-11454	8/12/2009	Borehole	0.08	0.001	U	0.01	0.00	U	1.74	0.39	0.01	U	0.0002	U	7.34	0.06	0.01	0.001	U	0.001	U	0.001	U	30.32	0.17	64.88	0.37
GW47-09-11453	8/17/2009	Borehole	0.06	0.004	0.000	0.01	0.00	U	1.53	0.35	1.24		0.0002	U	7.69	0.01	U	0.002	0.000	0.001	U	0.001	U	12.45	0.10	26.63	0.22
GW47-10-1975	10/15/2009	Bentonite Screening Sample	1.23	0.006	0.000	0.49	0.15	0.01	3.98	0.90	0.01	U	0.0108	0.0004	8.97	0.01	U	0.004	0.000	0.001	U	0.001	0.000	577.52	89.29	1235.88	191.08

Note: U = Not detected; NA = Not analyzed.

Table B-1.3-2
Analytical Results for Groundwater-Screening Samples for R-47i

Sample ID	Date Received	Sample Type	Sn rslt (ppm)	stdev (Sn)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
GW47-09-11454	8/12/2009	Borehole	0.001	U	3.76	0.033	0.000	0.001	U	0.002	U	0.001	U	0.0002	U	0.001	U	0.092	0.011	164	1.19	1.29	-0.04
GW47-09-11453	8/17/2009	Borehole	0.001	U	7.33	0.031	0.000	0.001	U	0.002	U	0.001	U	0.0002	0.0000	0.001	U	0.010	0.000	171	1.80	1.86	-0.02
GW47-10-1975	10/15/2009	Bentonite Screening Sample	0.006	0.000	167.00	0.073	0.000	0.003	0.000	0.571	0.006	0.001	U	0.0024	0.0001	0.004	0.000	0.058	0.001	1892	8.46	8.40	0.36

Note: U = Not detected; NA = Not analyzed.

Table B-1.3-3
Total Organic Carbon Concentrations from Well Development Samples

Sample ID	Date Received	Sample Type	Depth (ft)	TOC rslt (ppm)
GW47-10-6940	11/20/2009	Development	840.0–860.6	3.17
GW47-10-6941	11/20/2009	Development	840.0–860.6	3.46
GW47-10-6942	11/23/2009	Development	840.0–860.6	1.14
GW47-10-6943	11/24/2009	Development	840.0–860.6	1.72
GW47-10-6944	11/24/2009	Development	840.0–860.6	0.95

Appendix C

Borehole Video Logging
(on DVDs included with this document)

Appendix D

Geophysical Logs and
Schlumberger Geophysical Logging Report
(on CD included with this document)

Appendix E

Aquifer Testing Report

E-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted at R-47i, an intermediate-zone well located at (Technical Area) TA-14. The tests on R-47i were conducted to evaluate the hydraulic properties of the saturated perched zone in which the well is completed.

Testing consisted of brief trial pumping of R-47i, background water level data collection, and a 24-h constant-rate pumping test. Unlike most of the R-well pumping tests conducted on the plateau, an inflatable packer system was not used in R-47i to try to eliminate storage effects on the test data. The filter pack and transition sand collar extended to within a few feet of the static water level. As such, dewatering of the annular sand backfill materials was inevitable during testing. Thus, storage effects would have occurred regardless of whether or not a packer was employed.

Conceptual Hydrogeology

Well R-47i extends into the top of the Puye Formation. The well was completed with 20.6 ft of 5-inch stainless steel well screen from 840 to 860.6 ft below ground surface (bgs). The static water level measured on December 1, 2009, was above the top of the well screen, at 829.88 ft bgs. Based on an estimated land surface elevation of 7350 ft above mean sea level (amsl), the perched water table at an was at an elevation of about 6520 ft amsl.

Based on observations made during drilling, the perching layer was estimated to be at a depth of around 865 ft bgs. Thus, the saturated thickness of the penetrated perched zone was about 35 ft. For the purposes of analytical calculation in this report, the saturated zone was assumed to be unconfined.

R-47i Testing

Well R-47i was tested from December 1 to 6, 2009. After the drop pipe was filled on December 1, testing consisted of brief trial pumping on December 2, background data collection, and a 24-h constant-rate pumping test that was begun on December 4.

Three trial tests were conducted on December 2. Trial 1 was conducted at multiple discharge rates ranging from 0.5 to 0.71 gpm for 60 min from 8:00 to 9:00 a.m. and was followed by 60 min of recovery until 10:00 a.m.

Trial 2 was conducted for 60 min from 10:00 to 11:00 a.m. The initial discharge rate was 1.03 gpm but declined to 0.91 gpm. It was subsequently adjusted manually back to 1.03 gpm. Following shutdown, recovery data were recorded for 200 min until 2:20 p.m.

Trial 3 was conducted for 120 min from 2:20 p.m. to 4:20 p.m. The initial discharge rate was 1.35 gpm, declining to 1.11 gpm. Following shut down, recovery/background data were recorded for 2410 minutes until 8:30 a.m. on December 4.

At 8:30 a.m. on December 4, the 24-h pumping test was begun at a rate of 1.1 gpm. After a brief time, the rate declined to 0.92 gpm for the remainder of the test. Pumping continued until 8:30 a.m. on December 5. Following shutdown, recovery measurements were recorded for 1449 min until 8:39 a.m. on December 6 when the pump was tripped out of the well.

The consistent declines in discharge rate observed in all of the tests were an artifact of operating the pump at low rates–all near 1 gpm. At such low rates, the pump operated on an exceedingly flat portion of the pump curve where small increases in pumping head (drawdown) over time caused noticeable declines in discharge rate.

E-2.0 BACKGROUND DATA

The background water-level data collected in conjunction with running the pumping tests allow the analyst to see what water-level fluctuations occur naturally in the aquifer and to 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 to barometric pressure data from the area to determine if a correlation existed.

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

Subsequent pumping tests, including R-47i, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When 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 units by the barometric pressure change. However, if a nonvented transducer is used, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency and in the same direction as the barometric pressure change rather than in the opposite direction.

Barometric pressure data were obtained from TA-54 tower site from the Waste and Environmental Services Division–Environmental Data and Analysis (WES-EDA). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is approximately 7350 ft amsl. The static water level in R-47i was 829.88 ft below land surface, making the calculated water-table elevation roughly 6520 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-47i.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{R-47i} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-47i}}{T_{WELL}} \right) \right] \qquad \textbf{Equation E-1}$$

Where P_{WT} = barometric pressure at the water table inside R-47i

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

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

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

$E_{R\text{-}47i}$ = land surface elevation at R-47i site, in feet (7350 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-47i, in feet (6520 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 28.3 degrees Fahrenheit, or 271.1 degrees Kelvin)

T_{WELL} = air temperature inside R-47i, in degrees Kelvin (assigned a value of 54.2 degrees Fahrenheit, or 285.5 degrees Kelvin)

This formula is an adaptation of an equation WES-EDA 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 to the water-level hydrograph to discern the correlation between the two.

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 when 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-2

Where t_c = duration of casing storage effect, in minutes

D = inside diameter of well casing, in inches

d = outside diameter of column pipe, in inches

Q = discharge rate, in gallons per minute

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

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

For wells screened across the water table, there can be an additional storage contribution from the filter pack around the screen. 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-3

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

D_B = diameter of borehole, in inches

D_C = outside diameter of well casing, in inches

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

For wells where the water level lies above the screen and filter pack initially, but is pulled down into the filter pack during pumping, the storage duration must be calculated using a weighted average of both Equations E-2 and E-3 as a function of the fraction of the dewatered length that includes filter pack.

