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Date: JUN 18 2015
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John Kieling, Bureau Chief
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2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

Subject: Submittal of the Completion Report for Intermediate Aquifer Well CdV-9-1(i)

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Completion Report for Intermediate Aquifer Well CdV-9-1(i). This report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for intermediate aquifer groundwater well CdV-9-1(i), located within Technical Area 09 at Los Alamos National Laboratory. This monitoring well is intended to augment the existing monitoring well network to better define RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) contamination flow paths within the intermediate aquifer north of Cañon de Valle.

If you have any questions, please contact Steve Paris at (505) 606-0915 (smparis@lanl.gov) or Cheryl Rodriguez at (505) 665-5330 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Alison M. Dorries, Division Leader
Environmental Protection Division
Los Alamos National Laboratory

Sincerely,

Christine Gelles, Acting Manager
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AD/CG/DM/SP:sm

Enclosures: Two hard copies with electronic files – Completion Report for Intermediate Aquifer Well CdV-9-1(i) (EP2015-0094)

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June 2015
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Completion Report for Intermediate Aquifer Well CdV-9-1(i)

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

EP2015-0094

Completion Report for Intermediate Aquifer Well CdV-9-1(i)

June 2015

Responsible project manager:

Steve Paris	*[signature]*	Project Manager	Environmental Remediation Program	6/11/2015
Printed Name	Signature	Title	Organization	Date

Responsible LANS representative:

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Responsible DOE representative:

Christine Gelles	*[signature]*	Acting Manager	DOE-EM-LA	6/18/15
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EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for intermediate aquifer groundwater well CdV-9-1(i), located within Technical Area 09 at Los Alamos National Laboratory in Los Alamos County, New Mexico. The CdV-9-1(i) monitoring well is intended to augment the existing monitoring well network to better define RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) contamination flow paths within the intermediate aquifer north of Cañon de Valle.

The CdV-9-1(i) monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was used only to a depth of 695 ft below ground surface (bgs). CdV-9-1(i) was drilled to a total depth of 1220 ft bgs.

The following geologic formations were encountered at CdV-9-1(i): post-Tshirege alluvial fan deposit, Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, and the Puye Formation.

Well CdV-9-1(i) was completed as a dual-screen intermediate aquifer monitoring well with screened intervals set between 937.4 and 992.4 ft bgs and between 1023.7 and 1045.0 ft bgs in Puye Formation sediments. Two piezometers (PZ-1 and PZ-2) were installed outside the well casing with screened intervals set between 662.9 and 672.4 ft bgs in the Otowi Member of the Bandelier Tuff and between 852.9 and 862.4 ft bgs in the Puye Formation. The lower well screen was abandoned after a single-set inflatable packer was emplaced but could not be retrieved after preliminary development of the upper well screen. The piezometer and upper well screens allow evaluation of water quality and water levels within perched and intermediate aquifers. The static depth to water in the well casing after well installation and preliminary development was measured at 892.8 ft bgs. The depth to water in piezometer 1 and 2 after installation was 604.3 and 685.1 ft bgs, respectively.

The well was completed in accordance with a New Mexico Environment Department–approved well design. The well was developed and the intermediate aquifer groundwater met target water-quality parameters. Aquifer testing indicates that intermediate aquifer monitoring well CdV-9-1(i) will perform effectively in meeting the planned objectives. Transducers have been placed in the piezometers and within the upper well screened interval. A sampling system has been placed in the upper well screened interval and groundwater sampling at CdV-9-1(i) will be performed as part of the annual Interim Facility-wide Groundwater Monitoring Plan.

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Acronyms and Abbreviations

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

LANL	Los Alamos National Laboratory
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
TA	technical area
TD	total depth
TOC	total organic carbon
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for intermediate aquifer monitoring well CdV-9-1(i). The report is written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent (the Consent Order). The CdV-9-1(i) monitoring well borehole was drilled between October 24 and November 21, 2014, and completed between December 11, 2014, and January 19, 2015, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

Well CdV-9-1(i) is located within the Laboratory's Technical Area 09 (TA-09) in Los Alamos County, New Mexico (Figure 1.0-1). The primary purpose of CdV-9-1(i) is to provide groundwater monitoring for high explosives (HE) and other potential contaminants in the intermediate aquifer downgradient of the 260 Outfall in TA-16 and beneath infiltration pathways associated with Cañon de Valle. Well CdV-9-1(i) is also intended to augment the existing monitoring well network to better define RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) contamination flow paths within the intermediate aquifer north of Cañon de Valle, as required by the New Mexico Environment Department's (NMED's) approval with modifications for the CdV-9-1(i) drilling work plan (LANL 2013, 239226; NMED 2013, 522693). Secondary objectives were to identify and establish water levels in perched-intermediate aquifers and to collect drill-cuttings samples for lithologic description.

The CdV-9-1(i) borehole was drilled to a total depth (TD) of 1220 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. A dual-screen monitoring well was installed with screened intervals between 937.4 and 992.4 ft bgs and from 1023.7 to 1045.0 ft bgs within Puye Formation volcaniclastic sediments. The lower well screen was abandoned after a single set inflatable packer was emplaced but was unable to be retrieved after preliminary development of the upper well screen. The depth to water (DTW) of 892.8 ft bgs was recorded on January 29, 2015, after well installation and preliminary development of the upper well screen.

Two piezometers were installed outside the well casing with screened intervals set between 662.9 and 672.4 ft bgs in the Otowi Member of the Bandelier Tuff and between 852.9 and 862.4 ft bgs in the Puye Formation. The DTW in piezometer 1 (PZ-1) and 2 (PZ-2) after installation was 604.3 and 685.1 ft bgs, respectively.

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

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the EP Records Processing Facility. This report contains brief descriptions of activities and supporting figures, tables, and appendixes associated with the CdV-9-1(i) project.

2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide activities associated with the drilling, installation, and development of intermediate aquifer well CdV-9-1(i):

- "Drilling Work Plan for Intermediate Aquifer Well CdV-9-1(i)" (LANL 2013, 239226);
- "Field Implementation Plan for Intermediate Aquifer Well CdV-9-1(i)" (TerranearPMC 2014, 600459);
- "IWD [Integrated Work Document] for Drilling and Installation of LANL Wells R-63i, R-47, and CdV-9-1i" (TerranearPMC 2014, 262889);
- "Storm Water Pollution Prevention Plan for Regional Well Drilling" (LANL 2006, 092600); and
- "Waste Characterization Strategy Form: R-47, R-58, R-63i, CdV-9-1i" (LANL 2013, 244887).

3.0 DRILLING ACTIVITIES

This section describes the drilling approach and provides a chronological summary of field activities conducted at monitoring well CdV-9-1(i).

3.1 Drilling Approach

The drilling method, equipment and drill-casing sizes for the CdV-9-1(i) monitoring well were selected to retain the ability to investigate and case/seal off any perched groundwater encountered above the intermediate aquifer. Further, the drilling approach ensured that a sufficiently sized drill casing was used to meet the required 2-in.-minimum annular thickness of the filter pack around a 5.88-in. outside-diameter (O.D.) well screen.

Dual-rotary drilling methods using a Foremost DR-24HD drill rig were employed to drill the CdV-9-1(i) borehole. The drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, deck-mounted air compressor, and general drilling equipment. Auxiliary equipment included two Ingersoll Rand skid-mounted air compressors and one Ingersol Rand truck mounted compressor. Three sizes of A53 grade B flush-welded mild carbon-steel casing (20-in.- and 16-in.-O.D., and 12-in.–inside-diameter [I.D.]) were used for the CdV-9-1(i) project.

The dual-rotary drilling technique employed at CdV-9-1(i) used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all within the vadose zone) included potable water and a mixture of potable water with Baroid Quik Foam foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of the foaming agent was terminated at 695 ft bgs, roughly 100 ft above the expected top of the intermediate aquifer. A small amount of foam was used below 695 ft bgs to clean out the inside of the 16-in. drill casing. This foam was not used while the borehole was advanced. Total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the CdV-9-1(i) Well

The DR-24HD drill rig, drilling equipment, and supplies were mobilized to the CdV-9-1(i) drill site from October 20 to 23, 2014. The equipment and tooling were decontaminated before mobilization to the site. On October 24, following on-site equipment inspections, drilling of monitoring well borehole began at 0915 h using dual-rotary methods with an 18.5-in. tricone bit and 20-in. drill casing.

The 20-in. surface casing was advanced to 34.5 ft bgs in Unit 4 of the Tshirege Member of the Bandelier Tuff. Hydrated bentonite chips were used to fill and seal the annulus around the surface casing.

On October 25, open-hole drilling commenced using a 17.5-in. tricone bit. Drilling proceeded through the Tshirege Member and into the Otowi Member of the Bandelier Tuff to 696.0 ft bgs on November 6.

Between November 7 and November 9, a 16-in. casing string was installed in the open borehole to a depth of 695.0 ft bgs. Beginning November 9, a 16-in. underreaming hammer bit was used to advance the 16-in. casing through the Otowi Member and into the Puye Formation sediments to 922.5 ft bgs. Perched water was encountered and water levels were monitored in the borehole from November 11 to 13. The 16-in. casing shoe was cut on November 14 at 915.7 ft bgs, and a bentonite seal was installed in the 16-in. casing from 915.5 to 905.4 ft bgs before the 12-in. casing string was installed.

Between November 15 and November 17, a 12-in. casing string was installed to a depth of 904.0 ft bgs. The 12-in. casing string and an under-reaming hammer bit were advanced through the Puye Formation to a TD of 1220 ft bgs on November 21 at 0545 h. After reaching TD, the 12-in. casing was retracted to 923.7 ft bgs to record geophysical logs of the lower part of the borehole. Geophysical logs were recorded by Schlumberger logging services on November 23 and 24, and a Laboratory video log was recorded on November 24. On November 25, a 10.7-ft bentonite seal was installed through tremie pipe on top of borehole slough from 1195.0 to 1184.3 ft bgs. The 12-in. casing string was advanced back to 1101.5 ft bgs and the casing shoe was cut on December 2 at 1090.0 ft bgs.

During drilling from October 24 to November 25, field crews worked 24-h shifts, 7 d/wk. No work was performed from November 26 to December 1, during the Thanksgiving holiday. All associated activities proceeded normally without incident or delay.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well CdV-9-1(i). All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the CdV-9-1(i) monitoring well borehole at 5-ft intervals from ground surface to the TD of 1220 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected by the site geologist from the drilling discharge cyclone, placed in resealable plastic bags, labeled, and archived in core boxes. Whole rock and +35 and +10 sieve-size fractions were also processed, placed in chip trays, and archived for each 5-ft interval. Radiological control technicians screened the cuttings before removal from the site. All screening measurements were within the range of background values. The cuttings samples were delivered to the Laboratory's archive at the conclusion of drilling activities.

The stratigraphy encountered at CdV-9-1(i) is summarized in section 5.1 and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

One groundwater-screening sample was collected from a bailer and nine groundwater-screening samples were collected from the drilling discharge at various depths within the intermediate-perched aquifer during drilling activities. The bailed water sample was analyzed for anions, metals, low-level tritium (LH_3), perchlorate, HE, and RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine). The drilling discharge samples were analyzed for RDX.

Fourteen groundwater-screening samples were collected during development of the upper well screen from the pump's discharge line for anions, metals, total organic carbon (TOC), and RDX. One sample from each piezometer was collected during piezometer screen development with a bailer for RDX analysis. Six samples were collected during aquifer testing from the pump's discharge line and analyzed for anions, metals, TOC, and RDX.

Table 4.2-1 presents a summary of screening samples collected during the installation of monitoring well CdV-9-1(i). The TOC results and field water-quality parameters are presented in Appendix B.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for a full suite of constituents in accordance with the requirements of the Interim Facility-Wide Groundwater Monitoring Plan. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sampling frequency at CdV-9-1(i) will be evaluated and presented in the annual Interim Facility-Wide Groundwater Monitoring Plan.

5.0 GEOLOGY AND HYDROGEOLOGY

The geologic and hydrogeologic features encountered at CdV-9-1(i) are summarized below. The Laboratory's geology task leader and project site geologist examined cuttings to determine geologic contacts and hydrogeologic conditions. Drilling observations and water-level measurements were used to characterize groundwater encountered at CdV-9-1(i).

5.1 Stratigraphy

Rock units for the CdV-9-1(i) borehole are presented below in order of youngest to oldest in stratigraphic occurrence. Lithologic descriptions are based on binocular microscope analysis of drill cuttings collected from the discharge hose. Figure 5.1-1 illustrates the stratigraphy at CdV-9-1(i). A detailed lithologic log for CdV-9-1(i) is presented in Appendix A.

Post-Tshirege Alluvial Fan Deposit, Qf (0–10 ft bgs)

The post-Tshirege alluvial fan deposit was encountered from the surface to 10 ft bgs. Alluvial fan deposits consist of subrounded clasts of dacite and strongly welded, crystal-rich tuff.

Unit 4, Tshirege Member of the Bandelier Tuff, Qbt 4 (10–85 ft bgs)

Unit 4 of the Tshirege Member of the Bandelier Tuff was encountered from 10 to 85 ft bgs. Unit 4 is a distinctive tuff that consists of a basal, crystal-rich, pyroclastic surge deposit overlain by pumice-poor ash-flow tuffs.

Unit 3t, Tshirege Member of the Bandelier Tuff, Qbt 3t (85–105 ft bgs)

The upper part of Unit 3 is further subdivided into Unit 3t (transition) in the western part of the Laboratory. Unit 3t of the Tshirege Member of the Bandelier Tuff was encountered from 85 to 105 ft bgs. Unit 3t is a moderately welded ash-flow tuff and consists of pyroclastic surge deposits.

Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (105–230 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff was encountered from 105 to 230 ft bgs. Unit 3 is a poorly to moderately welded devitrified ash-flow tuff (i.e., ignimbrite) that is crystal-rich, slightly pumiceous and lithic-poor and exhibits a matrix of fine ash.

Unit 2, Tshirege Member of the Bandelier Tuff, Qbt 2 (230–290 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff was intersected from 230 to 290 ft bgs. Unit 2 represents a moderately to strongly welded devitrified rhyolitic ash-flow tuff (i.e., ignimbrite) that is composed of abundant (up to 40% by volume) quartz and sanidine crystals. Cuttings typically contain abundant fragments of indurated tuff and numerous free quartz and sanidine crystals.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (290–375 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff occurs from 290 to 375 ft bgs. Unit 1v is a poorly to moderately welded, devitrified rhyolitic ash-flow tuff that is pumiceous, generally lithic-poor and crystal-bearing to locally crystal-rich. Abundant ash matrix is rarely preserved in cuttings. Cuttings commonly contain numerous fragments of indurated crystal-rich tuff with devitrified pumice. Abundant free quartz and sanidine crystals dominate cuttings in many intervals and minor small (generally less than 10 mm in diameter) volcanic lithic inclusions also occur in cuttings

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (375–430 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 375 to 430 ft bgs. Unit 1g is a poorly welded vitric rhyolitic ash-flow tuff that is poorly to moderately indurated, strongly pumiceous, and crystal-bearing. White to pale orange, lustrous, glassy pumice lapilli are characteristic of Unit 1g. Cuttings contain abundant free quartz and sanidine crystals and minor small (up to 10 mm) volcanic (predominantly dacitic) lithic inclusions.

Cerro Toledo Interval, Qct (430–595 ft bgs)

The Cerro Toledo interval was encountered from 430 to 595 ft bgs. The Cerro Toledo interval is a sequence of poorly consolidated tuffaceous and volcaniclastic sediments that occurs intermediately between the Tshirege and Otowi Members of the Bandelier Tuff. The Cerro Toledo interval at CdV-9-1(i) contains grayish-orange to white pumice clasts and various dacitic and rhyolitic clasts. Silt and sand-sized grains are dominated by angular to subangular quartz and sanidine grains. Sediments are largely stained with orange oxidation on grain surfaces.

Otowi Member of the Bandelier Tuff, Qbo (595–805 ft bgs)

The Otowi Member of the Bandelier Tuff was encountered from 595 to 805 ft bgs. The Otowi Member is composed of poorly welded vitric rhyolitic ash-flow tuffs that are pumiceous, and crystal- and lithic-bearing. Drill cuttings contain pale orange, glassy pumices, volcanic lithic clasts (up to 10 mm) and quartz and sanidine crystals. Lithic fragments are commonly subangular to subrounded and generally of intermediate volcanic composition, including porphyritic dacites.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (805–820 ft bgs)

The Guaje Pumice Bed represents an air-fall tephra deposit of rhyolitic pumice that forms the base of the Otowi Member. The Guaje deposit was encountered from 805 to 820 ft bgs. Drill cuttings in this interval contain abundant (up to 90% by volume) lustrous vitric pumice lapilli (up to 15 mm in diameter) with trace occurrences of small volcanic lithic fragments. The deposit is poorly consolidated.

Puye Formation, Tpf (820–1220 ft bgs)

Puye Formation volcaniclastic sediments were encountered from 820 ft to the total borehole depth of 1220 ft bgs. The Puye Formation consists of alluvial fan deposits eroded from volcanic rocks in the nearby Jemez Mountains. Cuttings from this interval consist of grey, red, and purple dacitic and rhyolitic gravels, volcaniclastic sands, and minor devitrified pumice clasts. Cuttings are generally angular to subangular. These deposits likely contain intervals with cobbles and boulders, but these larger clasts are pulverized during drilling.

5.2 Groundwater

Drilling at CdV-9-1(i) proceeded without any groundwater indications until 922.0 ft bgs, as noted by the drilling crew. The borehole was then advanced to the TD of 1220.0 ft bgs. The water level was 1066.5 ft bgs on December 2, 2014, before well installation. The DTW in the upper screen of the completed well was 956.0 ft bgs on January 20, 2015. After preliminary development of the upper well screen, DTW was recorded at 892.8 ft bgs on January 29.

During development, pumping rates were variable between approximately 1.8 and 11.0 gallons per minute (gpm) depending on depth placement.

6.0 BOREHOLE LOGGING

A full suite of geophysical logs was recorded by Schlumberger on November 23 and 24, 2014, after the borehole was advanced to the TD of 1220.0 ft bgs (Appendix C). A video log was conducted with Laboratory video camera and staff on November 24 below the 12-in. casing in open borehole from 923.7 ft bgs to the top of slough at 1195.0 ft bgs (Appendix D).

7.0 WELL INSTALLATION CdV-9-1(i) MONITORING WELL

The CdV-9-1(i) well was installed between December 11, 2014, and January 19, 2015.

7.1 Well Design

The CdV-9-1(i) well was designed in accordance with requirements in the Consent Order, and NMED approved the final well design before the well was installed (Appendix E). The well was designed with two screened intervals between 937.4 and 992.4 ft bgs and between 1023.7 and 1045.0 ft bgs to monitor the groundwater quality in intermediate aquifers within the Puye Formation. Two piezometers were installed outside the well casing with screened intervals set between 662.9 and 672.4 ft bgs in the Otowi Member of the Bandelier Tuff and between 852.9 and 862.4 ft bgs in the Puye Formation to monitor groundwater levels in the perched aquifers.

7.2 Well Construction

From December 5 to 12, 2014, the stainless-steel well casing, screens, and tremie pipe were decontaminated, and the Pulstar workover rig and initial well construction materials were mobilized to the site.

The CdV-9-1(i) monitoring well was constructed of 5.0-in.-I.D./5.56-in.-O.D. type A304 passivated stainless-steel threaded casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The lower screened section utilized two 10-ft lengths of 5.0-in.-I.D. rod-based 0.040-in. wire-wrapped screens to make up the 21.0-ft-long screen interval. The upper screened section utilized five 10-ft lengths of 5.0-in.-I.D. rod-based 0.040-in. wire wrapped screens to make up the 55.0-ft-long screen interval. Compatible external stainless-steel couplings (also type A304 stainless-steel fabricated to ASTM A312 standards) were used to join the individual casing sections. The coupled unions between threaded sections were approximately 0.5 ft long. A 2-in. steel tremie pipe was used to deliver backfill and annular fill materials down-hole during well construction. The volumes of annular fill materials are presented in Table 7.2-1. Short lengths of 16-in. (6.8-ft casing and shoe from 915.7 to 922.5 ft bgs) and 12-in. drill casing (11.5-ft casing and shoe from 1090.0 to 1101.5 ft bgs) remain in the borehole. The 16-in. casing stub was encased in the hydrated bentonite seal above the upper fine-sand collar, and the 12-in. casing stub was encased in the bentonite backfill during well completion.

A 22.9-ft-long stainless-steel sump was placed below the bottom of the well screen. The well casing was started into the borehole on December 11 at 0830 h. The well casing was hung by wireline with the bottom at 1067.9 ft bgs. Stainless-steel centralizers (four sets of four) were welded to the well casing approximately 2.0 ft above and below the two screened intervals.

Two piezometers were installed with the stainless-steel well casing. The piezometers were constructed of 1.0-in.-I.D. Schedule 40 steel pipe with compatible external couplings. The piezometer screens each utilized two 5-ft lengths of 1.25-in.-I.D. stainless-steel rod-based 0.010-in. wire-wrapped screens to make up the 9.5-ft-long screen intervals. The piezometers were attached to the stainless-steel well casing with 2- to 3-in. welds every 5.0 to 7.0 ft. The upper piezometer (PZ-1) screen interval was set between 662.9 and 672.4 ft bgs, and the lower piezometer (PZ-2) screen interval was set between 852.9 and 862.4 ft bgs. Figures 7.2-1 and 7.2-2 present as-built schematics showing construction details for the completed well.

The installation of backfill materials began on December 17 after the bottom of the borehole was measured at 1183.2 ft bgs (approximately 37.0 ft of slough had accumulated in the borehole). The bentonite backfill was installed between December 17 and 19 from 1183.2 to 1050.0 ft bgs using 123.3 ft^3 of 3/8-in. bentonite chips.

The lower screen filter pack was installed between December 19 and 20 from 1050.0 to 1019.1 ft bgs using 70.0 ft^3 of 10/20 silica sand. The actual volume of filter-pack sand was 314% greater than the calculated volume and is likely because of the oversized borehole caused by sloughing in the unconsolidated Puye Formation. The lower filter pack was surged to promote compaction. The fine-sand collar was installed above the lower filter pack from 1019.1 to 1016.7 ft bgs using 8.5 ft^3 of 20/40 silica sand. On December 21, following installation of the fine-sand collar, a removable single set inflatable packer was installed in the well casing between the screened intervals with the top at 1008.7 ft bgs. On December 21, the middle bentonite seal was installed from 1016.7 to 996.9 ft bgs using 18.2 ft^3 of 3/8-in. bentonite chips.

Installation of the upper filter pack began on December 22 but was suspended for the holiday break until January 6, 2015. The upper filter pack was completed on January 9 from 996.9 to 932.2 ft bgs using

118.5 ft^3 of 10/20 silica sand. The actual volume of filter-pack sand was 253% greater than the calculated volume and is likely because of the oversized borehole caused by sloughing in the unconsolidated Puye Formation. The upper filter pack was surged to promote compaction. The fine-sand collar was installed above the upper filter pack from 932.2 to 930.5 ft bgs using 3.5 ft^3 of 20/40 silica sand. From January 9 to 12, the bentonite seal above the upper fine-sand collar was installed from 930.5 to 867.6 ft bgs using 70.0 ft^3 of 3/8-in. bentonite chips.

The lower piezometer filter pack was installed on January 12 from 867.6 to 848.1 ft bgs using 31.8 ft^3 of 10/20 silica sand. The fine-sand collar was installed above the lower piezometer filter pack from 848.1 to 846.2 ft bgs using 5.5 ft^3 of 20/40 silica sand. From January 12 to 14, the bentonite seal above the lower piezometer was installed from 846.2 to 676.9 ft bgs using 218.4 ft^3 of 3/8-in. bentonite chips.

The upper piezometer filter pack was installed on January 14 from 676.9 to 658.2 ft bgs using 30.5 ft^3 of 10/20 silica sand. The fine-sand collar was installed above the upper piezometer filter pack from 658.2 to 656.1 ft bgs using 3.5 ft^3 of 20/40 silica sand. From January 14 to 18, the bentonite seal above the upper piezometer was installed from 656.1 to 60.3 ft bgs using 877.8 ft^3 of 3/8-in. bentonite chips.

From January 18 to 19, a cement seal was installed from 60.3 to 3.0 ft bgs. The cement seal used 165.8 ft^3 of Portland Type I/II/V cement. This volume exceeded the calculated volume of 102.4 ft^3 by 162% and is likely from cement loss to the near-surface formations.

Operationally, well construction proceeded smoothly, 24 h/d, 7 d/wk, from December 11, 2014, to January 19, 2015, with a holiday break from December 22, 2014, to January 6, 2015.

8.0 POST-INSTALLATION ACTIVITIES

Following well installation at CdV-9-1(i), the upper well and piezometer screens were developed, the lower well screen was abandoned, and aquifer pumping tests were conducted. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system was installed. Site restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees.

8.1 Well Development

The upper well screen was initially developed between January 20 and 29, 2015. The screened interval was swabbed and bailed to remove formation fines in the filter pack and well casing above the single set inflatable packer. Bailing continued until water clarity visibly improved. Final development was then performed with a submersible pump.

The swabbing tool employed was a 4.5-in.-O.D., 1-in.-thick nylon disc attached to a weighted steel rod. The wireline-conveyed tool was drawn repeatedly across the screened interval, causing a surging action across the screen and filter pack. The bailing tool was a 4.0-in.-O.D. by 21.0-ft-long carbon-steel bailer with a total capacity of 12 gal. The tool was repeatedly lowered by wireline, filled, withdrawn from the well, and emptied into the cuttings pit. Approximately 396.2 gal. of groundwater was removed during bailing activities.

After bailing, a 5-horsepower (hp), 4-in. Grundfos submersible pump was installed in the well. The upper screened interval was pumped from top to bottom in 2-ft increments from January 24 to 25 and from bottom to top in 2-ft increments from January 25 to 26. The pump was then used to purge the well with the pump intake set above the packer on January 26. From January 27 to 28, the pump intake was set below the upper well screen at 997 ft bgs for purging. Approximately 29,449.3 gal. of groundwater was purged with the submersible pump during initial well development.

Development of the well was temporarily suspended on January 29 to retrieve the packer. The packer could not be retrieved following standard operating procedures. From February 1 to 13, several unsuccessful attempts were made to remove the packer with guidance from the manufacturer. From February 14 to 15, a second single-set inflatable packer was installed in the well casing above the first packer to ensure the well screen was isolated. The top of the second packer was set at 997.4 ft bgs, and a K-packer was set from 995.9 to 997.4 ft bgs above the inflatable packer before the sampling system was installed.

Following installation of the second packer, additional development of the upper screen was performed. A 10-hp, 4-in. Berkeley submersible pump was installed in the well with the pump intake set at the bottom of the upper well screen at 992.0 ft bgs. From February 17 to 19, approximately 12,110 gal. of groundwater was purged with the submersible pump. Because the purge rates were declining, the 10-hp Berkeley pump was removed and a 5-hp Grundfos pump was installed in the well. The pump intake was set at 990.0 ft bgs, and from February 20 to 25, approximately 13,460 gal. of groundwater was purged.

The two piezometers were developed between February 27 and March 4. Initially, a string of 3/8-in.-I.D. pipe was installed into the piezometers to core out formation fines. The piezometer sumps were then bailed with a 3/8-in.-I.D. by 5.0-ft-long steel bailer. The 3/8-in.-I.D. pipe string was reinstalled, and water was flushed through the pipe to clear the piezometers of additional formation fines. Minimal amounts of water were removed/added during development of the piezometers.

Total Volumes of Introduced and Purged Water

During drilling, approximately 1130 gal. of potable water was added between the top of the upper fine-sand collar and above the well-casing sump from approximately 930.0 to 1068.0 ft bgs. Approximately 24,058 gal. was added during installation of the annular seals. An additional 4994 gal. was added during packer retrieval attempts and inflation of the second packer. In total, approximately 30,182 gal. of potable water was introduced to the borehole between 930.0 and 1068.0 ft bgs during project activities.

Approximately 55,416.4 gal. of groundwater was purged at CdV-9-1(i) during well development activities. Another 19,058.2 gal. was purged during aquifer testing. The total amount of groundwater purged during post-installation activities was 74,474.6 gal.

8.1.1 Well Development Field Parameters

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

Field parameters were measured by collecting aliquots of groundwater from the discharge pipe using a flow-through cell. The final parameters at the end of well development were pH of 7.32, temperature of 12.70ºC, specific conductance of 144 µS/cm, and turbidity of 49.9 NTU. Table B-2.2-1 in Appendix B presents the field parameters and purge volumes measured during well development.

During the 72-h aquifer test, the turbidity values ranged from 12.6 to 80.3 NTU, with the final recorded value of 42.1 NTU.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at CdV-9-1(i) between March 5 and 11, 2015. Several short-duration tests with short-duration recovery periods were performed on the first 2 d of testing. A 72-h pump test with the pump intake at 989.2 ft bgs, followed by a 24-h recovery period completed the testing of the screened interval. The average pumping rate for the final 24-h of the 72-h test was approximately 3.3 gpm.

A 5-hp pump was used for the aquifer tests. A total of approximately 19,058.2 gal. of groundwater was purged during aquifer testing. Turbidity, temperature, pH, DO, ORP, and specific conductance were measured during the 72-h test. Measured parameters are presented in Appendix B. The CdV-9-1(i) aquifer test results and analysis are presented in Appendix F.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for CdV-9-1(i) was installed on April 30 and May 1, 2015. The pumping system utilizes an environmentally retrofitted 4-in. 3-hp Grundfos submersible pump set in a shroud near the bottom of the screened interval. The pump column is constructed of 1-in. threaded/coupled passivated stainless-steel pipe. A weep valve was installed at the bottom of the uppermost pipe joint to protect the pump column from freezing. To measure water levels in the well, two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) pipes were installed to sufficient depth to set a dedicated transducer and to provide access for manual water-level measurements. The PVC transducer tubes are equipped with 9-in. sections of 0.010-in. slot screen with a threaded end cap on the bottom of each tube. An In-Situ Level Troll 500 30-psig transducer was installed in one of the PVC tubes to monitor the water level in the well's screened interval.

Sampling system details for CdV-9-1(i) are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for the well. Figure 8.3-1c presents a performance curve for the submersible pump installed in the well.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 10 in. thick, was installed at the CdV-9-1(i) wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 16-in.-O.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. A total of four bollards, painted yellow for visibility, were set at the outside edges of the pad to protect the well from traffic. All four bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on April 9, 2015 (Table 8.5-1). The survey data conform to Laboratory Information Architecture project standards IA-CB02, "GIS Horizontal Spatial Reference System," and IA-D802, "Geospatial Positioning Accuracy Standard for A/E/C and Facility Management." All coordinates are expressed relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground surface elevation near the concrete pad, the top of the brass pin in the concrete pad, the top of the well casing, the top of the protective casing, and the top of the piezometers for the CdV-9-1(i) monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the CdV-9-1(i) project included drilling fluids, purged groundwater, drill cuttings, decontamination water, and contact waste. The waste characterization samples collected during drilling, well construction, and development of CdV-9-1(i) are summarized in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with "Waste Characterization Strategy Form: R-47, R-58, R-63i, CdV-9-1(i)" (LANL 2013, 244887).

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

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

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

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

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Well CdV-9-1(i) was drilled as specified in "Drilling Plan for Intermediate Aquifer Well CdV-9-1(i)" (LANL 2013, 239226).

Well CdV-9-1(i) was initially designed with one well screen. The final well design with two screens and two piezometers was based on conditions found during drilling and geophysical logging. The lower well screen was not developed and was abandoned after a single-set inflatable packer was emplaced but could not be retrieved after preliminary development of the upper well screen. Well construction was otherwise performed as specified in the drilling plan.

Groundwater characterization samples were not collected from the completed well between 10 and 60 d after well development in accordance with the Consent Order because of the extended sampling system design and review period. The Laboratory requested an extension to collect the initial groundwater sample, and NMED approved the request on April 27, 2015, via email.

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the CdV-9-1(i) monitoring well.

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

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

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

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

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

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), April 2013. "Drilling Work Plan for Well CdV-9-1(i)," Los Alamos National Laboratory document LA-UR-13-20779, Los Alamos, New Mexico. (LANL 2013, 239226)

LANL (Los Alamos National Laboratory), July 10, 2013. "Waste Characterization Strategy Form for R-47, R-58, R-63i, CdV-9-1i," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2013, 244887)

NMED (New Mexico Environment Department), May 31, 2013. "Approval with Modification, Drilling Work Plan for Well CdV-9-1(i)," New Mexico Environment Department letter to P. Maggiore (DOE-LASO) and J.D. Mousseau (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2013, 522693)

TerranearPMC, June 2, 2014. "IWD for Drilling and Installation of LANL Wells R-63i, R-47, and CdV-9-1i," prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2014, 262889)

TerranearPMC, October 2014. "Field Implementation Plan for Intermediate Well CdV-9-1(i)," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2014, 600459)

11.2 Map Data Sources

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

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

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

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

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

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

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

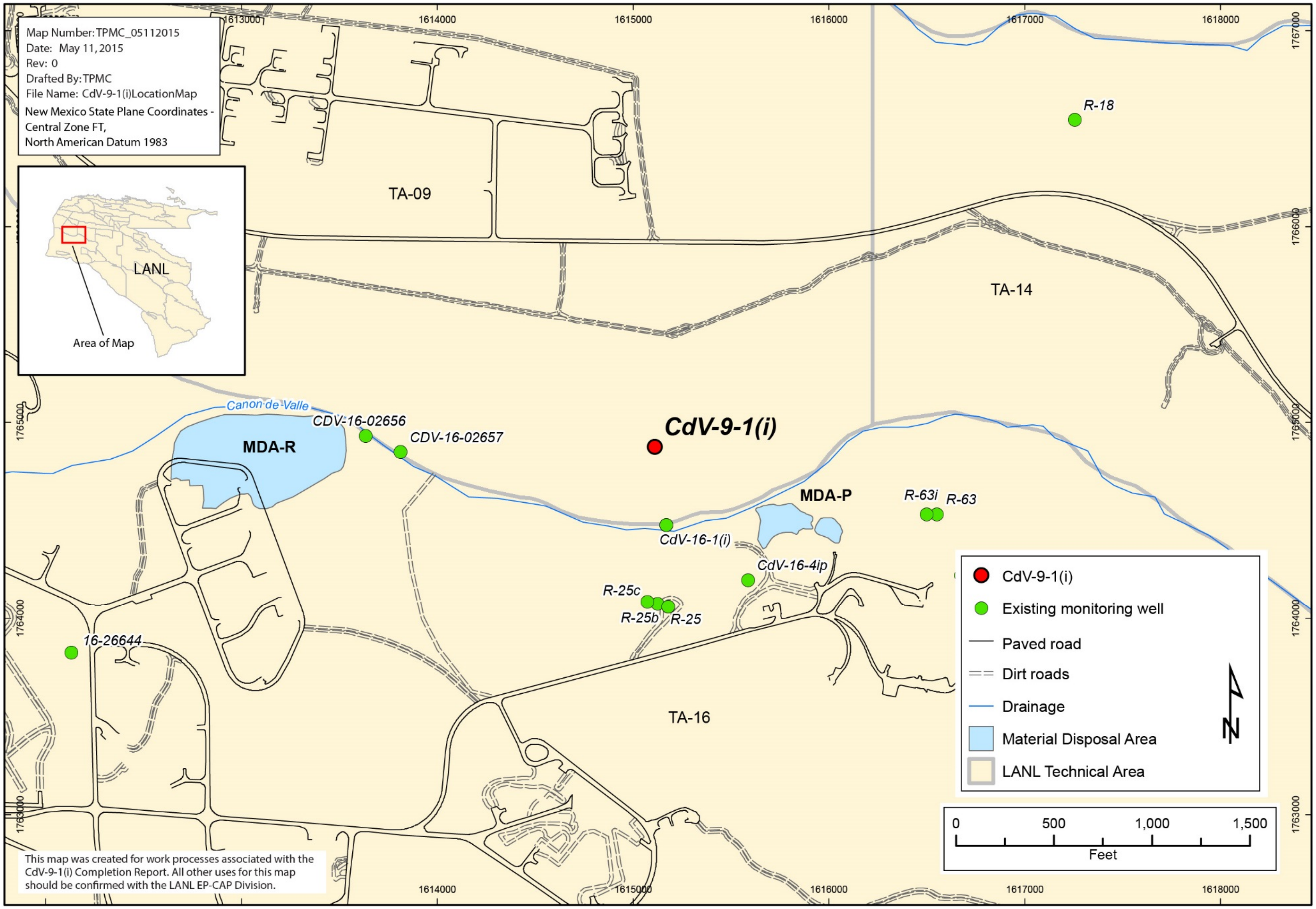


Figure 1.0-1 Location of monitoring well CdV-9-1(i)