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. While this option has been implemented for the R-well testing program in general, it was not applied to the R-47i pumping test because inevitable dewatering of the filter pack would have negated the effects of the inflatable packer.

Calculations for the R-47i tests yielded estimated storage durations of several hours. This meant that the brief data from the short trial tests could not be analyzed. Analysis was therefore restricted to the long recovery period following trial 3 and the 24-h pumping and recovery data sets.

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-4

Where,

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

Equation E-5

and

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

Equation E-6

and where s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

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

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

Equation E-7

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

Equation E-8

Where T = transmissivity, in gallons per day per foot

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

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

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

Equation E-9

The Cooper–Jacob equation is a simplified approximation of the Theis equation and is valid whenever the u value is less than about 0.05. For small radius values (e.g., corresponding to borehole radii), u is less than 0.05 at very early pumping times and therefore is less than 0.05 for most or all measured drawdown values. Thus, for the pumped well, the Cooper–Jacob equation usually can be considered a valid approximation of the Theis equation.

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-10

Where T = transmissivity, in gallons per day per foot

Q = discharge rate, in gallons per minute

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

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

Equation E-11

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

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

b = aquifer thickness

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

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

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

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

K_z = vertical hydraulic conductivity

K_r = horizontal hydraulic conductivity

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

$$\beta = \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b} \qquad \textbf{Equation E-12}$$

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

E-5.0 RECOVERY METHODS

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

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

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

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

E-6.0 UNCONFINED AQUIFER DRAWDOWN CORRECTION

For unconfined aquifers, the saturated aquifer thickness is reduced below the original thickness during testing. This results in drawdown values that deviate from theoretical predictions, because well hydraulics formulas are based on 100% aquifer saturation. Prior to analysis, the actual drawdown values must be corrected for dewatering effects using the following formula (Kruseman et al. 1991, 106681):

$$s_c = s_a - \frac{s_a^2}{2b} \qquad \textbf{Equation E-14}$$

Where s_c = corrected drawdown, in ft

S_a = observed drawdown, in ft

b = saturated aquifer thickness, in ft

Assumptions required for validity of Equation E-16 are (1) homogeneous hydraulic conductivity, (2) full penetration of the producing zone by the well screen, and (3) no head loss associated with vertical flow. This last assumption is satisfied by one of two extremes: either zero permeability in the vertical direction so there is no flow (and therefore no head loss) vertically or infinite vertical permeability. Failure to meet any of these three assumptions leads to modest errors in application of the drawdown correction equation.

R-47i exhibited aspects of both partial penetration and dewatering. For pumping water levels above the top of the well screen, it was likely that partial penetration effects would have been dominant and that dewatering effects would have been relatively less important. For pumping water levels within the well screen, however, it was likely that the dewatering correction would more closely describe the hydraulic performance.

E-7.0 SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas that are based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is unknown, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

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

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

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

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

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

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

To apply this procedure, a storage coefficient value must be assigned. Unconfined conditions were assumed for R-47i. Storage coefficient values for unconfined conditions can be expected to range from about 0.01 to 0.25 (Driscoll 1986, 104226). Values of 0.01 and 0.10 were used for the R-47i calculations. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate of the storage coefficient is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. For the purposes of this exercise, the saturated thickness was assumed to extend from the static water level at about 830 ft to the top of the identified perching layer at 865 ft—a total thickness of 35 ft.

E-8.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-47i tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure E-8.0-1 shows aquifer pressure data from R-47i 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-47i data are referred to in the figure as the “apparent hydrograph” because the measurements reflect the sum of water pressure and barometric pressure, having been recorded using a nonvented pressure transducer. The times of the pumping periods for the R-47i pumping tests are included on the figure for reference.

There were a few notable observations regarding the apparent hydrograph. First, the data trace did not reflect the changes in barometric pressure. This suggested a barometric efficiency near 100%. Indeed, subsequent data collected with the permanently installed vented transducer (not included here) showed a hydrograph nearly coincident with the barometric pressure signature, confirming the high barometric efficiency.

The subsequent data set also showed an overall background increase in water level over time, probably a water level rebound following substantial loss of water from the perched zone during drilling and well completion. Hints of this effect can be seen in the background data collected December 3 and 4. During this period, the ongoing recovery from the three previous trial tests, which would have been expected to show a steady flattening, instead showed a slight inflection and then increasing slope on December 4. From Figure E-8.0-1, it was not clear whether this effect was a delayed barometric effect of some kind or a steadily rising water table. However, the subsequent data collected with the permanent transducer suggested that it was caused by the background water level rise.

Finally, the recovery following the 24-h pumping test fell short of the previous recovery levels. This was likely a result of the greater duration of pumping preceding the recovery event.

The limited data set shown on Figure E-8.0-1 was insufficient to support calculation of the exact barometric efficiency. This parameter can be determined readily from the ongoing hourly data that will be collected from R-47i using the permanently installed transducer. The limited data set did imply, however, a high barometric efficiency.

E-9.0 WELL R-47i DATA ANALYSIS

This section presents the data obtained from the R-47i pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for trials 1, 2 and 3, as well as the 24-h constant-rate pumping test.

E-9.1 Well R-47i Trial 1

Figure E-9.1-1 shows a semilog plot of the drawdown data collected from trial 1. As indicated on the graph, the discharge rate was 0.5 gpm initially and was adjusted to 0.71 gpm after a few minutes. The test duration of 60 min was far less than the estimated casing storage duration of several hours and, thus, an analysis of the drawdown trace was not performed.

Figure E-9.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. As with the pumping data, the entire recovery data set was storage affected and not analyzed.

E-9.2 Well R-47i Trial 2

Figure E-9.2-1 shows a semilog plot of the drawdown data collected from trial 2. As indicated on the graph, the discharge rate was 1.03 gpm initially, declining to 0.91 gpm after several minutes. The decline in yield reflected the relationship between pump performance and increasing drawdown and pumping lift. At low discharge rates, the pumping rate is highly sensitive to slight changes in pumping lift. Toward the end of the test, the rate was manually adjusted back to the initial rate of 1.03 gpm. The test duration of 60 min was far less than the estimated casing storage duration of several hours and, thus, an analysis of the drawdown trace was not performed.

Figure E-9.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. As with the pumping data, the entire recovery data set was storage affected and not analyzed.

E-9.3 Well R-47i Trial 3

Figure E-9.3-1 shows a semilog plot of the drawdown data collected from trial 3. As indicated on the graph, the discharge rate was 1.35 gpm initially, declining to 1.11 gpm during the test. Again, the decline in yield reflected the relationship between pump performance and increasing drawdown and pumping lift. The test duration of 120 min was less than the estimated casing storage duration of several hours and, thus, an analysis of the drawdown trace was not performed.

Figure E-9.3-2 shows the recovery data collected following shutdown of the trial 3 pumping test. The times corresponding to casing storage duration are shown on the graph for reference.

Figure E-9.3-3 shows an expanded-scale plot of the recovery data. The late data produced an estimated transmissivity value of 50 gpd/ft. Based on a saturated thickness of 35 ft, the hydraulic conductivity was 1.4 gpd/ft, or 0.19 ft/d.