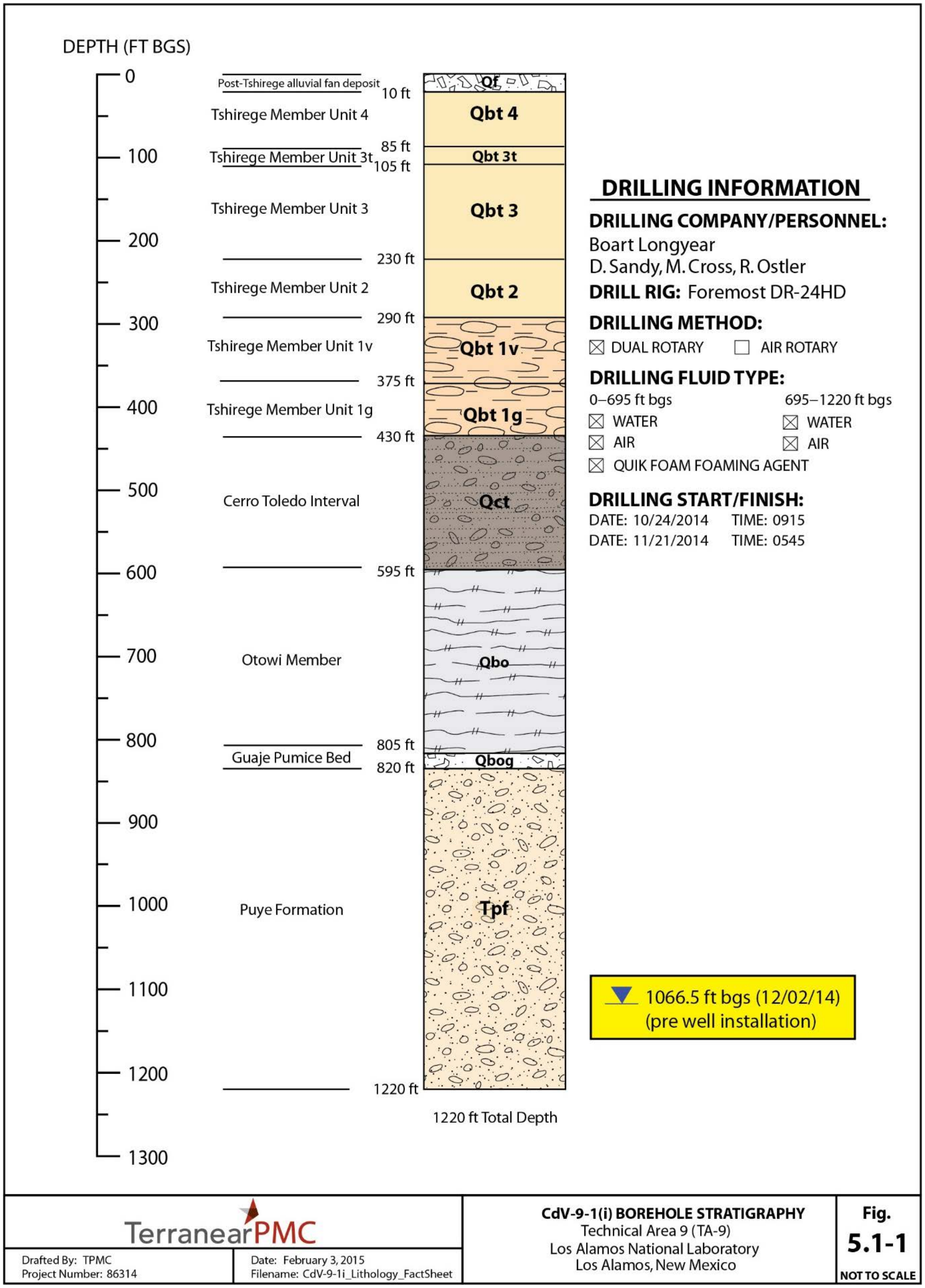


Figure 5.1-1 Monitoring well CdV-9-1(i) borehole stratigraphy

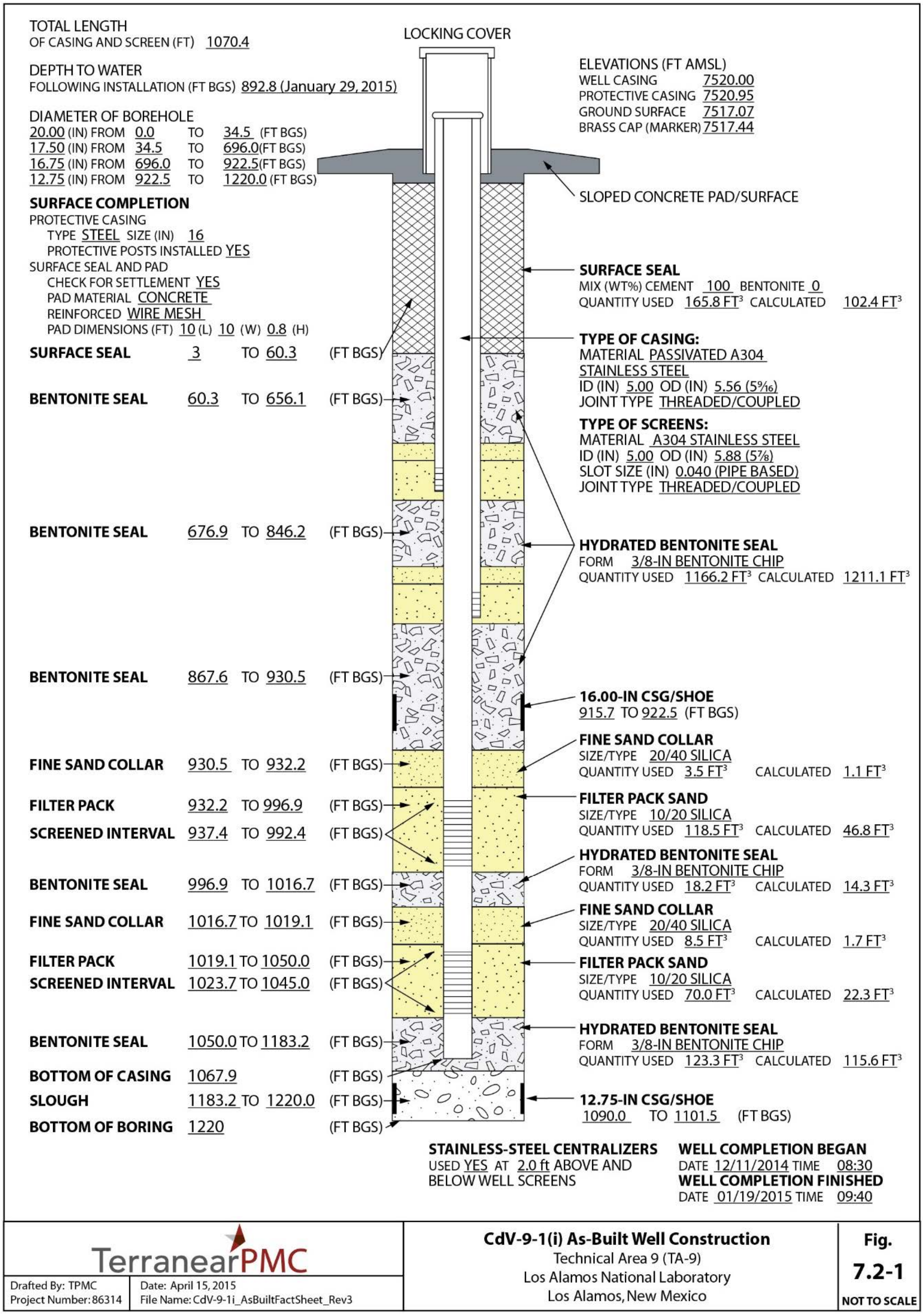


Figure 7.2-1 Monitoring well CdV-9-1(i) as-built well construction diagram

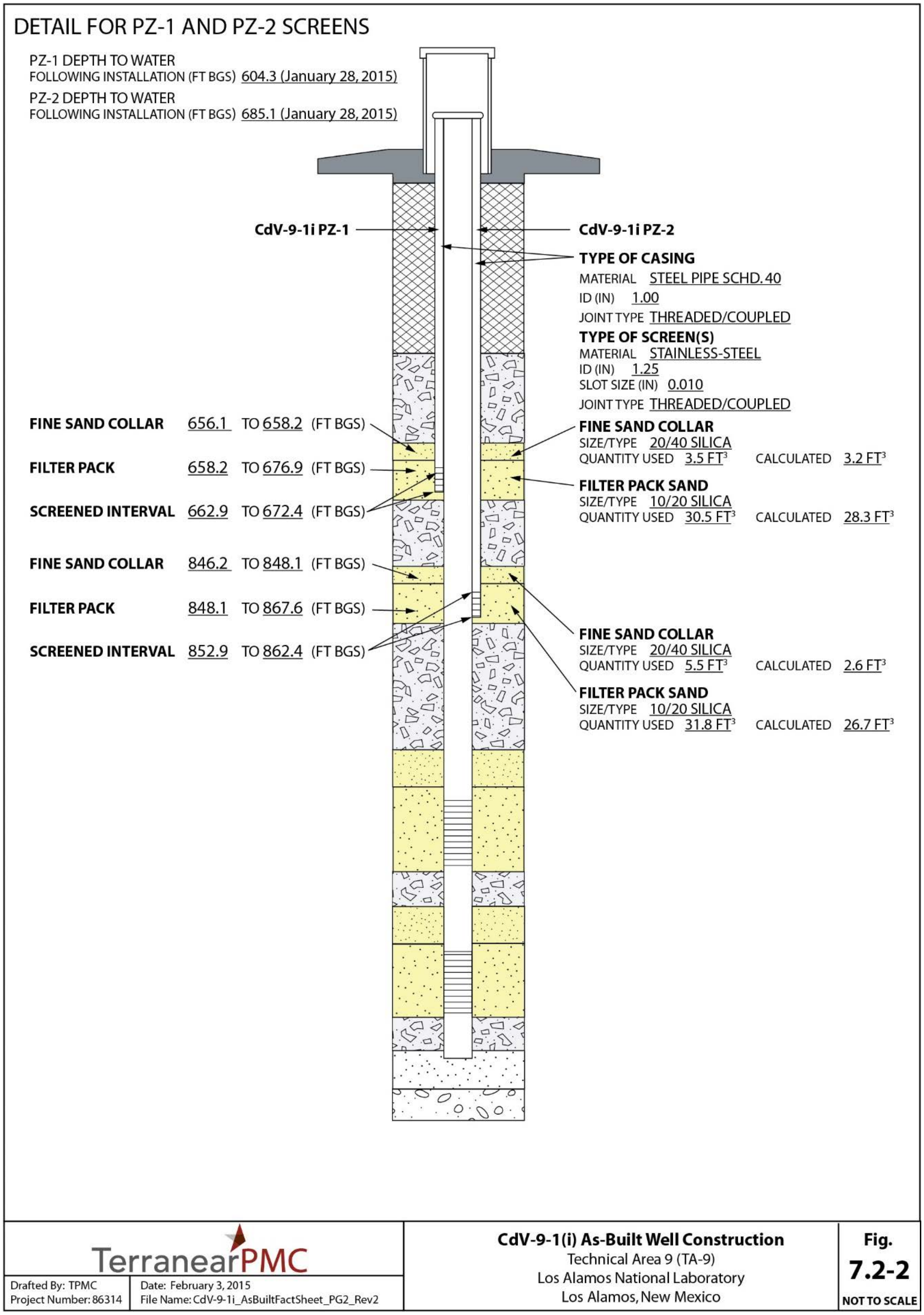


Figure 7.2-2 Monitoring well CdV-9-1(i) as-built well construction diagram

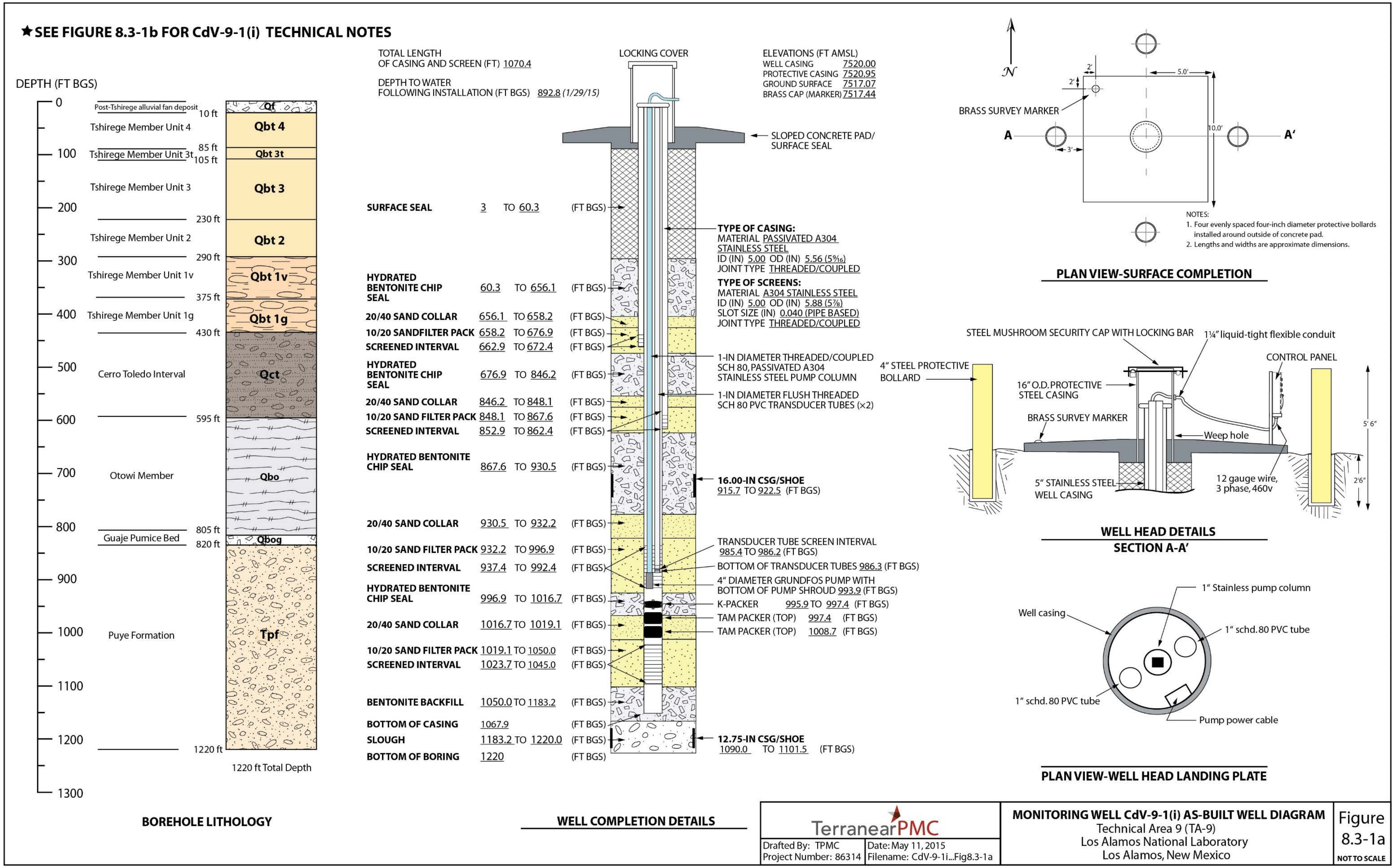


Figure 8.3-1a Monitoring well CdV-9-1(i) as-built diagram with borehole lithology and technical well completion details

CdV-9-1(i) TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker
Northing: 1764875.09 ft
Easting: 1615113.20 ft
Elevation: 7517.44 ft AMSL

Well Casing (top of stainless steel)
Northing: 1764875.04 ft
Easting: 1615117.24 ft
Elevation: 7520.00 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

Schlumberger geophysical suite
LANL video log

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam (to 695 ft bgs)

MILESTONE DATES

Drilling
Start: 10/24/2014
Finished: 11/21/2014

Well Completion
Start: 12/11/2014
Finished: 01/19/2015

Well Development
Start: 01/20/2015
Finished: 02/25/2015

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 55,416 gal.

Parameter Measurements (Final)
pH: 7.32
Temperature: 12.70°C
Specific Conductance: 144.0 µS/cm
Turbidity: 49.9 NTU

AQUIFER TESTING

Constant Rate Pumping Test
Water Produced: 19,058 gal.
Average Flow Rate: 3.3 gpm
Performed on: 03/05–11/2015

DEDICATED SAMPLING SYSTEM

Pump (Shrouded)
Make: Grundfos
Model: 5S30-820CBM
S/N: P11910088
Environmental retrofit
Base of shroud 993.9 ft bgs

Motor
Make: Franklin Electric
Model: 2343262604
3 hp, 3-phase, 460V

Pump Column
1-in. threaded/coupled schd. 80, pickled and passivated A304 stainless steel tubing

Transducer Tubes
2 × 1-in. flush threaded schd. 80 PVC tubing, 0.010-in. slot screens at 985.4-986.2 ft bgs

Transducer
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/N: 405998

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

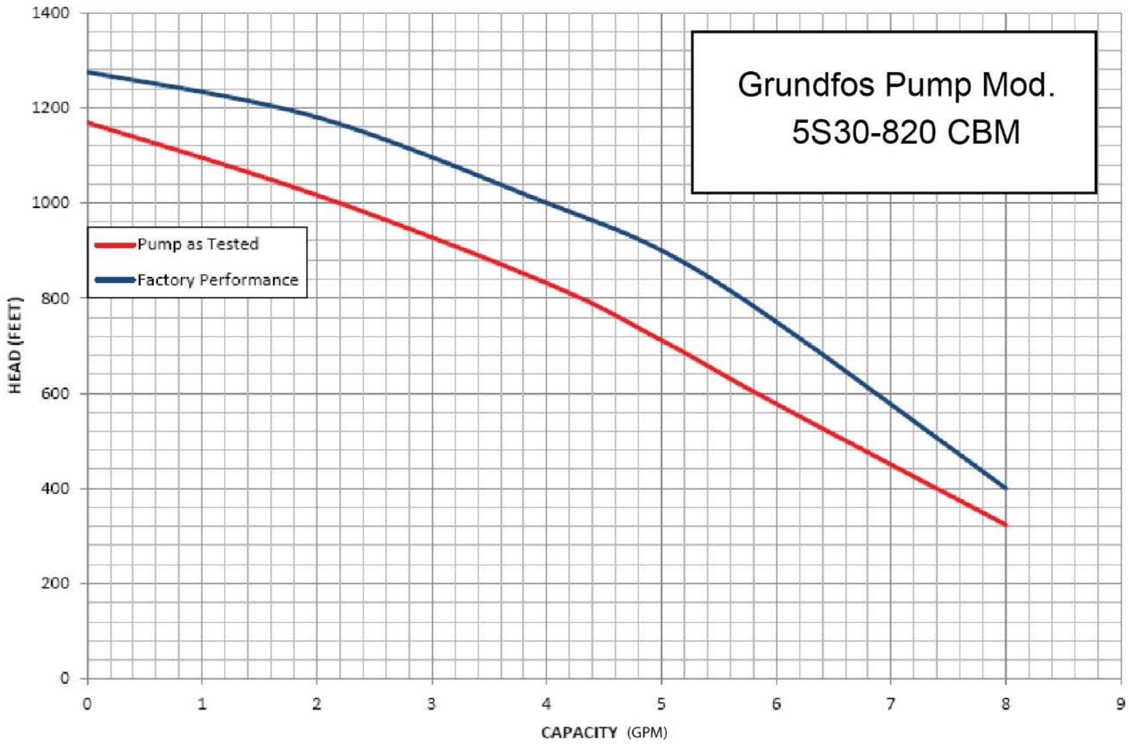
TerranearPMC
Drafted By: TPMC
Project Number: 86314
Date: May 6, 2015
Filename: CdV91i_TechnicalNotes_Fig8.3-1b