The data trace on which the analysis was based showed an unusual concave downward shape, flattening steadily over time. This was probably related to hysteretic effects associated with a reduced storage coefficient during early recovery (Bevan et al. 2005, 105186).

E-9.4 Well R-47i 24-H Constant-Rate Pumping Test

Figure E-9.4-1 shows a semilog plot of the drawdown data collected during the 24-h pumping test. The initial pumping rate was 1.1 gpm, declining to 0.92 gpm for most of the test.

Within a couple hours of starting the pump (prior to the cessation of casing storage effects), the pumping water level reached the well screen (at a drawdown of about 10 ft). At this point, partial penetration of the saturated formation became largely irrelevant and it was presumed that dewatering effects controlled the data response rather than partial penetration. Therefore, the drawdown data were corrected for dewatering effects using Equation E-14.

The corrected data yielded a formation transmissivity of 57 gpd/ft. Based on a saturated thickness of 35 ft, this implied a hydraulic conductivity of 1.6 gpd/ft, or 0.22 ft/d. The slope of the poststorage corrected data trace remained constant throughout the pumping test, implying uniform conditions throughout the zone of influence of pumping (i.e., no nearby boundaries or striking permeability changes).

Figure E-9.4-2 shows the recovery data collected following shutdown of the 24-h pumping test. The times corresponding to casing storage duration are shown on the graph for reference.

Figure E-9.4-3 shows an expanded-scale plot of the recovery data. The late data produced an estimated transmissivity value of 59 gpd/ft. The assumed saturated thickness of 35 ft implied a hydraulic conductivity of 1.7 gpd/ft, or 0.23 ft/d.

The data trace on which the analysis was based showed the same unusual concave downward shape observed following trial 3—this time with extreme flattening at late time. Again, this effect was probably related to hysteretic effects associated with a reduced storage coefficient during early recovery followed by a gradually increasing storage coefficient at late recovery time.

E-9.5 Well R-47i Specific Capacity Data

Because R-47i was pumped at several discharge rates, a comparison was made of the specific capacity values obtained at the various rates. To achieve a valid comparison, data were selected for the same pumping time from each test. A pumping time of 40 min was chosen because the pumping rates were fairly stable around that time for each of the tests.

Table E-9.5-1 shows the measured discharge rates and drawdown values for each of the tests after 40 min of pumping. In each case, the drawdown was less than 10 ft—the distance from the static water level to the top of the well screen. Because of this, it was presumed that partial penetration, rather than dewatering effects, would have constrained well performance and, therefore, a dewatering correction was not applied.

The computed specific capacity values showed some inconsistency and variation. This was probably attributable to the different antecedent pumping rate patterns that occurred during the first 40 min of pumping in each of the tests. Nevertheless, there was not a consistent decline in specific capacity with increasing pumping rate as would be expected if significant turbulent flow were present. This implied a preponderance of laminar flow at all discharge rates.

Late-time specific capacity data were used along with well geometry to estimate a lower-bound transmissivity value for the permeable zone penetrated by R-47i. This was done to provide a frame of reference for evaluating the foregoing analyses.

During the 24-h pumping test, the discharge rate of 0.92 gpm was maintained for 1440 min. The measured drawdown at this rate was 17.5 ft—about 7.5 ft below the top of the screen. The observed drawdown was corrected for dewatering effects using Equation E-14, yielding a corrected drawdown of 13.1 ft and a corrected specific capacity of 0.07 gpm/ft. In addition to specific capacity and pumping time, other input values used in the calculations included storage coefficient values of 0.01 and 0.10 and a borehole radius of 0.71 ft.

Applying the Brons and Marting method to these inputs for fully penetrating conditions yielded lower-bound transmissivity values of 67 and 45 gpd/ft for storage coefficient values of 0.01 and 0.10, respectively. Accounting separately for slight remaining partial penetration effects (associated with the bottom of the screen [860.6 ft bgs] lying 4.4 ft above the bottom of the aquifer [865 ft bgs]) raised the values slightly to 71 and 50 gpd/ft, respectively. These ranges were consistent with the values obtained from the pumping test analyses (50 to 59 gpd/ft), supporting the analytical results and implying a good well efficiency.

(Note: Technically, it is not valid to apply a dewatering correction and a subsequent partial penetration correction. The actual combined effect of dewatering and partial penetration is more complicated. Nevertheless, the computations suggested that ignoring the slight partial penetration effect associated with the bottom of the well screen lying above the base of the perched interval had only a minimal effect on the lower-bound transmissivity estimates. Further, the filter pack in R-47i extends to the base of the perched unit and thus provides a conduit for flow from the bottom saturated sediments. Therefore, from a practical standpoint, treating the well as penetrating to the base of the aquifer was considered to be a valid representation.)

E-10.0 SUMMARY

Constant-rate pumping tests were conducted on R-47i. The tests were performed to gain an understanding of the hydraulic characteristics of the saturated perched zone penetrated by the R-47i well screen. Numerous observations and conclusions were drawn for the tests as summarized below.

A comparison of barometric pressure and R-47i water level data suggested a barometric efficiency near 100%. The duration of data collection was insufficient to quantify the barometric efficiency and any possible lag time, although the ongoing hourly data collected using the permanent transducer will provide the information required for this.

The filter sand and fine sand collar extended above the well screen to within about two ft of the static water level. This meant that dewatering of the filter pack was inevitable at any viable discharge rate and that storage effects would occur during the test. Therefore, implementation of an inflatable packer to eliminate storage effects would have been futile and was not pursued.

The estimated saturated thickness of permeable sediments was about 35 ft – the distance between the static water level of 829.88 ft bgs and the observed top of the perching layer at approximately 865 ft bgs.

The transmissivity values computed from the tests ranged from 50 to 59 gpd/ft, averaging 55 gpd/ft. Based on the assumed saturated thickness of 35 ft, the average hydraulic conductivity computed to 1.6 gpd/ft^2, or 0.21 ft/d.

The flow regime was essentially laminar at all test rates.

R-47i produced 0.92 gpm with 17.5 ft of drawdown after 1440 min of pumping, resulting in a specific capacity of 0.053 gpm/ft and a corrected specific capacity of 0.70 gpm/ft. The corresponding computed lower-bound transmissivity values [for assumed fully penetrating conditions] ranged from 45 to 67 gpd/ft – similar to the pumping test values. This helped to corroborate the analytical results and suggested a fairly high well efficiency.

The test data suggested uniform conditions within the zone of influence of the test with no evidence of boundaries or large lateral changes in permeability.