CdV-9-1(i) TECHNICAL NOTES
Technical Area 9 (TA-9)
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 CdV-9-1(i)

CdV-9-1(i) PUMP CURVE:



TerranearPMC		CdV-9-1(i) DEDICATED PUMP PERFORMANCE CURVE Technical Area 9 (TA-9) Los Alamos National Laboratory Los Alamos, New Mexico	Fig. 8.3-1c NOT TO SCALE
Drafted By: TPMC Project Number: 86314	Date: April 15, 2015 Filename: CdV91i_PumpCurves_Fig8-3-1c		

Figure 8.3-1c Pump curves for monitoring well CdV-9-1(i)

Table 3.1-1
Fluid Quantities Used during CdV-9-1(i) Drilling and Well Construction

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	Quick Foam (gal.)	Cumulative Quick Foam (gal.)
Drilling					
10/24/14	0–35	1200	1200	6	6
10/25/14	35–65	600	1800	3	9
10/26/14	65–87	1800	3600	9	18
10/27/14	87–90.5	1500	5100	7.5	25.5
10/28/14	90.5–100	1500	6600	7.5	33
10/30/14	100–105	900	7500	4.5	37.5
10/31/14	105–114	1200	8700	6	43.5
11/1/14	114–196	3900	12600	24.5	68
11/2/14	196–244	3900	16500	18.5	86.5
11/3/14	244–254	2100	18600	10	96.5
11/4/14	254–337	3600	22200	10	106.5
11/5/14	337–497	3600	25800	16	122.5
11/6/14	497–696	3300	29100	0.5	123
11/9/14	696–744	1050	30150	1.5	124.5
11/10/14	744–844	3950	34100	7.5	132
11/11/14	844–924	850	34950	4	136
11/14/14	n/a*	5500	40450	n/a	136
11/17/14	924–978	780	41230	0	136
11/18/14	978–1060	0	41230	0	136
11/19/14	1060–1160	500	41730	0	136
11/20/14	1160–1220	5150	46880	0	136
11/21/14	n/a	6300	53180	0	136
11/25/14	n/a	3600	56780	0	136
Well Construction					
12/17/14	1183–1097	9194	9194	n/a	n/a
12/18/14	1097–1091	677	9871	n/a	n/a
12/19/14	1091–1031	8660	18531	n/a	n/a
12/20/14	1031–1012	5019	23550	n/a	n/a
12/21/14	1012–997	2830	26380	n/a	n/a
1/7/15	997–970	2600	28980	n/a	n/a
1/8/15	970–932	2989	31969	n/a	n/a
1/9/15	932–920	1960	33929	n/a	n/a
1/11/15	920–851	7876	41805	n/a	n/a
1/12/15	851–780	10,631	52436	n/a	n/a

Table 3.1-1 (continued)

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	Quick Foam (gal.)	Cumulative Quick Foam (gal.)
1/13/14	780–658	11,853	64289	n/a	n/a
1/14/15	658–563	10,349	74638	n/a	n/a
1/15/15	563–444	8370	83008	n/a	n/a
1/16/15	444–355	1401	84409	n/a	n/a
1/17/15	355–143	1650	86059	n/a	n/a
1/18/15	143–5	1620	87679	n/a	n/a
1/19/15	5–3	24	87703	n/a	n/a
Packer Retrieval and Inflation					
1/29/15	n/a	760	760	n/a	n/a
2/1/15	n/a	150	910	n/a	n/a
2/4/15	n/a	1800	2710	n/a	n/a
2/6/15	n/a	141	2851	n/a	n/a
2/7/15	n/a	165	3016	n/a	n/a
2/10/15	n/a	900	3916	n/a	n/a
2/11/15	n/a	50	3966	n/a	n/a
2/13/15	n/a	420	4386	n/a	n/a
2/14/15	n/a	334	4720	n/a	n/a
2/15/15	n/a	274	4994	n/a	n/a
Total Water Volume (gal.)					
CdV-9-1(i)	149,477				

*n/a = Not applicable.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Well Development, Aquifer Testing, and Piezometer Development at Well CdV-9-1(i)

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
CdV-9-1(i)	CACV-15-90457	11/13/14	924.0	Groundwater, Bailed	LH_3, HEXP, Perchlorate, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-90435	11/17/14	922.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90436	11/17/14	940.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90437	11/17/14	960.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90438	11/18/14	980.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90439	11/18/14	1020.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90440	11/18/14	1040.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90441	11/19/14	1061.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90442	11/19/14	1120.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90443	11/19/14	1140.0	Groundwater, Air lifted	RDX
Well Development					
CdV-9-1(i)	CACV-15-90100	1/26/15	1005.5	Groundwater, Pumped	Anions, Metals
CdV-9-1(i)	CACV-15-90107	1/26/15	1005.5	Groundwater, Pumped	TOC
CdV-9-1(i)	CACV-15-90445	1/26/15	1005.5	Groundwater, Pumped	RDX
CdV-9-1(i)	CACV-15-92696	1/27/15	992.0	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92697	1/28/15	992.0	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92698	2/17/15	992.4	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92699	2/18/15	992.4	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92700	2/19/15	992.4	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92701	2/20/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92702	2/21/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92703	2/22/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92704	2/23/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92705	2/24/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92706	2/25/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
Piezometer Development					
CdV-9-1(i)	CACV-15-90446	3/3/15	614.4	Groundwater, Pumped	RDX
CdV-9-1(i)	CACV-15-90447	3/3/15	614.1	Groundwater, Pumped	RDX
Aquifer Testing					
CdV-9-1(i)	CACV-15-92707	3/8/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92708	3/9/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92709	3/9/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92710	3/10/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-93354	3/10/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-93355	3/11/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals

Table 7.2-1
CdV-9-1(i) Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: cement slurry	165.8 ft^3
Upper bentonite seal: bentonite chips	877.8 ft^3
PZ-1 Fine-sand collar: 20/40 silica sand	3.5 ft^3
PZ-1 Filter pack: 10/20 silica sand	30.5 ft^3
PZ bentonite seal: bentonite chips	218.4 ft^3
PZ-2 Fine-sand collar: 20/40 silica sand	5.5 ft^3
PZ-2 Filter pack: 10/20 silica sand	31.8 ft^3
Middle bentonite seal	70 ft^3
Upper screen fine-sand collar: 20/40 sand	3.5 ft^3
Upper screen filter pack: 10/20 sand	118.5 ft^3
Mid-screen bentonite seal: bentonite chips	18.2 ft^3
Lower screen fine-sand collar: 20/40 sand	8.5 ft^3
Lower screen filter pack: 10/20 sand	70.0 ft^3
Backfill: bentonite chips	123.3 ft^3

Table 8.5-1
CdV-9-1(i) Survey Coordinates

Identification	Northing	Easting	Elevation
CdV-9-1(i) brass cap embedded in pad	1764875.09	1615113.20	7517.44
CdV-9-1(i) ground surface near pad	1764876.81	1615110.28	7517.07
CdV-9-1(i) top of stainless-steel well casing	1764875.04	1615117.24	7520.00
CdV-9-1(i) top of 16-in. protective casing	1764874.94	1615116.74	7520.95
CdV-9-1i piezometer 1	1764874.81	1615117.68	7519.49
CdV-9-1i piezometer 2	1764874.54	1615117.61	7519.56

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

Table 8.6-1
Summary of Waste Samples Collected during
Drilling, Development and Sample System Installation at CdV-9-1(i)

Location ID	Sample ID	Date Collected	Description	Sample Type
CdV-9-1(i)	WST09-15-95426	3/26/15	Drill fluids (unfiltered sample)	Liquid
CdV-9-1(i)	WST09-15-95425	3/26/15	Drill fluids (filtered sample)	Liquid
CdV-9-1(i)	WST09-15-95427	3/26/15	Drill fluids (field duplicate)	Liquid
CdV-9-1(i)	WST09-15-95429	3/26/15	Drill fluids (field trip blank)	Liquid
CdV-9-1(i)	Pending fluids removal	Pending	Drill cuttings (waste sample)	Solids
CdV-9-1(i)	Pending fluids removal	Pending	Drill cuttings (field trip blank)	Solids
CdV-9-1(i)	WST09-15-95319	5/6/15	Decon fluid (filtered sample)	Liquid
CdV-9-1(i)	WST09-15-95320	5/6/15	Decon fluid (unfiltered sample)	Liquid
CdV-9-1(i)	WST09-15-95321	5/6/15	Decon fluid (field duplicate)	Liquid
CdV-9-1(i)	WST09-15-95322	5/6/15	Decon fluid (field trip blank)	Liquid
CdV-9-1(i)	WST09-15-95409	3/26/15	Development water (filtered sample)	Liquid
CdV-9-1(i)	WST09-15-95410	3/26/15	Development water (unfiltered sample)	Liquid
CdV-9-1(i)	WST09-15-95411	3/26/15	Development water (field duplicate)	Liquid
CdV-9-1(i)	WST09-15-95412	3/26/15	Development water (field trip blank)	Liquid

Appendix A

Borehole CdV-9-1(i) Lithologic Log

<table>
<tr><td>BOREHOLE IDENTIFICATION (ID):
CdV-9-1(i)</td><td colspan="3">TECHNICAL AREA (TA): 09</td></tr>
<tr><td>DRILLING COMPANY:
Boart Longyear Company</td><td colspan="2">START DATE/TIME: 10/24/14; 0915</td><td>END DATE/TIME: 11/21/14; 0545</td></tr>
<tr><td>DRILLING METHOD:
Dual Rotary</td><td colspan="2">MACHINE: Foremost DR-24 HD</td><td>SAMPLING METHOD: Grab</td></tr>
<tr><td colspan="3">GROUND ELEVATION: 7517.07 ft amsl</td><td>TOTAL DEPTH: 1220 ft</td></tr>
<tr><td colspan="2">DRILLERS: D. Sandy, M. Cross, R. Ostler</td><td colspan="2">SITE GEOLOGISTS: T. Naibert, T. Sower, R. McGuill, J. Jordan, L. Anderson</td></tr>
<tr><td>DEPTH (ft bgs)</td><td>LITHOLOGY</td><td>LITHOLOGIC SYMBOL</td><td>NOTES</td></tr>
<tr><td>0–10</td><td>Coarse volcanic sediments—Rounded clasts of pale brown (5YR 5/2), strongly welded, crystal-bearing tuff and dacite.
0'–10' WR/+10F: 100% subrounded ash-flow tuff or dacite clasts
+35F: 95% rounded tuff and lithic fragments; <5% crystals</td><td>Qf</td><td>Note: Drill cuttings for descriptive analysis were collected at 5-ft intervals from ground surface to borehole TD at 1220 ft bgs.</td></tr>
<tr><td>10–35</td><td>UNIT 4 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:
Rhyolitic Tuff—Pale brown (5YR 5/2) strongly welded, crystal-bearing tuff with lithic fragments.
10'–35' WR/+10F: 95% welded ash-flow tuff fragments; 5% rhyolitic and dacitic lithic clasts.
+35F: 90% welded ash-flow tuff fragments; 5% rhyolitic and dacitic lithic clasts; <5% quartz and sanidine crystals.</td><td>Qbt 4</td><td>Unit 4 of the Tshirege Member of the Bandelier Tuff (Qbt 4), encountered from 10 to 85 ft bgs, is 75 ft thick.</td></tr>
<tr><td>35–65</td><td>Rhyolitic Tuff—pale orange (10YR 8/2), moderately welded, crystal-bearing tuff with lithic fragments.
35'–65' WR/+10F: 50%–70% welded ash-flow tuff fragments; 25%–45% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts.
+35F: 50%–90% quartz and sanidine crystals; 10%–50% welded ash-flow tuff fragments; trace rhyolitic and dacitic lithic clasts.</td><td>Qbt 4</td><td></td></tr>
<tr><td>65–70</td><td>No sample returns</td><td>Qbt 4</td><td></td></tr>
</table>

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
70–85	Rhyolitic Tuff—Light gray (N7 to N8) strongly welded, crystal-bearing tuff with minor lithic fragments 70'–85' WR/+10F: 50%–70% welded ash-flow tuff fragments; 25%–45% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts. +35F: 50%–80% quartz and sanidine crystals; 20%–50% welded ash-flow tuff fragments; trace rhyolitic and dacitic lithic clasts.	Qbt 4	The Qbt 4/Qbt 3t contact, estimated at 85 ft bgs, is based on natural gamma logging.
85–105	**UNIT 3t OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Rhyolitic Tuff—Light gray (N8) to grayish-orange (10R 8/2) strongly welded, crystal-bearing tuff with minor lithic fragments 85'–110' WR/+10F: 80%–90% welded ash-flow tuff fragments; 10%–20% quartz and sanidine crystals; trace rhyolitic and dacitic lithic clasts. +35F: 60%–90% welded ash-flow tuff fragments; 10%–40% quartz and sanidine crystals; trace rhyolitic and dacitic lithic clasts.	Qbt 3t	Unit 3t of the Tshirege Member of the Bandelier Tuff (Qbt 3t), encountered from 85 to 105 ft bgs, is approximately 20 ft thick. The Qbt 3t/Qbt 3 contact, estimated at 105 ft bgs, is based on natural gamma logging.
105–185	**UNIT 3 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Rhyolitic Tuff—Light gray (N8) to grayish-orange (10R 8/2) moderately welded, crystal-bearing tuff with minor lithic fragments 110'–185' WR/+10F: 40%–70% welded ash-flow tuff fragments; 25%–55% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts. +35F: 70%–90% quartz and sanidine crystals; 10%–30% welded ash-flow tuff fragments; trace rhyolitic and dacitic lithic clasts.	Qbt 3	Unit 3 of the Tshirege Member of the Bandelier Tuff (Qbt 3), encountered from 105 to 230 ft bgs, is approximately 125 ft thick.
185–230	Rhyolitic Tuff—Light gray (N8) to grayish-orange (10R 8/2) moderately welded, crystal-bearing tuff with minor lithic fragments 185'–230' WR/+10F: 60%–80% quartz and sanidine crystals; 20%–40% welded ash-flow tuff fragments; <5% rhyolitic and dacitic lithic clasts. +35F: 90%–95% quartz and sanidine crystals; 5%–10% welded ash-flow tuff fragments; trace rhyolitic and dacitic lithic clasts.	Qbt 3	The Qbt 3/Qbt 2 contact, estimated at 230 ft bgs, is based on abrupt slowing of penetration rate during drilling.
230–235	**UNIT 2 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—Gray (N6) to pale brown (5YR 6/2), strongly welded, crystal-rich tuff. 230'–235' WR/+10F: 55%–60% welded ash-flow tuff fragments; 40% quartz and sanidine crystals; <5% rhyolitic and dacitic lithic clasts. +35F: 80% quartz and sanidine crystals; 20% welded ash-flow tuff fragments; trace rhyolitic and dacitic lithic clasts.	Qbt 2	Unit 2 of the Tshirege Member of the Bandelier Tuff (Qbt 2), encountered from 230 to 290 ft bgs, is approximately 60 ft thick.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
235–275	Rhyolitic Tuff—Pale brown (5YR 6/2), strongly welded, crystal-rich tuff. 235’–275’ WR/+10F: 85%–95% welded ash-flow tuff fragments; 5%–15% quartz and sanidine crystals. +35F: 70%–90% welded ash-flow tuff fragments; 10%–30% quartz and sanidine crystals.	Qbt 2	
275–290	Rhyolitic Tuff—Pale brown (5YR 6/2), strongly welded, crystal-rich tuff. 275’–280’ WR/+10F: 85%–95% welded ash-flow tuff fragments; 5%–15% quartz and sanidine crystals. +35F: 70% quartz and sanidine crystals; 30% welded ash-flow tuff fragments.	Qbt 2	The Qbt 2/Qbt 1v contact, estimated at 290 ft bgs, is based on natural gamma logging.
290–300	**UNIT 1v OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—Pale brown (5YR 6/2), strongly welded, crystal-rich tuff. 280’–300’ WR/+10F: 85%–95% welded ash-flow tuff fragments; 5%–15% quartz and sanidine crystals. +35F: 50%–80% welded ash-flow tuff fragments; 20%–50% quartz and sanidine crystals.	Qbt 1v	Unit 1v of the Tshirege Member of the Bandelier Tuff (Qbt 1v), encountered from 290 to 375 ft bgs, is approximately 85 ft thick.
300–315	Rhyolitic Tuff—Pale brown (5YR 6/2), strongly welded, crystal-rich tuff. 300’–315’ WR/+10F: 85%–95% welded ash-flow tuff fragments; 5%–15% quartz and sanidine crystals. +35F: 50%–70% quartz and sanidine crystals; 30%–50% welded ash-flow tuff fragments.	Qbt 1v	
315–330	Rhyolitic Tuff—Pale brown (5YR 6/2), strongly welded, crystal-rich tuff. 315’–330’ WR/+10F: 85%–95% welded ash-flow tuff fragments; 5%–15% quartz and sanidine crystals. +35F: 80%–95% quartz and sanidine crystals; 5%–20% welded ash-flow tuff fragments.	Qbt 1v	
330–375	Rhyolitic Tuff—Light gray (N7), poorly welded, crystal-rich tuff with minor devitrified pumice. 330’–345’ WR: 70%–80% quartz and sanidine crystals; 20%–30% ash-flow tuff fragments; trace devitrified pumice. +10F: 30%–70% rhyolitic tuff fragments; 30%–70% euhedral quartz and sanidine crystals; trace pumice clasts. +35F: 80%–90% quartz and sanidine crystals; 10%–20% rhyolitic tuff fragments.	Qbt 1v	The Qbt 1v/Qbt 1g contact, estimated at 375 ft bgs, is based on natural gamma logging

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
375–385	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—Light gray (N6 to N7), poorly welded, crystal-rich tuff with minor glassy pumice. 345'–385' WR: 70%–80% quartz and sanidine crystals; 20%–30% ash-flow tuff fragments; <5% dacite lithics; trace devitrified pumice. +10F: 30%–70% rhyolitic tuff fragments; 30%–70% euhedral quartz and sanidine crystals; <5% dacite lithics; trace pumice clasts. +35F: 80%–90% quartz and sanidine crystals; 10%–20% rhyolitic tuff fragments; trace lithic fragments.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 375 to 460 ft bgs, is approximately 85 ft thick.
385–395	Rhyolitic Tuff—medium gray (N6), poorly welded, crystal-rich tuff with minor glassy pumice. 385'–395' WR: 50%–70% quartz and sanidine crystals; 25%–30% ash-flow tuff fragments; 5%–20% dacite lithics; trace devitrified pumice. +10F: 30%–70% rhyolitic tuff fragments; 20%–40% dacite lithics; 20%–40% euhedral quartz and sanidine crystals; trace pumice clasts. +35F: 80%–90% quartz and sanidine crystals; 10%–20% rhyolitic tuff fragments; trace lithic fragments.	Qbt 1g	
395–430	Rhyolitic Tuff—Light gray (N6 to N7), poorly welded, crystal-rich tuff with abundant glassy pumice. 395'–430' WR: 30%–50% quartz and sanidine crystals; 20%–40% white to orange pumice clasts; 10%–20% dacite lithics; <10% ash-flow tuff fragments. +10F: 30%–70% rhyolitic tuff fragments; 30%–70% pumice clasts; 5%–15% euhedral quartz and sanidine crystals; <5% dacite lithics. +35F: 80%–90% quartz and sanidine crystals; 10%–20% pumice clasts; 5%–10% ash-flow tuff fragments; trace lithic fragments.	Qbt 1g	The Qbt 1g/Qct contact, estimated at 430 ft bgs, is based on natural gamma logging.
430–530	**CERRO TOLEDO INTERVAL** Volcaniclastic Sediments—Silt- to sand-size angular quartz grains with orange oxidation staining, reworked white and orange pumice clasts, and dacite and rhyolite clasts. 430'–530' WR: 20%–50% quartz grains; 20%–50% white to orange pumice clasts; 10%–40% dacite clasts. +10F: 30%–70% dacite and rhyolite clasts; 30%–70% pumice clasts; 5%–15% angular quartz grains; +35F: 80%–90% angular quartz grains; 10%–20% pumice clasts; 5%–10% volcanic clasts.	Qct	The Cerro Toledo interval (Qct), encountered from 430 to 595 ft bgs, is approximately 165 ft thick.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
530–580	Volcaniclastic Sediments—Silt- to sand-size angular quartz grains with orange oxidation staining, reworked white and orange pumice clasts, and dacite and rhyolite clasts. 530’–580’ WR: 30%–50% dacite clasts; 20%–40% quartz grains; 10%–30% white to orange pumice clasts. +10F: 50%–80% dacite and rhyolite clasts; 20%–50% pumice clasts. +35F: 60%–80% angular quartz grains; 20%–30% volcanic clasts; 10%–20% pumice clasts.	Qct	
580–595	Volcaniclastic Sediments—Silt- to sand-size angular quartz grains with orange oxidation staining, reworked white and orange pumice clasts, and dacite and rhyolite clasts. 580’–595’ WR: 40%–60% dacite clasts; 20%–40% quartz grains; 5%–20%; white to orange pumice clasts. +10F: 70%–90% dacite and rhyolite clasts; 10%–30% pumice clasts. +35F: 40%–60% angular quartz grains; 20%–30% volcanic clasts; 20%–30% pumice clasts.	Qct	The Qct/Qbo contact, estimated at 595 ft bgs, is based on natural gamma logging.
595–650	**OTOWI MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—White (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 595’–650’ WR: 30%–50% white to orange pumices; 20%–40% dacite lithics; 20%–30% quartz grains. +10F: 40-60% dacite and rhyolite lithics; 40%–60% pumice clasts. +35F: 80%–95% angular quartz grains; 5%–20% pumice; 0%–5% volcanic lithics.	Qbo	The Otowi Member of the Bandelier Tuff (Qbo), encountered from 595 to 805 ft bgs, is approximately 210 ft thick.
650-695	Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 650’–695’ WR: 40%–70% white to orange pumice; 10%–30% dacite lithics; 10%–30% quartz grains. +10F: 50%–80% pumice; 20%–50% dacite and rhyolite lithics. +35F: 40%–60% angular quartz grains; 30%–50% pumice; 5%–10% volcanic lithics.	Qbo	
695–700	No sample returns	Qbo	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
700–710	Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 620'–650' WR: 30%–50% white to orange pumice; 20%–40% dacite lithics; 20%–30% quartz grains. +10F: 40-60% dacite and rhyolite lithics; 40%–60% pumice. +35F: 80%–95% angular quartz grains; 5%–20% pumice; 0%–5% volcanic lithics.	Qbo	
710–725	No sample returns	Qbo	
725–745	Rhyolitic Tuff—White (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 725'–745' WR: 40%–70% white to orange pumice; 10-30% dacite lithics; 10%–30% quartz grains. +10F: 50%–80% pumice; 20%–50% dacite and rhyolite lithics. +35F: 40%–60% angular quartz grains; 30%–50% pumice; 5%–10% volcanic lithics.	Qbo	Note: The samples collected as a single sample between 725 and 745 ft and were separated into multiple chip trays.
745–800	Rhyolitic Tuff—White (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 745'–800' WR: 40%–60% white to orange pumice; 30%–50% quartz grains; 10%–20% dacite lithics. +10F: 50%–80% pumice; 20%–50% dacite and rhyolite lithics. +35F: 75%–90% angular quartz grains; 5%–20% pumice; 5%–10% volcanic lithics.	Qbo	
800–805	Rhyolitic Tuff—White (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 800'–805' WR/+10F: 80% rounded gray dacite or red-purple rhyolite lithics; 20% rounded white pumice; trace quartz crystals. +35F: 70% rounded gray dacite or red-purple rhyolite lithic fragments; 25%–30% rounded white pumice; <5% quartz crystals.	Qbo	The Qbo/Qbog contact, estimated at 805 ft bgs, is based on observations of increased pumice while drilling.
805–815	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—White (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 805'–815' WR/+10F: 40%–70% white pumice; 30%–60% gray dacite or red-purple rhyolite lithics; trace quartz crystals. +35F: 50%–60% rounded white pumice; 40%–50% rounded gray dacite or red-purple rhyolite lithic fragments; <5% quartz crystals.	Qbog	The Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog), encountered from 805 to 820 ft bgs, is approximately 15 ft thick. Note: The samples collected as a single sample between 805 and 825 ft and were separated into multiple chip trays.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
815–820	Rhyolitic Tuff—white (N9) poorly welded, pumice- and lithic-rich, crystal-poor tuff. 815'–820' WR/+10F: 40%–70% white pumice; 30%–60% gray dacite or red-purple rhyolite lithics; trace quartz crystals. +35F: 50%–60% rounded white pumice; 40%–50% rounded gray dacite or red-purple rhyolite lithic fragments; <5% quartz crystals.	Qbog	The Qbog/Tpf contact, estimated at 820 ft bgs, is based on volcaniclastic sediments in cuttings, drillers' observations, and natural gamma logging.
820–850	**PUYE FORMATION** Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 820'–850' WR/+10F/+35F: 99%–100% angular to subangular clasts of dacite and rhyolite; <1% devitrified white pumice clasts (possibly falling from above); trace quartz grains.	Tpf	The Puye Formation (Tpf), encountered from 820 to 1220 ft bgs, is at least 400 ft thick.
850–900	Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 850'–900' WR/+10F/+35F: 99%–100% angular to rounded clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: Increased rounding in granule to small gravel size clasts from 850 to 865 ft bgs.
900–950	Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 900'–950' WR/+10F/+35F: 99%–100% angular to subangular clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: More rounding in this interval.
950–975	Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 950'–975' WR/+10F/+35F: 99%–100% angular to subangular clasts of dacite and rhyolite; trace quartz grains in +35F.	Tpf	Note: Increase is grain size to 25+ mm and increase in angular clasts compared with above indicates coarser conglomerates at these depths.
975–1080	Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 975'–1080' WR/+10F/+35F: 99%–100% angular to subangular clasts of dacite and rhyolite up to 20 mm; trace quartz grains in +35F.	Tpf	
1080–1110	Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 1080'–1110' WR/+10F/+35F: 99%–100% angular to subangular clasts of dacite and rhyolite up to 15 mm; trace quartz grains in +35F.	Tpf	Note: Clasts are more uniform in size and dominantly angular, indicating large clasts in conglomerates were broken up while drilling and possibly this zone is more cemented than above. Crew observed lots of fine silt in cuttings while drilling, which was largely lost when chips were wet sieved.
1110–1220	Volcaniclastic Sediments—Varicolored grains of dacite and rhyolite. 1110'–1220' WR/+10F/+35F: 99%–100% angular to subangular clasts of dacite and rhyolite up to 15mm; trace quartz grains in +35F.	Tpf	Note: Crew observed easier drilling and less sand-/silt-size clasts in this zone while drilling. Total depth=1220 ft

ABBREVIATIONS

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

% = Estimated percent by volume of a given sample constituent.

amsl = above mean sea level

bgs = below ground surface

Qf = Post-Tshirege alluvial fan deposit

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

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

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

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

Qbt 1v = Unit 1v (vapor-phase) of the Tshirege Member of the Bandelier Tuff

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

Qct = Cerro Toledo interval

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed

Tpf = Puye Formation

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in

1 in = 25.4 mm

Appendix B

Screening Groundwater Analytical Results for Well CdV-9-1(i)

B-1.0 SCREENING GROUNDWATER ANALYSES AT CdV-9-1(i)

Well CdV-9-1(i) is a dual-screen intermediate aquifer monitoring well with screened intervals set between 937.4 and 992.4 ft below ground surface (bgs) and between 1023.7 and 1045.0 ft bgs in Puye Formation volcaniclastic sediments. Two piezometers (PZ-1 and PZ-2) were installed outside the well casing with screened intervals set between 662.9 and 672.4 ft bgs in the Otowi Member of the Bandelier Tuff, and between 852.9 and 862.4 ft bgs in the Puye Formation. The lower well screen interval was abandoned before development of the screen. This appendix presents screening analytical results for samples collected during drilling, well development and aquifer testing of the upper well screen, and development of the two piezometers at CdV-9-1(i).

Laboratory Analyses

Ten groundwater-screening samples were collected during drilling. Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14) analyzed one of the drilling samples for anions, metals, low-level tritium (LH_3), perchlorate (ClO_4), high explosives (HE), and RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) and nine samples for RDX.

Fourteen groundwater-screening samples were collected during well screen development, and six groundwater samples were collected during aquifer testing. One groundwater sample from each piezometer was collected during piezometer screen development. The Laboratory's EES-14 analyzed the well development samples and the aquifer test samples for anions, metals, total organic carbon (TOC), and RDX. EES-14 also analyzed the piezometer development samples for RDX. Table B-1.0-1 lists the samples submitted for analyses from CdV-9-1(i).

Field Analyses

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

B-2.0 SCREENING ANALYTICAL RESULTS

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

B-2.1 TOC

TOC concentrations were between 1.1 and 2.0 mgC/L in 12 groundwater samples collected during well development at well CdV-9-1(i) (Table B-2.1-1). TOC concentrations were below the target concentration of 2.0 mgC/L at the end of well development. Table B-2.1-1 also presents the U.S. Environmental Protection agency (EPA) method by which the samples were analyzed.

B-2.2 Field Parameters

Field parameters measured during well development and aquifer testing are summarized in Table B-2.2-1. Well development of the upper well screen was initially conducted for 8 d. Development was suspended for 12 d to remove the TAM single set packer between the two well screens. After a second TAM packer was deployed above the first, ensuring isolation of the well screens, development of the upper well screen was conducted for an additional 9 d. Development of PZ-1 and PZ-2 was conducted for 6 d. Aquifer testing was then conducted for 6 d. Well development and aquifer test field parameters are summarized below.

During well development and aquifer testing, pH varied from 5.92 to 8.48 and temperature ranged from 8.51°C to 16.81°C. DO concentrations varied from 1.92 to 7.60 mg/L. Specific conductance ranged from 2 µS/cm to 227 µS/cm, and turbidity values varied from 4.8 to 869.1 nephelometric turbidity units (NTU). Corrected oxidation-reduction potential (Eh) values, determined from field ORP measurements, varied from 271.9 mV to 420.9 mV. One temperature-dependent correction factor was used to calculate Eh values from field ORP measurements: 208.9 mV at 15°C. Figure B-2.2-1 shows the field parameters measured over the course of well development and aquifer testing.

The final parameters measured at the end of the aquifer testing period were pH of 7.11, temperature of 13.44°C, DO of 4.89 mg/L, specific conductance of 146.0 µS/cm, and turbidity of 42.1 NTU.

B-3.0 SUMMARY OF SCREENING ANALYTICAL RESULTS

TOC concentrations were below the target level of 2.0 mgC/L, and turbidity was 42.1 NTU at the end of aquifer testing. CdV-9-1(i) will be sampled quarterly for 1 yr and the data collected will be assessed and incorporated into the Interim Facility-Wide Groundwater Monitoring Plan. Data from ongoing sampling at CdV-9-1(i) will be analyzed and presented in the appropriate periodic monitoring report.

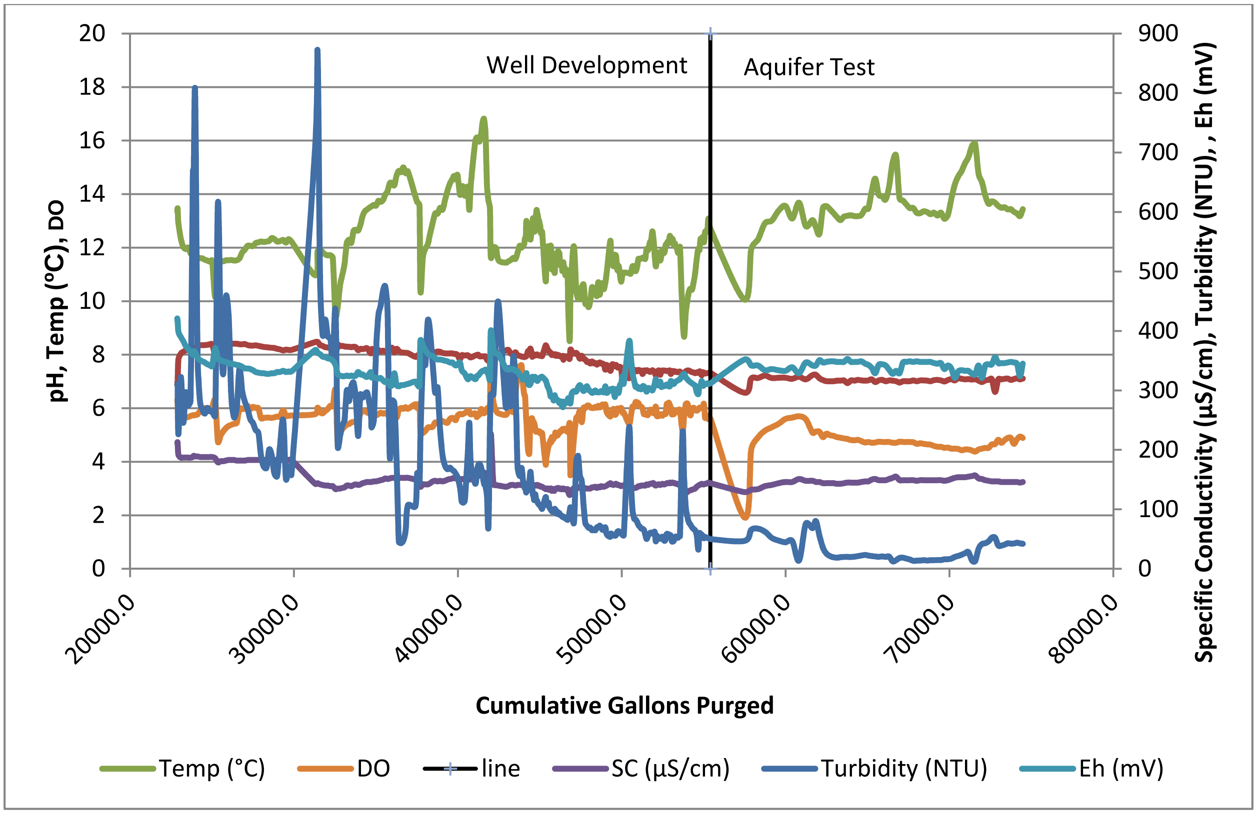


Figure B-2.2-1 Field parameters versus volume purged during CdV-9-1(i) well development and aquifer testing

Table B-1.0-1
Summary of Groundwater Screening Samples Collected during Drilling, Well Development, Aquifer Testing, and Piezometer Development at Well CdV-9-1(i)

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
CdV-9-1(i)	CACV-15-90457	11/13/14	924.0	Groundwater, Bailed	LH_3, HEXP, ClO_4, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-90435	11/17/14	922.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90436	11/17/14	940.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90437	11/17/14	960.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90438	11/18/14	980.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90439	11/18/14	1020.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90440	11/18/14	1040.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90441	11/19/14	1061.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90442	11/19/14	1120.0	Groundwater, Air lifted	RDX
CdV-9-1(i)	CACV-15-90443	11/19/14	1140.0	Groundwater, Air lifted	RDX
Well Development					
CdV-9-1(i)	CACV-15-90100	1/26/15	1005.5	Groundwater, Pumped	Anions, Metals
CdV-9-1(i)	CACV-15-90107	1/26/15	1005.5	Groundwater, Pumped	TOC
CdV-9-1(i)	CACV-15-90445	1/26/15	1005.5	Groundwater, Pumped	RDX
CdV-9-1(i)	CACV-15-92696	1/27/15	992.0	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92697	1/28/15	992.0	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92698	2/17/15	992.4	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92699	2/18/15	992.4	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92700	2/19/15	992.4	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92701	2/20/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92702	2/21/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92703	2/22/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92704	2/23/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92705	2/24/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92706	2/25/15	990.7	Groundwater, Pumped	TOC, RDX, Anions, Metals

Table B-1.0-1 (continued)

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Aquifer Testing					
CdV-9-1(i)	CACV-15-92707	3/8/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92708	3/9/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92709	3/9/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-92710	3/10/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-93354	3/10/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
CdV-9-1(i)	CACV-15-93355	3/11/15	989.2	Groundwater, Pumped	TOC, RDX, Anions, Metals
Piezometer Development					
CdV-9-1(i)	CACV-15-90446	3/3/15	614.4	Groundwater, Pumped	RDX
CdV-9-1(i)	CACV-15-90447	3/3/15	614.1	Groundwater, Pumped	RDX

Table B-2.1-1
TOC Results

Sample ID	EPA Method	TOC Concentration (mgC/L)
CACV-15-90107	SW-846:9060	2.0
CACV-15-92696	SW-846:9060	1.8
CACV-15-92697	SW-846:9060	1.7
CACV-15-92698	SW-846:9060	1.6
CACV-15-92699	SW-846:9060	1.4
CACV-15-92700	SW-846:9060	1.5
CACV-15-92701	SW-846:9060	1.4
CACV-15-92702	SW-846:9060	1.4
CACV-15-92703	SW-846:9060	1.1
CACV-15-92704	SW-846:9060	1.5
CACV-15-92705	SW-846:9060	1.4
CACV-15-92706	SW-846:9060	1.3