E-11.0 REFERENCES

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

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

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Bradbury, K.R., and E.R. Rothschild, March-April 1985. "A Computerized Technique for Estimating the Hydraulic Conductivity of Aquifers from Specific Capacity Data," *Ground Water,* Vol. 23, No. 2, pp. 240-246. (Bradbury and Rothschild 1985, 098234)

Brons, F., and V.E. Marting, 1961. "The Effect of Restricted Fluid Entry on Well Productivity," *Journal of Petroleum Technology,* Vol. 13, No. 2, pp. 172-174. (Brons and Marting 1961, 098235)

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Hantush, M.S., September 1961. "Aquifer Tests on Partially Penetrating Wells," Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, pp. 171–195. (Hantush 1961, 106003)

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Schafer, D.C., January-February 1978. "Casing Storage Can Affect Pumping Test Data," *The Johnson Drillers Journal,* pp. 1-6, Johnson Division, UOP, Inc., St. Paul, Minnesota. (Schafer 1978, 098240)

Theis, C.V., 1934-1935. "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage," *American Geophysical Union Transactions,* Vol. 15-16, pp. 519-524. (Theis 1934-1935, 098241)

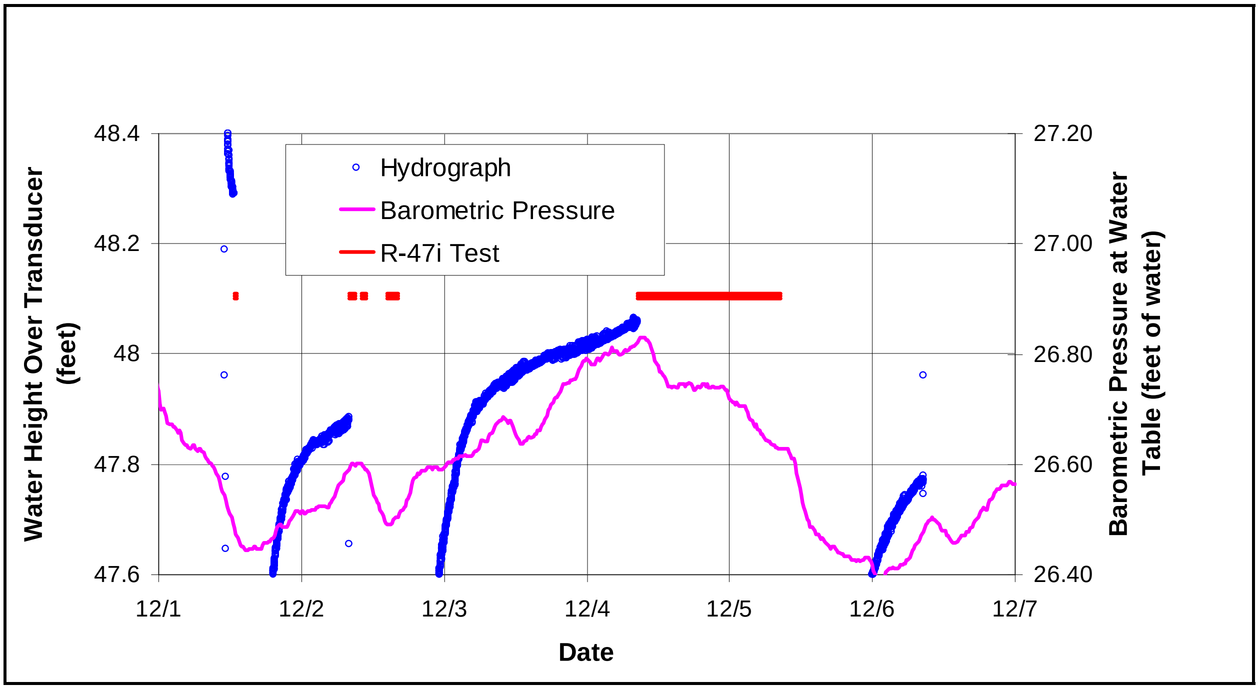


Figure E-8.0-1 Well R-47i apparent hydrograph

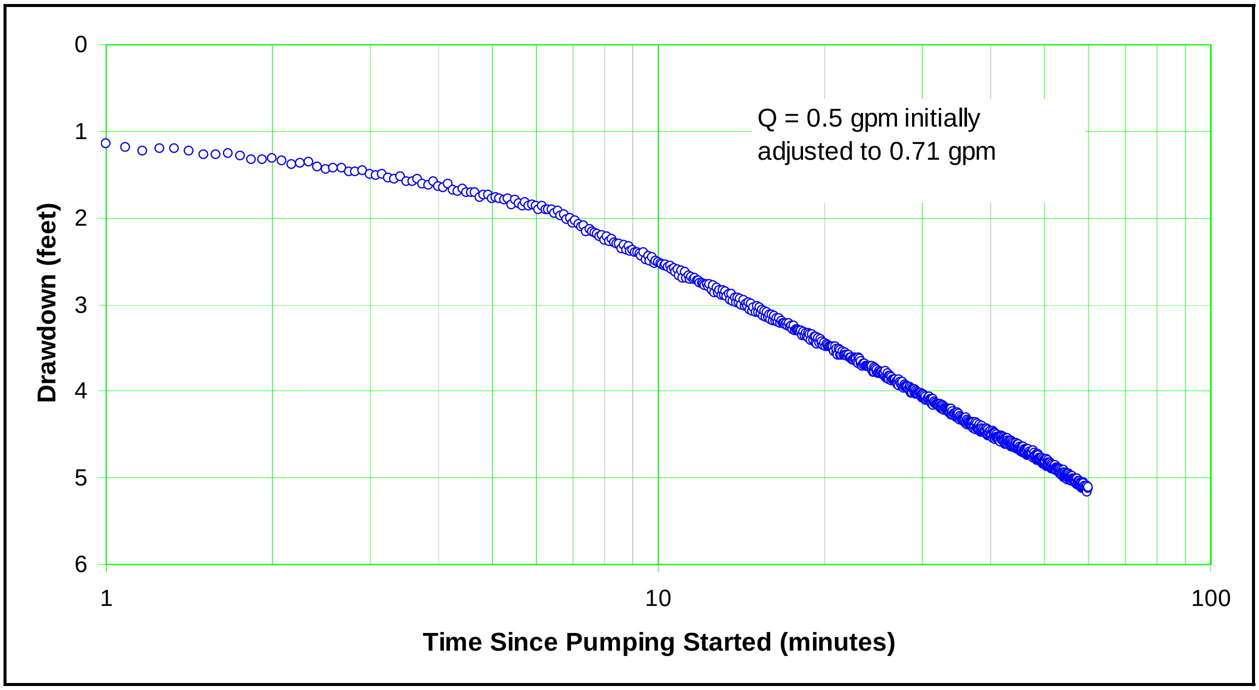


Figure E-9.1-1 Well R-47i trial 1 drawdown

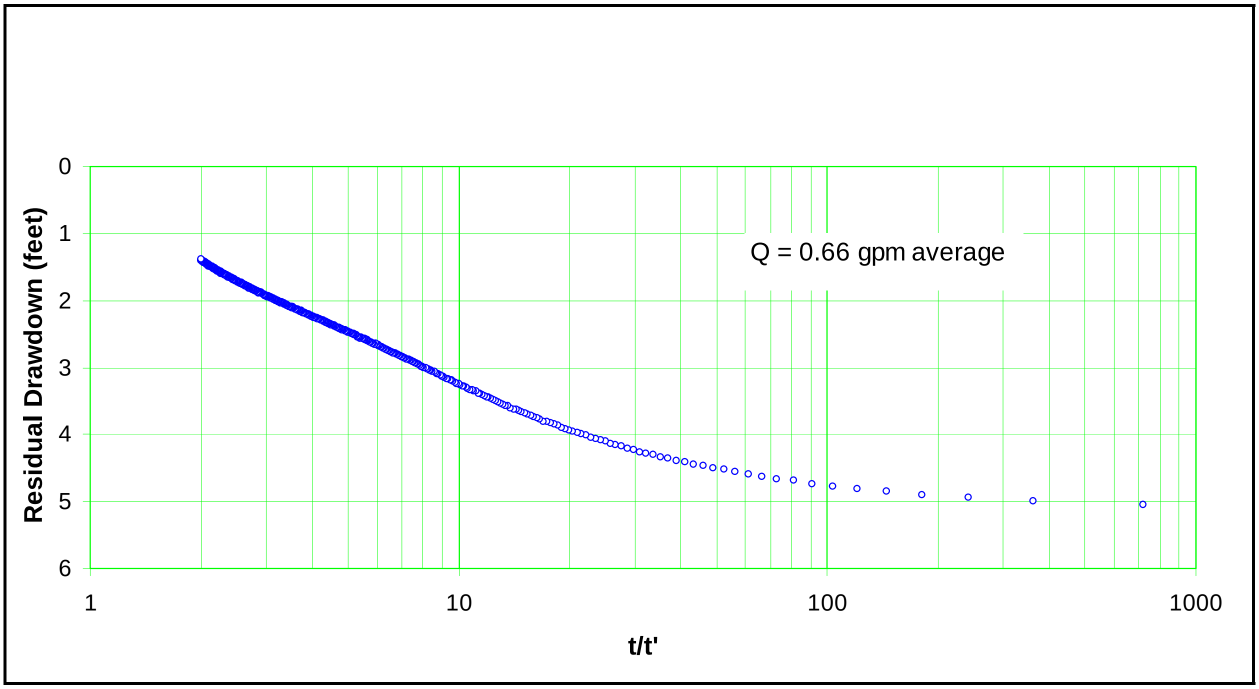


Figure E-9.1-2 Well R-47i trial 1 recovery

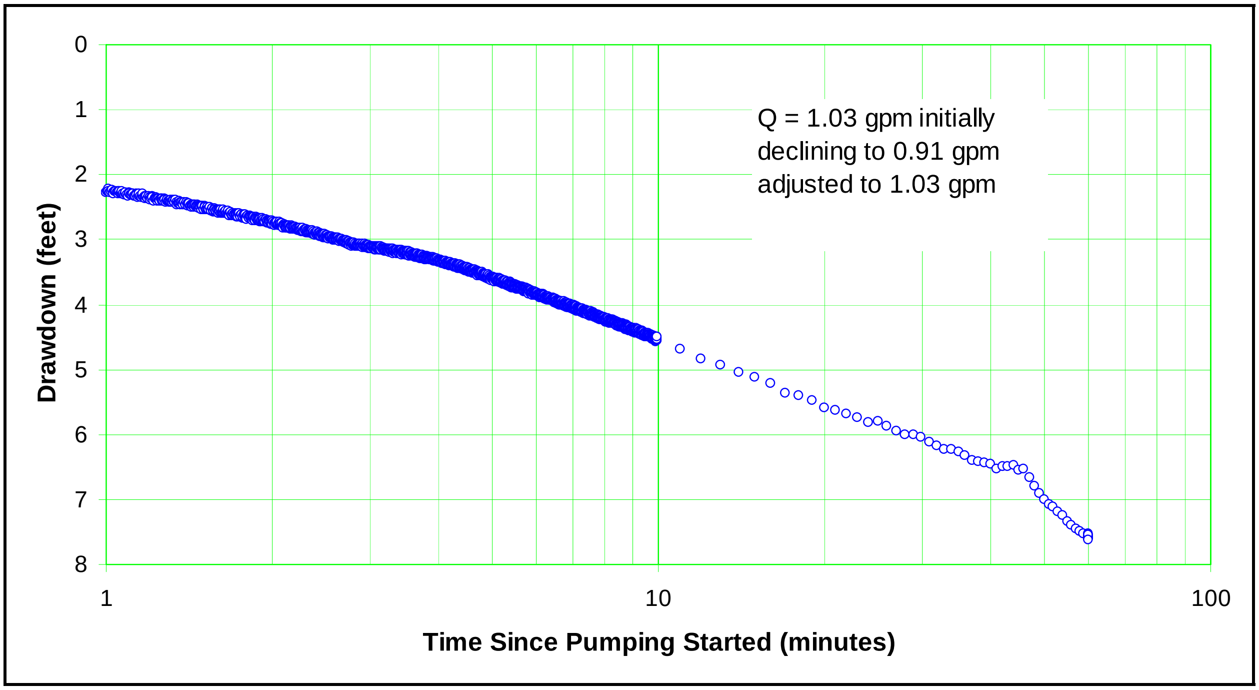


Figure E-9.2-1 Well R-47i trial 2 drawdown

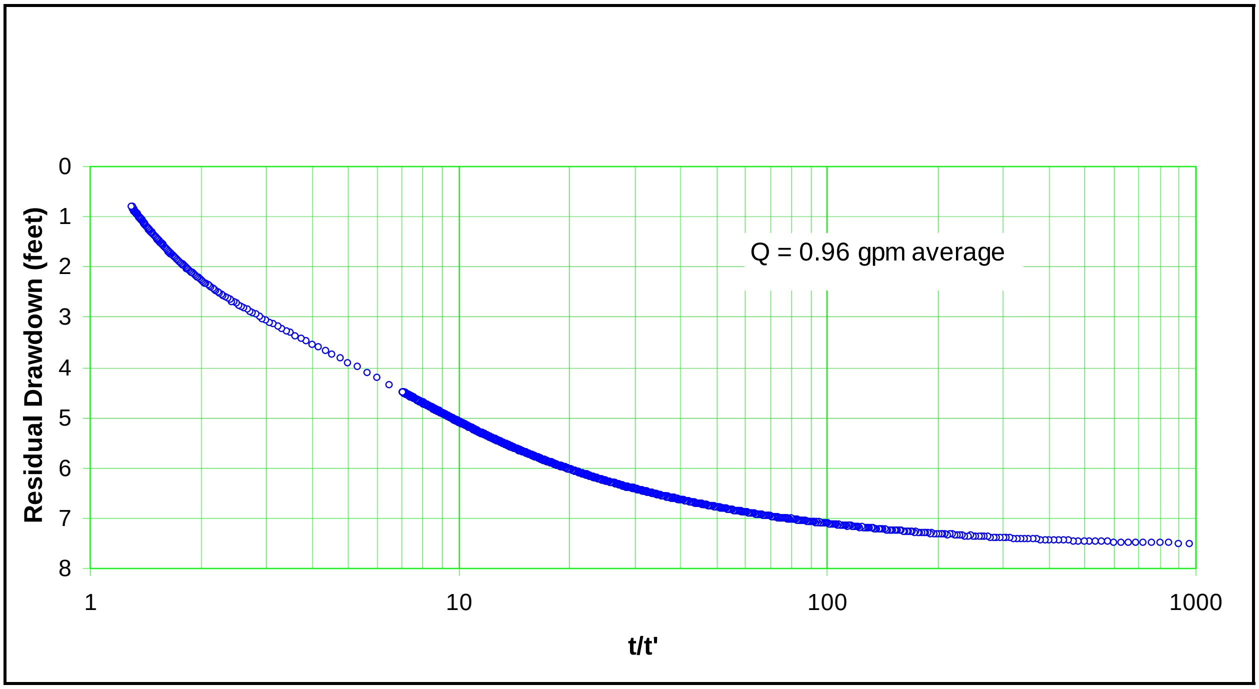


Figure E-9.2-2 Well R-47i trial 2 recovery