Table B-2.2-1
Purge Volumes and Field Parameters during Well Development and Aquifer Testing at CdV-9-1(i)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development									
1/20/15	n/r*; bailing							22.7	22.7
1/21/15	n/r; bailing							358.5	381.2
1/23/15	n/r; bailing							15	396.2
1/24/15	n/r; pumping through screen							6210	6606.2
1/25/15	n/r; pumping through screen							6864.4	13470.6
1/26/15	n/r; pumping in sump							6048.9	19519.5
1/27/15	6.88	13.36	6.27	212	420.9	212	309.6	3356.4	22875.9
	6.97	13.43	6.32	209	417.9	213	310.7	9.8	22885.8
	6.98	13.47	6.33	209	417.9	213	310.3	9.8	22895.6
	7.82	12.92	5.50	190	398.9	192	226.3	49.2	22944.8
	8.04	12.34	5.59	181	389.9	187	322.5	147.6	23092.4
	8.11	12.03	5.65	174	382.9	187	245.8	147.6	23240.0
	8.16	11.95	5.65	166	374.9	187	296.6	147.6	23387.6
	8.21	12.00	5.67	161	369.9	187	274.3	147.6	23535.2
	8.24	11.79	5.71	156	364.9	187	282.2	147.6	23682.8
	8.28	11.70	5.74	151	359.9	188	669.7	147.6	23830.4
	8.18	11.69	5.73	157	365.9	190	670.4	49.2	23879.6
	8.21	11.68	5.75	155	363.9	189	798.4	88.6	23968.2
	8.34	11.64	5.77	146	354.9	189	360.1	147.6	24115.8
	8.35	11.61	5.89	142	350.9	188	281.1	147.6	24263.4
	8.36	11.60	5.87	140	348.9	188	267.4	147.6	24411.0
	8.36	11.55	6.00	138	346.9	188	261.0	147.6	24558.6
	8.37	11.52	5.98	135	343.9	188	270.6	147.6	24706.2
	8.39	11.48	5.99	134	342.9	188	264.9	147.6	24853.8
	8.39	11.52	6.03	132	340.9	188	265.1	147.6	25001.4
1/28/15	8.03	10.15	6.30	162	370.9	186	257.2	188.6	25189.9
	8.34	11.37	4.75	144	352.9	179	614.8	164.7	25354.6
	8.38	11.49	4.98	142	350.9	181	408.9	164.7	25519.3
	8.38	11.49	5.14	140	348.9	181	327.6	164.7	25684.0
	8.39	11.53	5.26	139	347.9	182	457.8	164.7	25848.7
	8.41	11.53	5.34	137	345.9	183	424.3	164.7	26013.4
	8.41	11.54	5.38	136	344.9	183	287.2	164.7	26178.1
	8.41	11.52	5.42	135	343.9	183	254.4	164.7	26342.8

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
1/28/15	8.41	11.53	5.46	134	342.9	182	271.0	164.7	26507.5
	8.39	11.60	5.99	133	341.9	182	336.8	164.7	26672.2
	8.39	11.82	5.97	131	339.9	182	299.1	164.7	26836.9
	8.40	11.93	5.99	128	336.9	182	281.0	164.7	27001.6
	8.36	12.07	6.09	128	336.9	183	268.2	164.7	27166.3
	8.34	12.07	5.97	127	335.9	183	251.6	164.7	27331.0
	8.34	12.06	6.05	125	333.9	183	245.1	164.7	27495.7
	8.35	12.17	6.01	122	330.9	183	233.3	164.7	27660.4
	8.33	12.20	6.00	121	329.9	183	228.5	164.7	27825.1
	8.31	12.23	5.63	120	328.9	183	189.6	164.7	27989.8
	8.29	12.21	5.64	120	328.9	183	171.7	164.7	28154.5
	8.28	12.23	5.65	119	327.9	183	169.8	164.7	28319.2
	8.27	12.25	5.65	119	327.9	183	200.6	164.7	28483.9
	8.26	12.36	5.64	120	328.9	183	191.1	153.7	28637.7
	8.25	12.32	5.66	120	328.9	183	160.4	164.7	28802.4
	8.22	12.23	5.69	122	330.9	183	155.9	164.7	28967.1
	8.20	12.24	5.69	122	330.9	183	202.8	164.7	29131.8
	8.16	12.29	5.92	124	332.9	183	250.0	208.6	29340.4
	8.19	12.19	5.72	122	330.9	183	151.9	164.7	29505.1
	8.18	12.32	5.72	123	331.9	183	172.8	164.7	29669.8
	8.18	12.23	5.73	123	331.9	183	158.9	175.7	29845.5
2/17/15	8.47	10.97	5.78	159	367.9	143	706.6	1438.8	31284.3
	8.48	11.86	6.02	154	362.9	144	869.1	153	31437.3
	8.36	11.95	5.86	152	360.9	142	489.3	153	31590.3
	8.33	11.83	5.81	148	356.9	141	393.7	153	31743.3
	8.28	11.75	5.90	147	355.9	140	419.3	163.2	31906.5
	8.27	11.71	5.97	145	353.9	140	390.7	153	32059.5
	8.24	11.72	6.09	144	352.9	139	387.7	153	32212.5
	8.27	11.62	6.08	141	349.9	139	353.0	153	32365.5
2/18/15	8.03	9.44	6.66	134	342.9	134	433.7	167.1	32532.6
	8.36	9.80	4.63	118	326.9	135	205.0	138	32670.6
	8.32	10.58	5.04	116	324.9	135	223.1	138	32808.6
	8.33	10.98	5.22	115	323.9	136	241.4	138	32946.6
	8.31	11.40	5.31	115	323.9	137	250.7	138	33084.6
	8.30	12.18	5.39	116	324.9	140	300.1	138	33222.6

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/18/15	8.30	12.30	5.41	115	323.9	140	282.1	138	33360.6
	8.28	12.18	5.47	116	324.9	139	307.3	138	33498.6
	8.30	12.63	5.49	115	323.9	141	313.0	138	33636.6
	8.28	12.67	5.50	116	324.9	142	285.6	138	33774.6
	8.17	12.64	5.55	122	330.9	141	223.3	138	33912.6
	8.22	12.85	5.79	118	326.9	142	293.2	138	34050.6
	8.21	13.19	5.89	118	326.9	144	287.9	138	34188.6
	8.23	13.36	5.90	115	323.9	145	294.0	138	34326.6
	8.24	13.43	5.84	114	322.9	146	296.2	138	34464.6
	8.05	13.53	5.79	122	330.9	146	262.7	220.8	34685.4
	8.21	13.54	5.80	113	321.9	146	237.7	46	34731.4
	8.19	13.60	5.78	113	321.9	147	249.6	138	34869.4
	8.19	13.57	5.74	112	320.9	147	365.5	138	35007.4
	8.18	13.75	5.78	111	319.9	148	425.6	138	35145.4
	8.12	13.71	5.83	112	320.9	149	442.2	138	35283.4
	8.15	13.78	5.80	108	316.9	150	467.5	147.2	35430.6
	8.12	13.98	5.82	105	313.9	152	474.8	138	35568.6
	8.10	14.11	5.77	107	315.9	151	435.0	138	35706.6
	8.21	14.41	5.84	99	307.9	152	189.0	138	35844.6
	8.26	14.42	5.90	100	308.9	153	282.6	138	35982.6
	8.09	14.33	5.84	120	328.9	153	279.2	138	36120.6
	8.22	14.70	5.65	100	308.9	154	183.4	138	36258.6
	8.14	14.87	5.94	98	306.9	153	45.6	138	36396.6
	8.09	14.82	6.01	100	308.9	153	43.1	138	36534.6
	8.08	15.00	5.98	100	308.9	153	47.7	138	36672.6
	8.07	14.78	6.04	101	309.9	153	64.3	138	36810.6
	8.06	14.85	5.98	102	310.9	153	106.8	138	36948.6
	7.92	13.91	6.15	106	314.9	150	105.6	460	37408.6
	7.97	13.70	6.01	101	309.9	148	160.7	110.4	37519.0
	7.98	13.59	6.15	98	306.9	148	145.3	138	37657.0
2/19/15	7.60	10.37	5.07	175	383.9	138	218.8	57.8	37714.8
	7.93	11.64	5.08	167	375.9	142	345.9	150	37864.8
	8.03	11.96	5.15	159	367.9	142	342.4	150	38014.8
	8.10	12.13	5.28	153	361.9	142	417.3	150	38164.8
	8.06	12.55	5.29	150	358.9	144	395.5	150	38314.8

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/19/15	8.09	12.93	5.31	149	357.9	147	343.1	150	38464.8
	8.09	13.28	5.47	145	353.9	148	296.0	150	38614.8
	8.12	13.27	5.44	143	351.9	147	304.7	150	38764.8
	8.11	13.49	5.55	143	351.9	148	233.8	150	38914.8
	8.07	13.42	5.52	142	350.9	147	190.8	150	39064.8
	8.05	13.77	5.48	141	349.9	148	173.2	150	39214.8
	8.05	14.13	5.46	140	348.9	150	167.5	150	39364.8
	8.05	14.40	5.60	138	346.9	151	170.2	150	39514.8
	8.05	14.56	5.64	138	346.9	152	166.0	150	39664.8
	8.03	14.68	5.59	135	343.9	153	164.2	105	39769.8
	8.03	14.55	5.56	133	341.9	152	159.5	105	39874.8
	7.99	14.71	5.72	135	343.9	152	154.2	105	39979.8
	7.83	13.98	5.79	138	346.9	150	137.1	147	40126.8
	7.98	14.28	5.77	125	333.9	151	113.3	105	40231.8
	7.98	14.28	5.79	122	330.9	151	111.2	97.5	40329.3
	7.97	13.94	5.82	119	327.9	150	114.9	97.5	40426.8
	7.98	14.27	5.90	110	318.9	150	194.8	176.4	40603.2
	7.93	13.41	5.88	113	321.9	150	245.6	94.5	40697.7
	7.90	14.37	5.77	115	323.9	151	175.2	94.5	40792.2
	7.97	15.99	5.81	110	318.9	158	143.1	270	41062.2
	7.99	16.12	5.67	115	323.9	157	162.7	90	41152.2
	8.00	16.00	5.77	116	324.9	156	174.5	90	41242.2
	7.94	15.97	5.76	119	327.9	158	176.3	84	41326.2
	7.94	16.23	5.97	122	330.9	159	171.0	90	41416.2
	7.94	16.68	5.89	124	332.9	160	157.2	90	41506.2
	7.94	16.81	5.81	124	332.9	162	142.9	90	41596.2
	7.93	16.27	5.88	126	334.9	159	138.5	90	41686.2
	7.81	14.33	5.99	122	330.9	151	122.5	90	41776.2
	7.78	13.76	6.03	117	325.9	149	71.3	90	41866.2
	7.82	13.46	6.06	109	317.9	148	237.6	90	41956.2
2/20/15	5.92	11.65	7.03	191	399.9	227	293.6	54.9	42011.1
	7.77	12.01	6.23	160	368.9	142	292.7	157.5	42168.6
	7.98	11.98	5.91	153	361.9	141	386.1	157.5	42326.1
	8.06	11.53	5.81	152	360.9	140	445.7	157.5	42483.6

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/21/15	8.16	11.44	5.75	128	336.9	138	273.2	439.7	42923.3
	8.18	11.49	5.90	126	334.9	139	337.7	154.5	43077.8
	8.04	11.54	5.91	127	335.9	141	273.2	154.5	43232.3
	8.01	11.62	5.87	127	335.9	141	357.4	154.5	43386.8
	8.09	11.58	6.54	124	332.9	140	309.7	127.5	43514.3
	7.98	11.81	7.19	123	331.9	141	171.6	127.5	43641.8
	7.96	12.07	7.56	117	325.9	141	156.1	127.5	43769.3
	7.93	12.00	7.60	114	322.9	141	169.7	115.5	43884.8
	7.92	12.09	6.91	109	317.9	142	149.0	85.5	43970.3
	7.91	12.13	6.51	114	322.9	142	138.2	76.5	44046.8
	7.92	12.35	6.47	115	323.9	142	135.1	48	44094.8
	7.93	12.31	6.03	118	326.9	141	136.3	42	44136.8
	7.95	12.75	5.66	119	327.9	142	128.4	26.25	44163.0
	7.95	12.99	5.44	120	328.9	143	130.4	26.25	44189.3
	8.13	12.37	4.47	102	310.9	138	132.9	86.8	44276.1
	8.15	12.66	4.31	100	308.9	138	144.2	81	44357.1
	8.23	12.30	5.59	102	310.9	137	163.1	67.5	44424.6
	8.12	12.54	5.60	107	315.9	138	148.7	55.5	44480.1
	8.05	12.83	5.63	108	316.9	141	135.2	37.5	44517.6
	7.92	12.86	5.61	114	322.9	140	134.2	25	44542.6
	8.02	13.10	5.44	109	317.9	141	124.1	37.5	44580.1
	8.00	12.97	5.49	111	319.9	141	122.0	37.5	44617.6
	7.99	12.82	5.44	112	320.9	140	115.4	37.5	44655.1
	7.97	12.60	5.36	114	322.9	140	123.8	37.5	44692.6
	7.98	12.86	5.17	113	321.9	140	125.2	37.5	44730.1
	7.99	13.19	5.12	110	318.9	140	118.2	37.5	44767.6
	8.01	13.41	5.14	109	317.9	141	114.5	37.5	44805.1
	8.01	13.30	5.13	107	315.9	141	114.1	37.5	44842.6
	7.99	13.18	5.15	108	316.9	140	110.5	37.5	44880.1
	7.97	13.06	5.13	110	318.9	140	109.2	37.5	44917.6
	7.97	13.01	5.14	111	319.9	140	107.7	37.5	44955.1
	7.97	12.90	5.13	112	320.9	139	106.8	37.5	44992.6
	7.96	12.79	5.06	113	321.9	139	105.4	37.5	45030.1
	7.96	12.54	5.09	113	321.9	138	103.8	37.5	45067.6
	7.95	12.57	5.08	114	322.9	138	102.5	37.5	45105.1
	7.95	12.59	5.07	114	322.9	138	100.8	37.5	45142.6

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/22/15	8.35	10.76	3.91	108	316.9	134	120.6	213.6	45356.2
	8.33	11.59	4.13	105	313.9	135	109.7	37.5	45393.7
	8.28	11.83	4.25	102	310.9	135	107.4	37.5	45431.2
	8.22	11.84	4.40	98	306.9	135	111.7	37.5	45468.7
	8.18	12.05	4.52	96	304.9	135	106.4	37.5	45506.2
	8.15	11.55	4.59	94	302.9	133	111.1	37.5	45543.7
	8.10	11.72	4.70	91	299.9	134	103.8	37.5	45581.2
	8.09	11.74	4.74	86	294.9	134	101.6	37.5	45618.7
	8.08	12.08	4.81	81	289.9	135	100.3	37.5	45656.2
	8.04	11.98	4.72	81	289.9	135	98.2	37.5	45693.7
	7.99	11.19	4.92	82	290.9	131	98.4	37.4	45731.1
	8.00	11.68	4.85	80	288.9	134	96.0	33	45764.1
	8.02	11.67	4.83	78	286.9	134	96.4	33	45797.1
	7.99	11.66	4.83	78	286.9	134	96.8	17.6	45814.7
	8.01	11.40	4.89	74	282.9	134	97.5	33	45847.7
	8.00	11.10	4.94	79	287.9	131	99.0	33	45880.7
	8.02	11.06	4.93	83	291.9	133	100.9	31.5	45912.2
	8.01	11.48	5.09	79	287.9	134	98.9	31.5	45943.7
	7.96	11.59	5.05	78	286.9	135	98.8	29.4	45973.1
	8.00	11.78	5.01	75	283.9	135	93.1	31.5	46004.6
	8.00	11.65	5.03	76	284.9	135	94.3	37.5	46042.1
	7.96	11.52	4.98	75	283.9	135	95.8	37.5	46079.6
	7.99	11.88	5.03	74	282.9	136	91.9	37.5	46117.1
	7.98	11.54	5.05	72	280.9	135	92.4	37.5	46154.6
	7.96	11.80	5.09	70	278.9	135	93.7	37.5	46192.1
	7.96	11.44	5.14	73	281.9	135	91.6	37.5	46229.6
	7.93	11.33	5.12	72	280.9	134	90.1	37.5	46267.1
	7.94	11.35	5.15	68	276.9	135	89.7	37.5	46304.6
	7.93	11.35	5.19	66	274.9	134	88.5	37.5	46342.1
	7.95	11.12	5.22	64	272.9	134	87.3	37.5	46379.6
	7.95	11.38	5.21	63	271.9	135	88.1	37.5	46417.1
	7.81	11.45	5.23	72	280.9	135	87.7	25	46442.1
	7.94	11.14	5.20	70	278.9	134	86.0	37.5	46479.6
	7.94	11.26	5.17	69	277.9	134	85.9	37.5	46517.1
	7.93	10.97	5.23	71	279.9	134	86.4	37.5	46554.6

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/22/15	7.92	11.10	5.22	71	279.9	134	84.0	37.5	46592.1
	7.92	10.98	5.22	70	278.9	133	84.9	30	46622.1
	7.94	11.16	5.15	72	280.9	134	83.2	37.5	46659.6
	7.94	11.15	5.12	74	282.9	134	82.2	37.5	46697.1
	7.93	9.75	5.21	78	286.9	129	83.6	37.5	46734.6
2/23/15	7.85	8.51	5.43	74	282.9	124	96.7	88.8	46823.4
	8.19	10.09	3.52	69	277.9	130	103.5	42	46865.4
	8.19	10.57	3.77	77	285.9	130	99.3	42	46907.4
	8.13	11.24	3.81	86	294.9	132	96.1	42	46949.4
	8.04	12.04	4.90	90	298.9	136	78.2	136.5	47085.9
	8.07	10.44	5.63	89	297.9	135	179.7	136.5	47222.4
	7.98	10.08	5.71	96	304.9	136	189.9	112.5	47334.9
	7.85	10.15	5.89	100	308.9	138	156.6	112.5	47447.4
	7.96	10.52	5.48	95	303.9	137	147.5	112.5	47559.9
	7.85	10.62	6.02	90	298.9	137	106.3	112	47671.9
	7.82	9.90	6.01	95	303.9	135	76.9	105	47776.9
	7.73	9.92	6.09	98	306.9	135	72.5	102	47878.9
	7.74	9.78	6.10	92	300.9	135	68.9	102	47980.9
	7.67	10.03	6.03	90	298.9	135	69.2	102	48082.9
	7.75	10.52	6.01	87	295.9	137	64.9	102	48184.9
	7.68	10.46	6.01	88	296.9	137	66.0	102	48286.9
	7.69	10.47	6.05	91	299.9	138	64.8	102	48388.9
	7.63	10.19	6.02	88	296.9	136	69.8	95.2	48484.1
	7.68	10.71	6.09	88	296.9	138	69.7	87	48571.1
	7.71	10.24	6.03	88	296.9	137	72.6	87	48658.1
	7.67	10.66	6.09	90	298.9	139	69.4	87	48745.1
	7.67	10.57	6.14	89	297.9	138	65.4	87	48832.1
	7.63	10.45	6.05	88	296.9	138	67.1	82.5	48914.6
	7.44	10.71	6.14	98	306.9	139	69.6	88	49002.6
	7.62	11.08	5.85	87	295.9	140	58.2	82.5	49085.1
	7.40	12.25	5.69	93	301.9	144	53.8	214.5	49299.6
	7.44	11.69	5.86	91	299.9	142	59.4	44	49343.6
	7.64	11.44	5.78	94	302.9	142	57.1	78	49421.6
	7.63	11.32	5.98	93	301.9	141	56.4	78	49499.6
	7.57	11.73	5.76	80	288.9	142	55.6	78	49577.6

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/23/15	7.62	11.69	5.79	93	301.9	143	56.7	78	49655.6
	7.53	11.16	5.99	91	299.9	141	62.2	78	49733.6
	7.52	11.32	5.92	87	295.9	141	63.3	78	49811.6
	7.55	10.99	5.95	100	308.9	140	60.6	78	49889.6
	7.50	10.73	6.01	103	311.9	139	60.3	78	49967.6
	7.01	11.02	5.83	115	323.9	140	56.8	78	50045.6
	7.48	11.07	5.84	103	311.9	140	56.2	78	50123.6
2/24/15	7.12	11.05	5.42	173	381.9	133	236.5	319.4	50443.0
	7.44	11.03	5.67	150	358.9	136	155.8	105	50548.0
	7.46	11.30	6.06	121	329.9	135	100.4	105	50653.0
	7.44	11.30	6.05	107	315.9	136	84.3	105	50758.0
	7.42	11.12	6.23	97	305.9	136	82.9	87	50845.0
	7.38	11.27	6.22	98	306.9	137	79.2	87	50932.0
	7.43	11.58	6.19	94	302.9	139	73.5	87	51019.0
	7.41	11.58	6.08	95	303.9	139	70.8	87	51106.0
	7.40	11.59	6.06	93	301.9	140	67.8	82.5	51188.5
	7.28	11.63	5.99	98	306.9	140	67.3	82.5	51271.0
	7.41	11.62	5.78	98	306.9	140	65.3	82.5	51353.5
	7.39	11.58	5.81	94	302.9	140	57.5	82.5	51436.0
	7.42	11.95	5.75	89	297.9	142	50.1	82.5	51518.5
	7.40	11.90	5.75	95	303.9	141	55.3	82.5	51601.0
	7.36	12.21	5.94	94	302.9	143	60.3	122.5	51723.5
	7.38	12.28	5.93	93	301.9	143	60.8	73.5	51797.0
	7.42	12.61	5.93	91	299.9	144	59.3	73.5	51870.5
	7.39	12.29	5.81	96	304.9	144	60.8	73.5	51944.0
	7.35	11.70	5.90	102	310.9	141	62.3	67.5	52011.5
	7.23	11.30	6.06	110	318.9	140	46.2	67.5	52079.0
	7.37	11.57	5.71	100	308.9	141	55.7	67.5	52146.5
	7.40	11.82	5.70	100	308.9	142	50.2	67.5	52214.0
	7.41	11.75	5.72	100	308.9	142	52.5	67.5	52281.5
	7.25	11.52	5.77	106	314.9	141	52.4	67.5	52349.0
	7.39	11.70	5.77	97	305.9	142	50.4	67.5	52416.5
	7.41	11.92	5.72	98	306.9	143	54.1	67.5	52484.0
	7.41	11.79	5.78	98	306.9	142	49.2	67.5	52551.5
	7.41	11.84	5.81	99	307.9	142	46.9	67.5	52619.0

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
2/24/15	7.40	12.11	5.79	99	307.9	143	50.1	63	52682.0
	7.39	12.12	6.16	101	309.9	144	58.5	63	52745.0
	7.40	12.23	6.15	99	307.9	144	58.7	63	52808.0
	7.40	12.17	6.21	98	306.9	144	57.5	63	52871.0
	7.41	12.44	6.12	98	306.9	145	57.1	63	52934.0
	7.28	12.34	6.02	107	315.9	144	55.7	63	52997.0
	7.38	12.35	5.77	103	311.9	145	46.1	63	53060.0
	7.39	12.30	5.79	102	310.9	145	45.9	63	53123.0
	7.39	12.09	5.78	102	310.9	144	47.5	61.5	53184.5
	7.36	12.16	5.89	105	313.9	144	53.1	61.5	53246.0
	7.37	12.02	5.90	106	314.9	143	54.4	61.5	53307.5
	7.35	11.98	5.86	107	315.9	143	52.7	61.5	53369.0
	7.35	11.81	5.88	108	316.9	142	52.2	61.5	53430.5
	7.35	11.96	5.95	109	317.9	142	54.8	61.5	53492.0
	7.37	12.03	5.94	110	318.9	143	54.9	61.5	53553.5
2/25/15	7.26	9.35	5.15	117	325.9	124	229.2	158.9	53712.4
	7.30	8.67	5.70	119	327.9	126	151.5	96	53808.4
	7.38	9.54	6.15	113	321.9	127	104.9	96	53904.4
	7.41	10.00	6.18	110	318.9	129	88.3	96	54000.4
	7.41	10.35	6.00	107	315.9	131	78.3	96	54096.4
	7.38	10.47	5.73	105	313.9	132	74.4	96	54192.4
	7.35	10.43	5.95	103	311.9	133	70.0	96	54288.4
	7.34	10.70	6.02	101	309.9	134	66.8	96	54384.4
	7.31	11.05	5.94	99	307.9	135	64.8	96	54480.4
	7.34	11.58	5.91	88	296.9	138	56.8	96	54576.4
	7.32	11.96	5.95	85	293.9	140	32.2	96	54672.4
	7.38	11.91	6.02	98	306.9	141	60.2	69	54741.4
	7.35	12.33	6.02	99	307.9	142	57.6	69	54810.4
	7.23	12.30	6.02	107	315.9	143	57.6	69	54879.4
	7.34	12.40	6.01	99	307.9	142	55.4	69	54948.4
	7.33	12.20	6.16	100	308.9	142	51.4	69	55017.4
	7.30	12.59	5.64	102	310.9	143	53.4	69	55086.4
	7.31	12.63	5.66	102	310.9	143	52.8	69	55155.4
	7.31	12.6	5.73	103	311.9	144	52.4	69	55224.4
	7.32	13.09	5.59	102	310.9	145	51.2	69	55293.4
	7.32	12.7	5.61	103	311.9	144	49.9	123	55416.4

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pump Test									
3/5/15	n/r, pumping, mini-tests							231.9	55648.3
3/6/15	n/r, pumping, mini-tests							1573.5	57221.8
3/8/15 to 3/11/15	6.58	10.06	1.92	143	351.9	129	46.9	266.9	57488.7
	7.11	11.94	4.46	133	341.9	133	65.6	414.6	57903.3
	7.13	12.31	4.91	133	341.9	134	67.5	417	58320.3
	7.22	12.91	5.16	125	333.9	139	62.5	417.6	58737.9
	7.13	13.01	5.29	127	335.9	141	52.1	416.4	59154.3
	7.14	13.38	5.42	125	333.9	144	47.5	417	59571.3
	7.14	13.56	5.60	124	332.9	146	44.6	416.4	59987.7
	7.10	13.09	5.65	130	338.9	146	46.8	415.8	60403.5
	7.18	13.68	5.70	120	328.9	151	13.9	415.2	60818.7
	7.08	12.81	5.59	138	346.9	148	75.7	413.4	61232.1
	7.24	13.03	5.09	133	341.9	148	68.3	409.8	61641.9
	7.25	12.76	5.13	133	341.9	146	80.3	204.3	61846.2
	7.12	12.52	5.12	142	350.9	146	55.8	219	62065.2
	7.05	13.5	4.92	138	346.9	144	35.1	219	62284.2
	7.01	13.55	5.05	139	347.9	144	25.5	213	62497.2
	7.01	13.43	4.99	140	348.9	144	21.4	213.6	62710.8
	7.01	13.29	4.97	140	348.9	144	19.4	213	62923.8
	7.03	13.14	4.92	139	347.9	143	18.7	213	63136.8
	7.03	13.03	4.90	139	347.9	143	19.5	212.4	63349.2
	7.04	13.16	4.87	139	347.9	144	20.0	212.4	63561.6
	6.94	13.19	4.85	144	352.9	145	20.1	212.4	63774.0
	7.04	13.21	4.81	139	347.9	145	19.9	212.4	63986.4
	7.03	13.18	4.80	139	347.9	145	20.3	212.4	64198.8
	7.06	13.18	4.82	139	347.9	145	21.3	212.4	64411.2
	7.04	13.22	4.77	140	348.9	146	22.4	211.8	64623.0
	7.03	13.46	4.72	136	344.9	147	23.3	243.57	64866.5
	7.04	13.46	4.74	134	342.9	147	22.3	180.03	65046.6
	7.08	14.11	4.71	129	337.9	150	21.4	211.2	65257.8
	6.98	14.58	4.72	120	328.9	151	20.8	211.8	65469.6
	7.04	13.98	4.75	134	342.9	149	20.2	211.8	65681.4
	7.06	13.92	4.74	135	343.9	149	20.9	211.8	65893.2
	7.01	13.8	4.74	133	341.9	149	20.1	211.8	66105.0

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
3/8/15 to 3/11/15	7.04	14.29	4.74	126	334.9	151	20.6	211.8	66316.8
	7.03	15.19	4.71	119	327.9	153	12.6	215.94	66532.7
	7.01	15.44	4.71	124	332.9	155	14.5	208.27	66741.0
	6.96	13.84	4.75	120	328.9	149	18.3	212.4	66953.4
	7.01	13.76	4.74	138	346.9	149	18.7	210.6	67164.0
	7.01	13.61	4.74	139	347.9	149	17.1	210	67374.0
	7.01	13.48	4.74	140	348.9	149	15.6	210.6	67584.6
	7.04	13.48	4.73	139	347.9	149	13.4	210	67794.6
	7.01	13.3	4.67	140	348.9	148	13.7	210.6	68005.2
	7.04	13.29	4.69	139	347.9	149	14.0	210	68215.2
	7.04	13.36	4.67	139	347.9	149	14.5	210.6	68425.8
	7.03	13.33	4.65	139	347.9	149	14.0	210.6	68636.4
	7.01	13.25	4.64	139	347.9	149	14.5	210.6	68847.0
	7.05	13.31	4.59	137	345.9	149	14.4	210.6	69057.6
	7.06	13.2	4.56	136	344.9	149	14.8	210.6	69268.2
	7.04	13.31	4.56	137	345.9	149	14.8	210.6	69478.8
	7.00	13.08	4.52	127	335.9	148	16.0	211.2	69690.0
	7.05	13.22	4.53	133	341.9	149	16.2	211.2	69901.2
	7.09	13.81	4.49	128	336.9	151	17.1	210	70111.2
	7.04	14.35	4.49	112	320.9	153	20.0	210	70321.2
	7.12	14.66	4.48	123	331.9	154	21.7	208.8	70530.0
	7.10	14.86	4.43	125	333.9	154	23.7	208.8	70738.8
	7.08	15.15	4.46	124	332.9	154	26.2	208.2	70947.0
	7.09	15.38	4.46	124	332.9	155	28.1	208.2	71155.2
	7.07	15.81	4.42	119	327.9	156	13.7	228.36	71383.5
	7.09	15.88	4.38	118	326.9	157	13.1	186.3	71569.8
	7.03	14.76	4.46	133	341.9	152	33.7	207	71776.8
	6.98	14.46	4.49	112	320.9	151	41.5	201.6	71978.4
	7.04	13.95	4.52	133	341.9	149	43.1	205.2	72183.6
	7.06	13.64	4.52	135	343.9	148	46.3	204.6	72388.2
	7.09	13.73	4.65	135	343.9	147	52.5	198.6	72586.8
	6.61	13.68	4.66	147	355.9	147	52.3	197.4	72784.2
	7.08	13.56	4.82	137	345.9	147	39.2	195	72979.2
	7.08	13.49	4.71	137	345.9	146	39.0	192.6	73171.8
	7.10	13.51	4.81	137	345.9	146	40.7	192	73363.8

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
3/8/15 to 3/11/15	7.11	13.43	4.89	138	346.9	146	43.0	190.8	73554.6
	7.06	13.44	4.89	139	347.9	146	42.3	189.6	73744.2
	7.09	13.34	4.67	138	346.9	146	42.6	188.4	73932.6
	7.12	13.28	4.84	136	344.9	146	43.9	187.8	74120.4
	7.08	13.18	4.94	115	323.9	145	42.9	184.8	74305.2
	7.11	13.44	4.89	136	344.9	146	42.1	169.4	74474.6

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

*n/r = Not recorded.

Appendix C

Schlumberger Geophysical Logs
(on CD included with this document)

Appendix D

Borehole Video Logging
(on DVD included with this document)

Appendix E

Final Well Design and
New Mexico Environment Department Approval

CdV-9-1(i) Well Objectives

The CdV-9-1(i) well is intended to characterize the northern extent of HE-contaminated deep-perched groundwater associated with the 260 Outfall. CdV-9-1(i) is located to intersect potential pathways for HE migration from the infiltration region north of Canon de Valle.

The drilling work plan for CdV-9-1(i) (LANL 2013, ERID 239226) called for completion of a monitoring well tentatively designed with a single well screen to be placed near the depth of CdV-16-4ip screen 2 (projected to be 1156–1187 ft) in Puye Formation deposits. Alternatively, the work plan specified that the uppermost producing interval corresponding to the highest RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) screening results observed during drilling may be selected for screen placement. Final selection of well screen length and position would be based on data obtained during drilling, including information from lithologic logs of cuttings, water-level measurements, RDX screening results, video logs, geophysical logs, and drill crew observations.

CdV-9-1(i) Recommended Well Design

It is recommended that CdV-9-1(i) be completed with two screens within the 5 in. ID stainless steel well casing and two 1-in carbon steel pipe with stainless steel screen piezometers installed in the annulus. The piezometers will be completed with 10 ft screens; one at 665-675 ft, bgs and one at 855-865 ft, bgs. The CdV-9-1(i) well screens (40-slot) will be placed at 940-995 ft, bgs and 1025-1045 ft, bgs. The depth to top of regional saturation is estimated at ~1263 feet (see discussion below). The primary filter packs for each screen will consist of 10/20 sand extending 5 ft above and 5 ft below the screen openings. A 2-ft secondary filter pack will be placed above each primary filter pack. The proposed well design is shown in Figure 1.

This well design is based on the objectives stated above and on the information summarized below.

CdV-9-1(i) Well Design Considerations

Preliminary lithologic logs indicate that the geologic units encountered while drilling the CdV-9-1(i) borehole include the Tshirege Member of the Bandelier Tuff (surface to 430 ft), Cerro Toledo interval (430-595 ft), Otowi Member of the Bandelier Tuff (595-803 ft), Guaje Pumice Bed (803-814 ft), and Puye Formation (814-1220 ft). Groundwater was observed, either flowing or standing, in the Otowi Member, Guaje Pumice Bed, and Puye Formation. The top of regional saturation is within the Puye Formation.

Perched water was expected starting at approximately 795 ft. While 16-in casing-advance drilling was initially extended to 924 ft, no groundwater was observed. However, when the casing was retracted to 624 ft, water levels were observed to rise from 791 to 661 ft. A video log documented groundwater flow into the borehole starting at 650 ft. Over the next 76 ft of drilling with casing-advance methods, the borehole produced an estimated 5-8 gpm. From 1000-1020 ft the formation appeared undersaturated suggesting a potential perching zone. A second undersaturated interval, representing another possible perching horizon was identified at 1050-1055 ft. The formation continued to produce approximately 8 gpm down to 1080 ft at which point apparent water production ceased except for a brief show at 1121-1141 ft.

Piezometer #1

The observed groundwater entering the borehole at 650 ft, bgs represents the shallowest occurrence of deep-perched groundwater at any of the boreholes advanced from the mesa top in the western part of the Laboratory. The upper piezometer will allow monitoring of pressure responses to pumping in the uppermost perched groundwater at this location and is not intended for RCRA compliant sampling. Any screening samples from this piezometer will be qualified data. Note: due to the partial water saturated nature of the vadose zone, it is difficult to guarantee that the piezometer screens will align with a perching zone of full water saturation.

Piezometer #2

Placement of the deeper piezometer (855-865 ft) is designed to allow monitoring of pressure responses to pumping at well CdV-16-4ip which is screened at a comparable elevation and is not intended for RCRA compliant sampling. Any screening samples from this piezometer will be qualified data. This interval targets an electrical conductivity low (coarser grained) interval above an electrical conductivity high, possible perching zone in the 880 ft range. Note: due to the partial water saturated nature of the vadose zone, it is difficult to guarantee that the piezometer screens will align with a perching zone of full water saturation.

Upper Monitoring Well Screen

The upper screen in the stainless steel monitoring well is proposed for 940 to 995 ft bgs. Geophysical logs suggest this interval has water, and the screening data show relatively-high RDX concentrations in this interval (123, 299, and 282 ug/L at 940, 960, and 980 ft, respectively). A relatively long screen (55 ft, 5 10-ft screen section with 1-ft blank connectors) is proposed to maximize yield, and to allow assessment of the potential for RDX source removal. This upper screen is the preferred choice of all the screen options for CdV-9-1(i), based on the geophysical data, which show an increase in free (movable) water, particularly at the depth from 965 to 982 ft. A fine-grained perching horizon was observed from 1000 to 1010 ft, and drilling observations indicate this zone is “dry” (i.e. potentially not-fully water saturated). The upper screen in CdV-9-1(i) would be completed above this perching horizon, to reduce the potential for dewatering and cross-flow to deeper strata.

Lower Monitoring Well Screen

The proposed lower screen would be completed between 1025 to 1045 ft bgs. Located beneath the 10-ft undersaturated interval of fine-grained materials at 1000 to 1010 ft bgs, this screen would also be in an interval showing high screening RDX concentrations ranging from 268 to 244 ug/L (at depths of 1020 and 1040 ft, respectively). The geophysics show a possible perching-horizon from 1054 to 1057 ft, and this proposed screen would be located directly above this horizon to minimize the potential for dewatering and downward migration of contaminants into deeper strata.

Completion of a 20 ft screen in the interval from 1025 to 1045 ft bgs would allow assessment of the vertical hydraulic connection between the upper and lower screens, and could also be used to assess the potential for RDX source removal. The degree of hydraulic connection with CdV-16-4ip would also be evaluated. Given the apparent high RDX and the potential for a reasonable amount of water, this screen could potentially be used (possibly along with the upper screen) for source-removal activities in the future, if yield is sufficient.