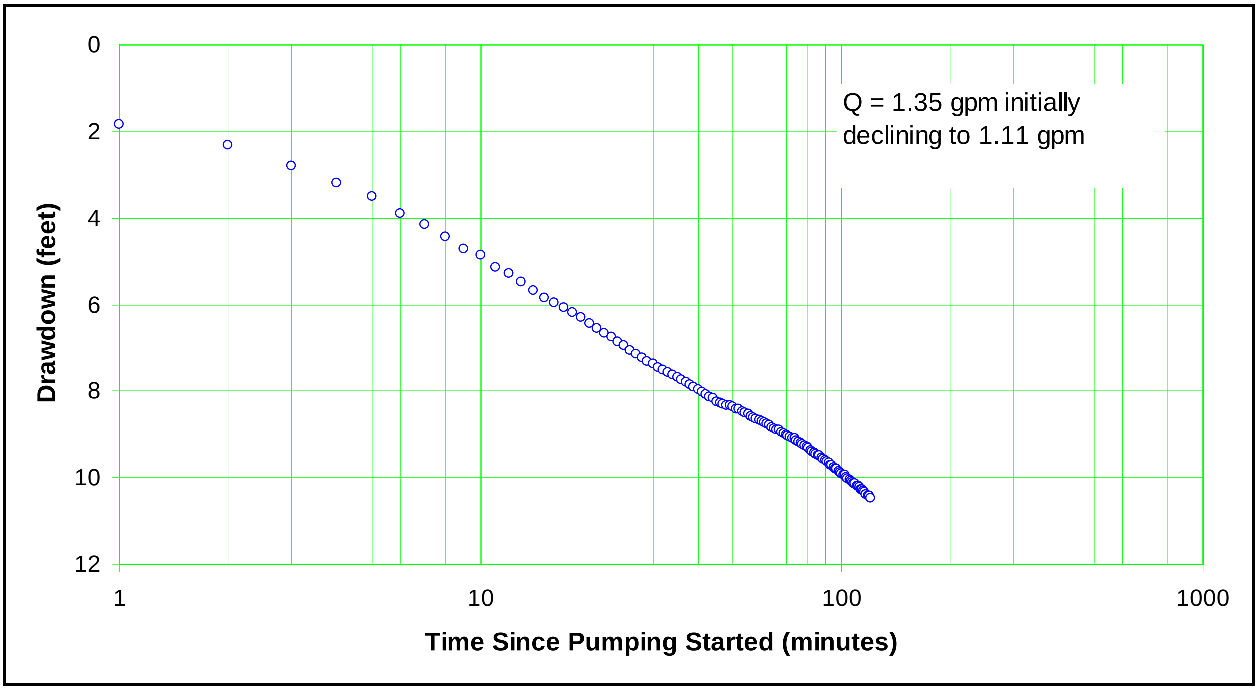


Figure E-9.3-1 Well R-47i trial 3 drawdown

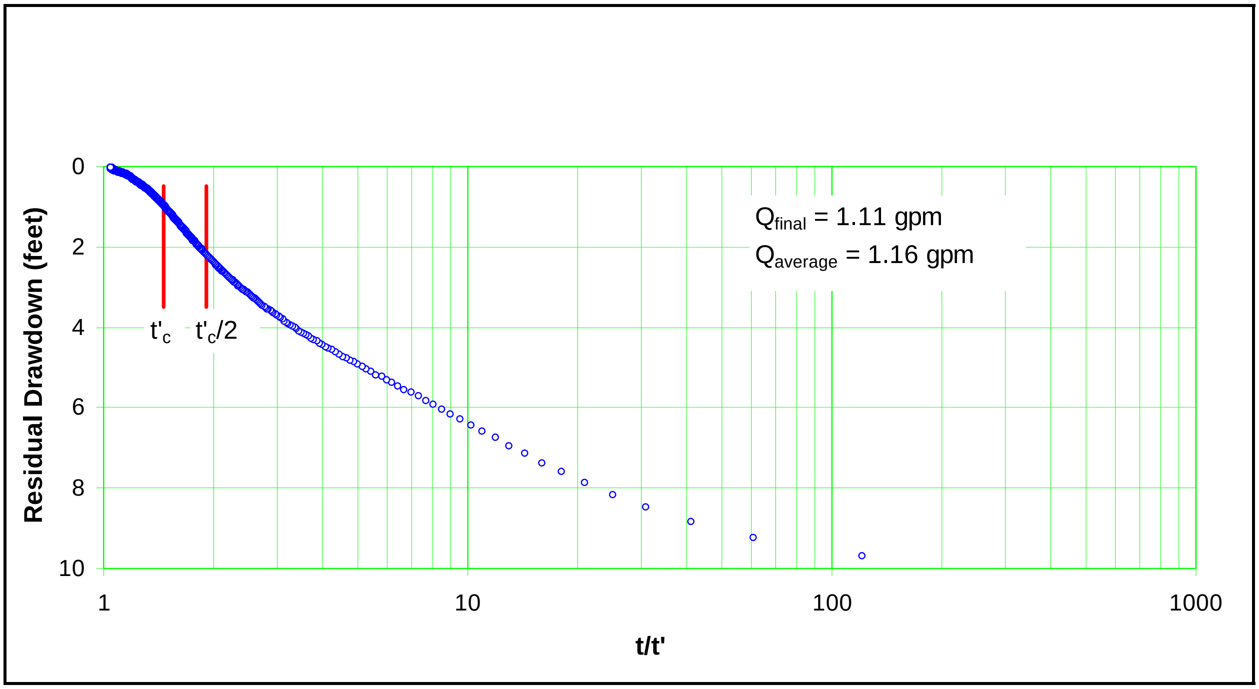


Figure E-9.3-2 Well R-47i trial 3 recovery

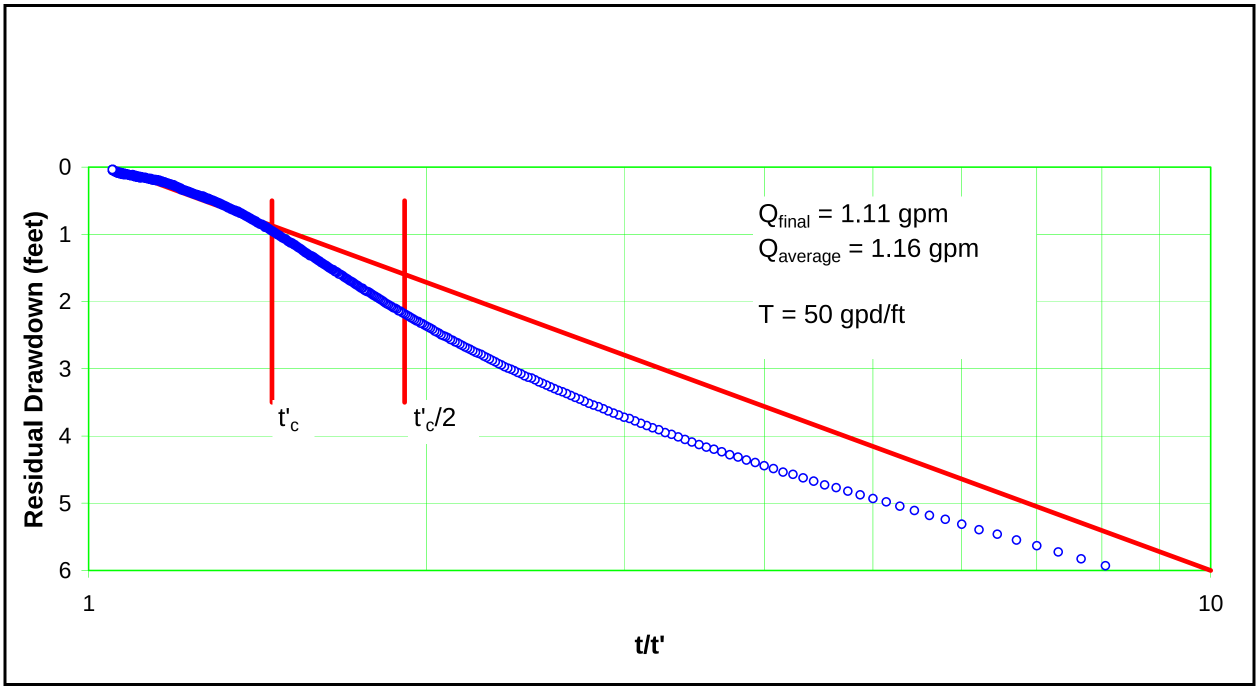


Figure E-9.3-3 Well R-47i trial 3 recovery—expanded scale

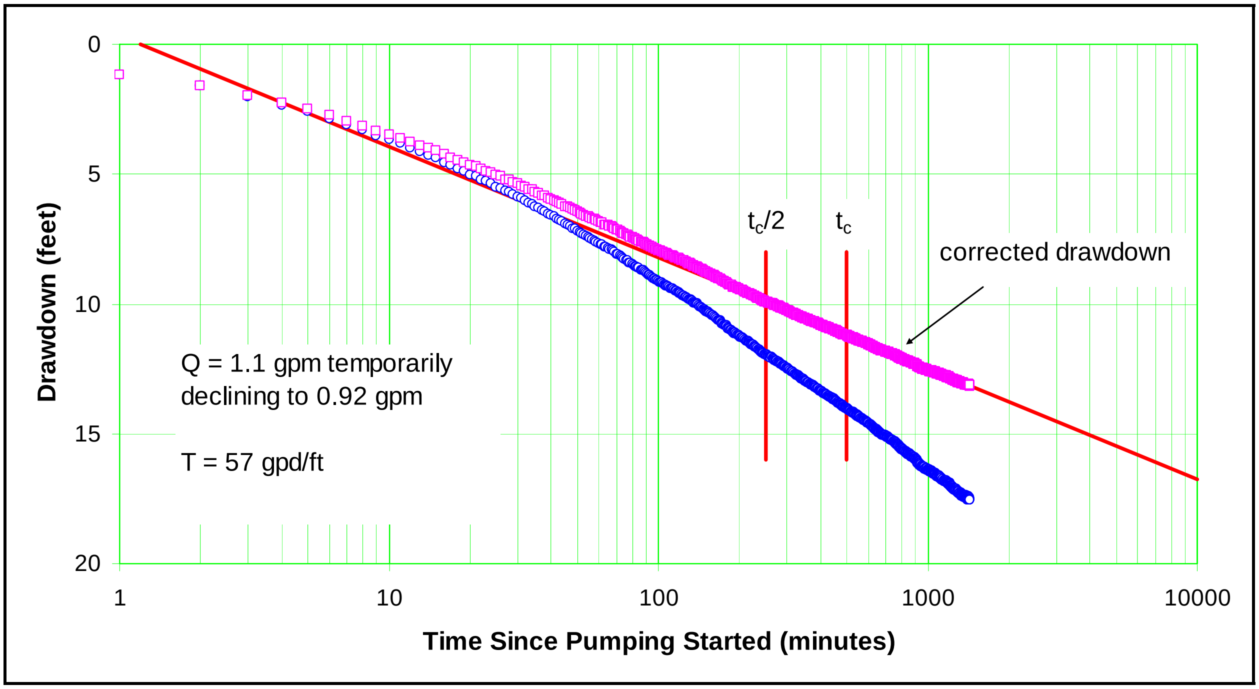


Figure E-9.4-1 Well R-47i drawdown

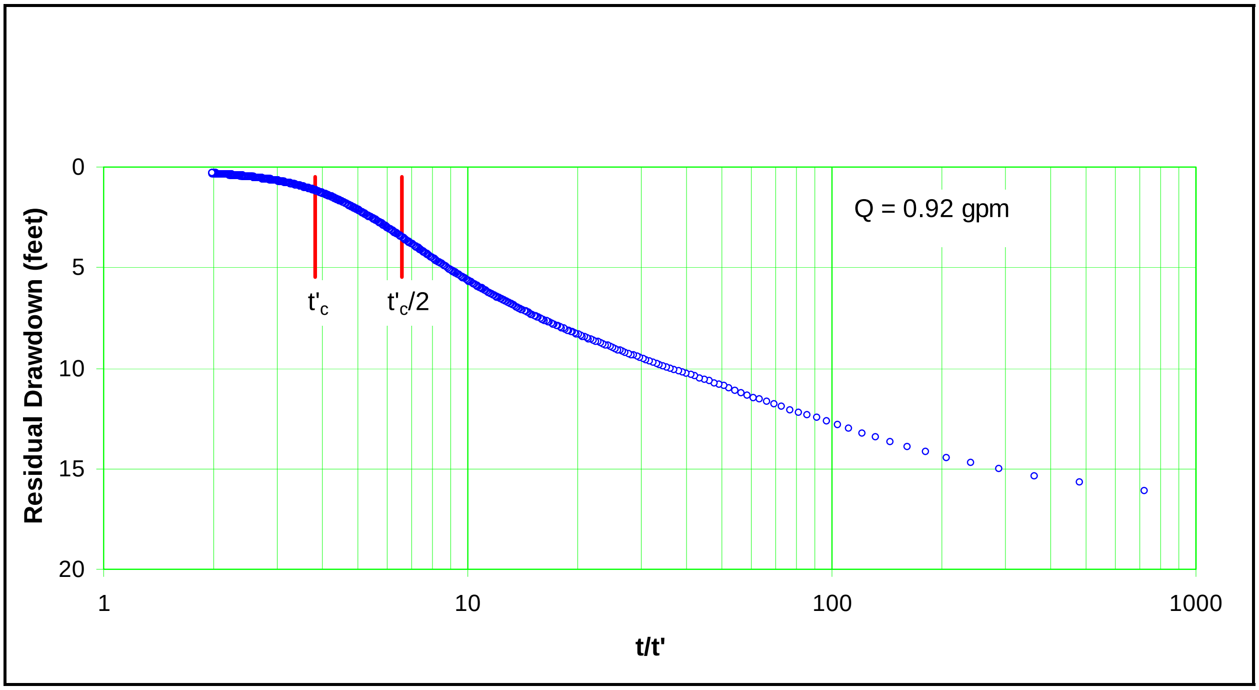


Figure E-9.4-2 Well R-47i recovery

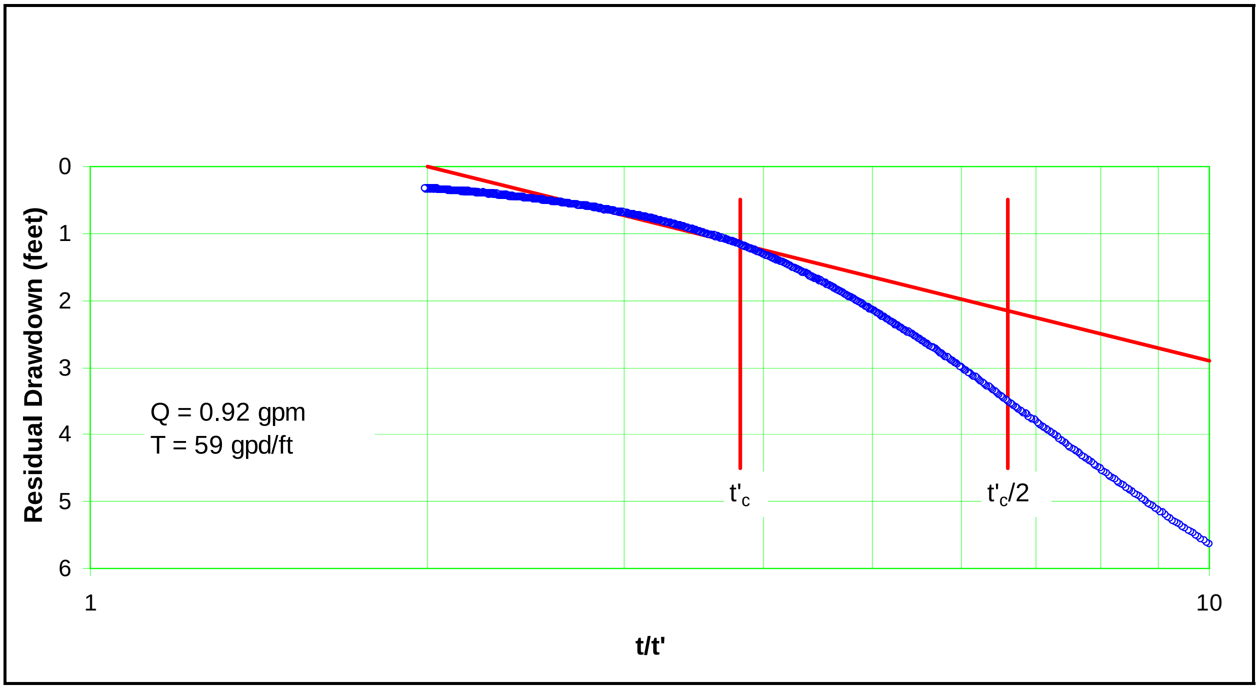


Figure E-9.4-3 Well R-47i recovery—expanded scale

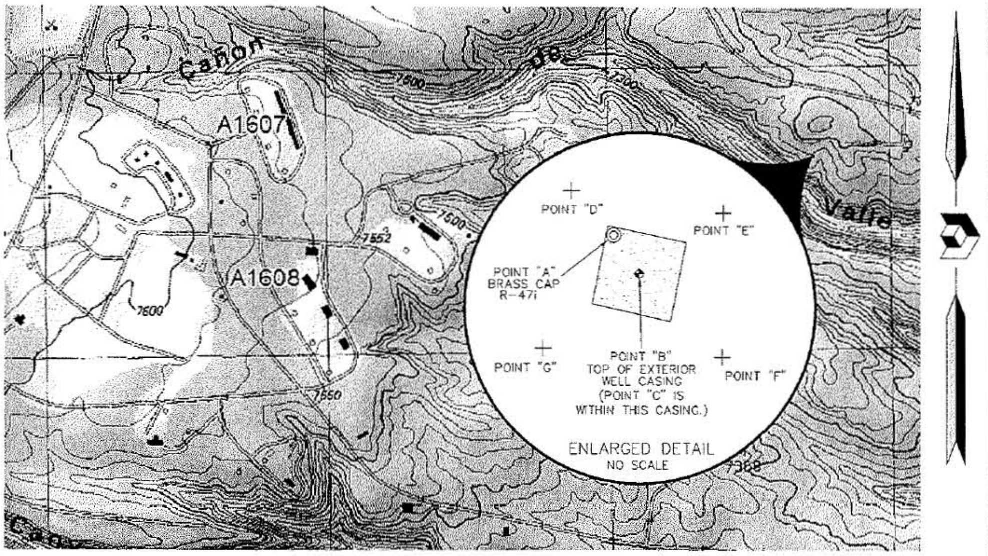
Table E-9.5-1
Specific Capacity Values

Test	Q (gpm)	s (ft)	Q/s (gpm/ft)
Trial 1	0.71	4.51	0.157
Trial 2	0.91	6.53	0.139
24-Hour	1.09	6.65	0.164
Trial 3	1.19	8.01	0.149

Appendix F

R-47i Professional Surveyor Location Report

LANL MONITORING WELL LOCATION REPORT
DESIGNATED R-47 i
WITHIN TECHNICAL AREA 16
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS COUNTY, NEW MEXICO
JANUARY, 2010



POINT	DESCRIPTION	EASTING (X)	NORTHING (Y)	ELEVATION
A	BRASS CAP R-47i	1619250.01	1763907.91	7358.41
B	TOP OF 16" WELL CASING	1619253.18	1763903.12	7361.10
C	TOP OF 6" INNER CASING	1619253.30	1763903.20	7360.76
D	GROUND	1619244.76	1763913.41	7358.35
E	GROUND	1619263.58	1763910.66	7358.03
F	GROUND	1619263.45	1763892.78	7357.15
G	GROUND	1619241.27	1763893.88	7357.68

Notes

1.) FIELD SURVEY COMPLETED ON JANUARY 27, 2010.

2.) THIS AREA LIES WITHIN LOS ALAMOS NATIONAL LABORATORY PROPERTY IN TECHNICAL AREA 16, LOS ALAMOS COUNTY, NEW MEXICO.

3.) HORIZONTAL COORDINATES CALCULATED USING TOPCON HIPER+ RECEIVER AND ARE BASED UPON GPS LOCALIZATION DERIVED FROM LANL LAB WIDE CONTROL NETWORK MONUMENTS A0001, A0002, A0003, A0006, A0009, A0306, A1607, A1608, B0001, B0002, B0004, B3303, PAJ10, PAJ16, NMSR4 15 AND NMSR4 25. LANL LAB WIDE CONTROL NETWORK HORIZONTAL DATUM: NAD 1983.

4.) VERTICAL COORDINATES ARE BASED UPON GPS LOCALIZATION DERIVED FROM LANL LAB WIDE CONTROL NETWORK MONUMENTS A0003, A0006, A0306, A0602, A1607, A1608, B0001, B0004, B3303, BC1709, NMSR4-2, PAJ10, AND PAJ16. VERTICAL DATUM: NGVD 1929.

5.) HORIZONTAL COORDINATES ARE STATE PLANE GRID COORDINATES, NEW MEXICO CENTRAL ZONE, NAD 83.

AUTHORITY:
THIS MONITORING WELL LOCATION REPORT WAS PREPARED FROM A SURVEY DONE UNDER MY SUPERVISION ON THE 27TH DAY OF JANUARY, 2010 AND FROM INSTRUCTION PROVIDED TO US BY NORTH WIND, INC.

LARRY W. MEDRANO, N.M.P.L.S. NO. 11993 *DATE* 3/30/10

LARRY W. MEDRANO
NEW MEXICO
11993
REGISTERED PROFESSIONAL SURVEYOR

PRECISION SURVEYS, INC. 1460 TRINITY DRIVE, SUITE 3 LOS ALAMOS, N.M. 87544 **PHONE** (505) 661-4262 **FAX** (505) 661-4263