Alternative Design Considerations

The first alternative to the design presented above has the lower screen placed in the 1120-1140 interval. During drilling this was the only interval below 980 ft where groundwater was observed mixed with the cuttings air-lifted from the borehole. A screen at this depth could provide useful information for both comparison to water level and RDX concentrations at abandoned CdV-16-4ip screen #2, and the elevated RDX screening results (230 and 297 ug/L at 1120 and 1140 ft, respectively) collected in this borehole. However, the geophysics does not suggest that this is a particularly productive zone. Additionally, this zone has been exposed to the groundwater observed cascading down in the borehole and may therefore yield RDX concentrations that are difficult to interpret. For these reasons we do not recommend placing a screen at this depth in this borehole.

The other alternative design included a screen placed within either the piezometer #1 or #2 intervals. This design was discounted because the borehole in those intervals is a nominal 17.5-in diameter. Completing a well in this size borehole would leave an annulus too large for effective well development. The inability to effectively develop in this large annulus is compounded by the use of drilling foam in the piezometer #1 interval. As mentioned above in the CdV-9-1(i) Well Design Considerations section, the observed water level of 661 ft is 134 ft higher than anticipated. Therefore, drilling foam use was not terminated high enough in the borehole to prevent potential impact to this zone.

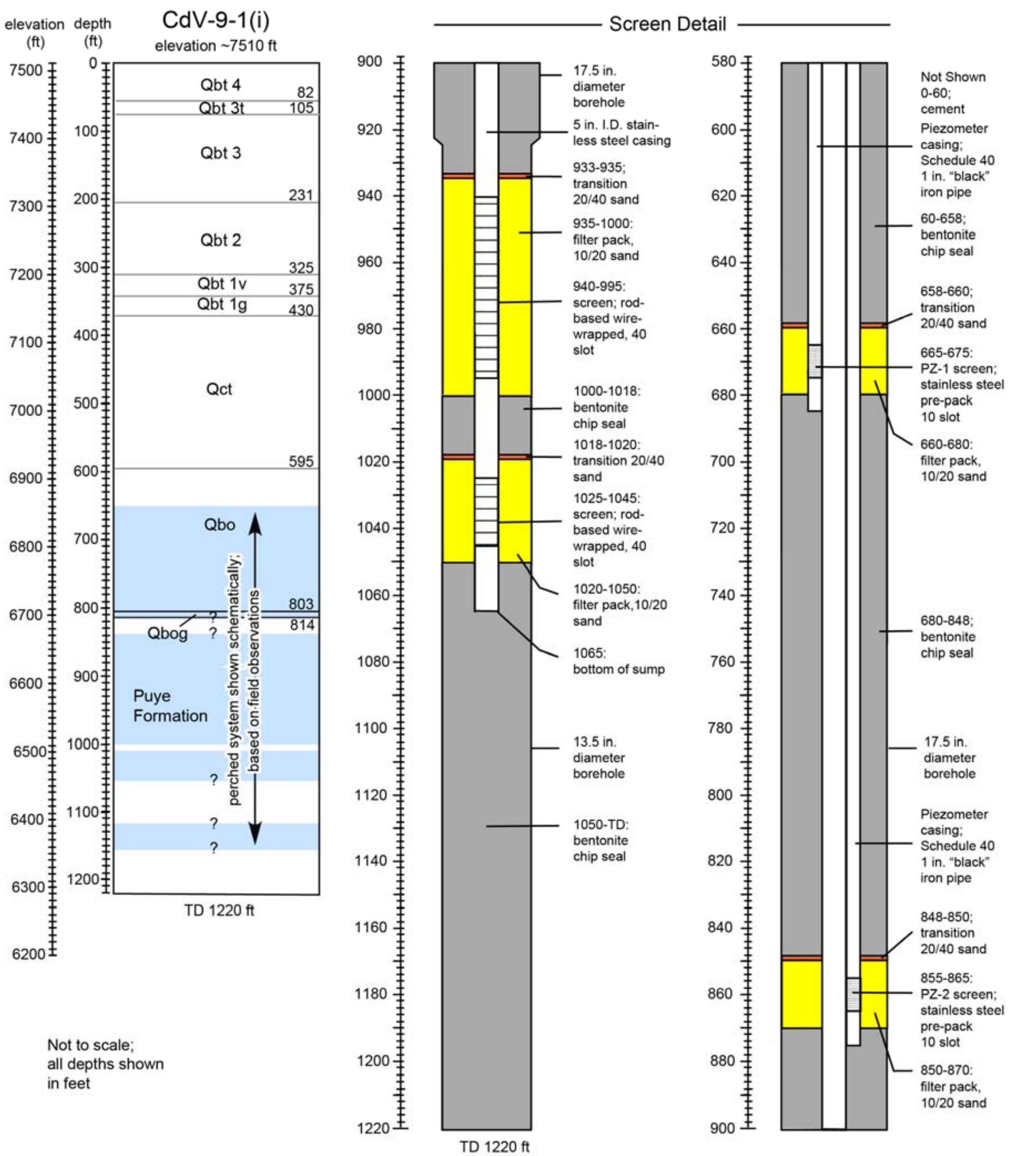


Figure 1. Proposed well design, CdV-9-1(i) (Qbt 4, 3t, 3, 2, 1v, 1g = subunits of the Tshirege Member of the Bandelier Tuff; Qct = Cerro Toledo interval; Qbo = Otowi Member of Bandelier Tuff; Qbog = Guaje Pumice Bed..

From: Dale, Michael, NMENV <Michael.Dale@state.nm.us>
Sent: Thursday, December 04, 2014 4:42 PM
To: Everett, Mark Capen
Cc: Cobrain, Dave, NMENV; Wear, Benjamin, NMENV; Kulis, Jerzy, NMENV; Rodriguez, Cheryl L; Shen, Hai; McInroy, Dave; McCann, John Phillips; Paris, Steven M; Lynnes, Kate; Longmire, Patrick; Yanicak, Stephen M; Granzow, Kim P
Subject: FW: CdV-9-1i proposed well design

Mark,

This e-mail serves as NMED approval for the installation of perched intermediate well CdV-9-1i as proposed in the document attached to the original e-mail received by NMED today (December 04, 2014 at 3:17 PM). This approval is based on the information available to NMED at the time of the approval. NMED understands that LANL will provide the results of preliminary sampling, any modifications to the well design proposed in the above-mentioned e-mail, and any additional information related to the installation of well CdV-9-1i as soon as such information becomes available. In addition, LANL shall notify NMED within three days of water-quality sampling at the conclusion of the aquifer-testing period at CdV-9-1i. LANL shall give notice of this installation to the New Mexico Office of the State Engineer as soon as possible. Thank you.

Michael Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 661-2673

From: Dale, Michael Ray [mdale@lanl.gov]
Sent: Thursday, December 04, 2014 3:20 PM
To: Dale, Michael, NMENV
Subject: FW: CdV-9-1i proposed well design

From: Everett, Mark Capen
Sent: Thursday, December 04, 2014 3:17 PM
To: Dale, Michael Ray
Cc: Dave Cobrain (dave.cobrain@state.nm.us); Wear, Benjamin, NMENV (Benjamin.Wear@state.nm.us); Jerzy Kulis (jerzy.kulis@state.nm.us); McInroy, Dave; Mccann, John Phillips; Paris, Steven M; Rodriguez, Cheryl L; Shen, Hai; Lynnes, Kate
Subject: CdV-9-1i proposed well design

Michael,

Attached is DOE/LANL's proposed design for intermediate aquifer well CdV-9-1i. As you will see, the design is consistent with what we what we discussed on Tuesday and includes two screens in the stainless steel well and two carbon steel piezometers in the annulus. Please respond to this e-mail with your concurrence or give a call so that we can discuss it further.

Thanks,

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

Appendix F

Well CdV-9-1(i) Aquifer Testing Report

F-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted during March 2015 at well CdV-9-1(i), a dual-screened perched zone well located at Technical Area 09 (TA-09). During well construction and development, a temporary packer was installed between the two well screens to provide hydraulic separation of two saturated perched intervals. Eventually, the packer became stuck (probably sand-locked) and could not be retrieved. Therefore, the lower screen (screen 2) was abandoned and only the upper screened interval (screen 1) could be tested.

The tests on CdV-9-1(i) screen 1 were conducted to characterize the saturated materials, quantify the hydraulic properties of the screened interval, and estimate the potential pumping capacity of the well for remediation purposes. Testing consisted of a brief step-drawdown test, background water-level data collection, and a 72-h constant rate pumping test. In addition, limited antecedent water-level data recorded during the final week of development and purging were examined.

In most of the pumping tests conducted on the Pajarito Plateau, an inflatable packer system has been used to eliminate casing storage effects on the test data, thereby enhancing the value of the early test data. In CdV-9-1(i), however, the inflatable packer was not used because it would have been ineffective at eliminating storage effects. During development and purging operations, the well screen and surrounding filter pack were routinely dewatered, likely draining the portion of the filter pack above the top of the screen. This zone would have remained partially dewatered after development pumping ceased because rising water levels would have trapped air in the filter pack behind the well casing just above the screen. During testing, expansion and compression of this trapped air in response to pumping and recovery would have created a storage-like effect, negating the value of early pumping and recovery data and obviating the need for a packer. In addition, it was expected that much of the filter pack and well screen would be dewatered during the planned testing, thus introducing additional storage effects regardless of whether an inflatable packer was used. Therefore, testing proceeded without the use of an inflatable packer.

Conceptual Hydrogeology

CdV-9-1(i) is completed within saturated perched sediments in the Puye Formation. Screen 1 is 55 ft long, extending from 937.4 to 992.4 ft below ground surface (bgs). Screen 2 is 21.3 ft long, running from 1023.7 to 1045.0 ft bgs. When the well was built, two nested 1-in. piezometers were installed in the annulus between the 5-in. well casing and the borehole. CdV-9-1(i) PZ-1 (PZ-1) was completed within the Otowi Member of the Bandelier Tuff with 9.5 ft of screen from 662.9 to 672.4 ft bgs. CdV-9-1(i) PZ-2 (PZ-2) was completed in Puye sediments with 9.5 ft of screen from 852.9 to 862.4 ft bgs.

Determining a representative static water level was problematic because water-level stabilization was not achieved at any time during development, purging, or testing. The perched zone appeared to be laterally limited and was dewatered substantially during development and purging when nearly 60,000 gal. of water was pumped from the well. Water levels measured at various times during development and purging varied substantially as a function of the amount of water added to, or removed from, the well around the time the measurement was made.

The static water level measured in screen 1 on March 5, 2015, before the test pump was installed was 919.79 ft bgs. The ground surface elevation at the well was surveyed at 7517.07 ft above mean sea level (amsl), making the corresponding water level elevation 6597.28 amsl. Before the 72-h pumping test began, the water level was lower, at about 922.2 ft bgs, having been affected by the antecedent step-drawdown test pumping. Simple extrapolation of recovery data following testing implied an approximate static water level of 918 ft bgs (elevation of approximately 6599 ft amsl).

Water levels measured in PZ-1 and PZ-2 on March 4 were 613.58 and 603.95 ft bgs, respectively. However, these measurements were made shortly after development water was added to the wells so that equilibration had not yet occurred. Thus, the measured levels were not representative of ambient conditions. PZ-2 was particularly sluggish in equilibrating, requiring more than 2 d for the water level to decline 20 ft to an equilibrated level following installation of the dedicated pressure transducer.

The proximity of the water table to the top of the well screen in CdV-9-1(i) and the substantial dewatering that occurred during testing implied that unconfined aquifer response could be assumed in the data analysis.

CdV-9-1(i) Testing

CdV-9-1(i) was tested from March 5 to 19, 2015. On March 5, the pump was installed and operated long enough to fill the drop pipe and adjust the control valve to establish a suitable discharge rate. Beginning at 7:00 a.m. on March 6, a 4-h step-drawdown test was conducted at discharge rates ranging from 2.3 to 11.0 gallons per minute (gpm). Following shutdown, recovery/background data were recorded for 44 h until the start of the 72-h pumping test.

Following background data collection, the 72-h pumping test was begun at 7:00 a.m. on March 8, at a discharge rate of 7.0 gpm. This rate was maintained for approximately 11 h before pump cavitation began to occur. It was surmised (and subsequently confirmed in the data set) that the pumping water level had reached the pump intake. The discharge rate was reduced to 3.5 gpm, eliminating pump cavitation and restoring normal pump operation. Over the next 50 h, the discharge rate slowly declined to 3.4 gpm, a natural consequence associated with the gradually increasing drawdown in the well. Over the final 11 h of pumping, the pumping rate declined more rapidly, suggesting (and later confirmed in the data set) that the pumping water level had reached the pump intake, again causing cavitation. The final discharge rate at the end of the pumping test was approximately 3.1 gpm and was continuing to decline.

Following shutdown at 7:00 a.m. on March 11, recovery data were recorded for more than 8 d until 12:00 noon on March 19. After the first 24 h of recovery, the pump was pulled. At that point, the transducer was downloaded, reprogrammed to continue recording water levels, and rerun into the well. Thus, there was a brief interruption in the recovery record, with monitoring being discontinued at 7:00 a.m. on March 12 and restarted at 6:00 p.m. that same day.

F-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 help to distinguish between water-level changes caused by conducting the pumping test and changes associated with other causes.

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

Previous pumping tests on the plateau have demonstrated a barometric efficiency 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 vented pressure transducers. 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 CdV-9-1(i), 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, for example, a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, 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.

Data presented in this report include measurements from both vented and nonvented transducers. Well CdV-9-1(i), nearby perched zone well R-63i and multiscreened well R-25 were monitored with nonvented transducers, while PZ-1, PZ-2, and nearby perched zone well R-25b were monitored with vented transducers.

Barometric pressure data were obtained from TA-54 tower site from the Environmental Protection Division–Environmental Compliance Programs (ENV-CP). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is at 7517.07 ft amsl. The static water level in CdV-9-1(i) was 919.79 ft below land surface, making the water-table elevation 6597.28 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 CdV-9-1(i).

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

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

Where, P_{WT} = barometric pressure at the water table inside CdV-9-1(i)

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_{CdV} = land surface elevation at CdV-9-1(i) site, in feet (7517.07 ft)

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

E_{WT} = elevation of the water level in CdV-9-1(i), in feet (6597.28 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 43.2 degrees Fahrenheit, or 279.4 degrees Kelvin)

T_{WELL} = air column temperature inside CdV-9-1(i), in degrees Kelvin (assigned a value of 51.7 degrees Fahrenheit, or 284.1 degrees Kelvin)

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

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

F-3.0 IMPORTANCE OF EARLY DATA

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

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

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

Equation F-2

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

D = inside diameter of well casing, in inches

d = outside diameter of column pipe, in inches

Q = discharge rate, in gallons per minute

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

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

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

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

Equation F-3

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

D_B = diameter of borehole, in inches

D_C = outside diameter of well casing, in inches

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

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. As discussed in section F-1.0, this was not possible in CdV-9-1(i), obviating the use of an inflatable packer and requiring that casing storage effects be considered in the analysis.

F-4.0 TIME-DRAWDOWN METHODS

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

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

Where,

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

and

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

and where, s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

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

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

Equation F-7

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

Equation F-8

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

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

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

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

Equation F-9

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

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

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

Equation F-10

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

Q = discharge rate, in gallons per minute

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

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

Equation F-11

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

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

b = aquifer thickness

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

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

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

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

K_z = vertical hydraulic conductivity

K_r = horizontal hydraulic conductivity

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

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

Equation F-12

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

F-5.0 RECOVERY METHODS

Recovery data were analyzed using the Theis recovery method. 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:

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

Equation F-13

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

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

F-6.0 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):

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

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 F-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 that 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.

F-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 not known, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

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

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

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

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

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

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. Storage coefficient values generally range from 10^{-5} to 10^{-3} for confined aquifers and 0.01 to 0.25 for unconfined aquifers (Driscoll 1986, 104226). For CdV-9-1(i), unconfined conditions were assumed, so calculations were performed for an assigned storage coefficient range of 0.01 to 0.2. The lower-bound transmissivity calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b, and well screen length, L. As discussed below in section F-9.0, data collected from the pumping test suggested that most of the production from the well came from above 963 ft. Therefore, this horizon was considered to be the bottom of the permeable saturated perched zone. Combining this with the observed water level of 922.2 ft before starting the 72-h test made b = 40.8 ft, and L = 25.6 ft for the purpose of partial penetration corrections.

F-8.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the CdV-9-1(i) tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Well CdV-9-1(i)

Figure F-8.0-1 shows aquifer water level data from CdV-9-1(i) during the test period along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The CdV-9-1(i) data are referred to in the figure as the “apparent hydrograph” because the measurements were recorded using a nonvented pressure transducer. The times of the pumping test periods for CdV-9-1(i) are included on the figure for reference. Note that the magnitude of the water-level scale is 100 times greater than the barometric pressure scale. It is clear that changes in water level were large compared with barometric pressure fluctuations, making it certain that barometric pressure correction would not be required for the data set.

To illustrate this further, a portion of the water-level response was plotted at the same scale magnitude as the barometric pressure data on Figure F-8.0-2 so the effect of barometric pressure on water levels could be discerned. As indicated, changes in barometric pressure had little effect on the apparent water levels, implying a highly barometrically efficient screen zone. For example, the sinusoidal dip and rebound seen in the barometric pressure curve on March 18 caused little deflection of the water level curve, confirming that water level correction for barometric pressure change was not needed.

Well R-63i

Data from well R-63i were examined to determine if there was a response to pumping CdV-9-1(i). Figure F-8.0-3 shows a plot of the apparent hydrograph from R-63i along with the barometric pressure at the water table. The two curves were remarkably similar except for the gradual separation that occurred over time, suggesting a slowly declining water level in R-63i.

The data were corrected for water level decline and replotted on Figure F-8.0-4. An optimum match to the barometric pressure curve was achieved for an assumed water level decline rate of 0.014 ft/d. The similarity of the curves on the figure indicated the water level in R-63i remained stationary throughout the monitoring period (except for the gradual decline), with the observed fluctuations in measured pressure being attributable entirely to the change in barometric pressure. The data showed no response occurred in R-63i to pumping CdV-9-1(i).

The negligible amount of movement of the water level in R-63i in response to barometric pressure changes was surprising. This indicated that either (1) the well has a very low barometric efficiency (near zero), or (2) the zone is extremely tight, precluding the movement of water in and out of the well in response to atmospheric pressure changes. A low barometric efficiency is considered highly unlikely based on observations of all other well responses on the plateau to barometric pressure fluctuations. The great depth of the well makes it probable that the barometric efficiency would be high, possibly near 100%, not zero. Thus, the more likely explanation for the observed response is that the zone is tight and may not support sufficient groundwater flow for conventional sampling.

Piezometers PZ-1 and PZ-2

Figure F-8.0-5 shows relative water-level data from PZ-1 and PZ-2 recorded from early March 2015 to early April. The curves are nearly identical, suggesting that the Otowi Member of the Bandelier Tuff and the uppermost portion of the Puye Formation are in direct hydraulic communication and respond essentially as a single hydraulic unit. The early data showed that water-level equilibration was sluggish in both piezometers, especially PZ-2. After the pressure transducers were installed, it took approximately 6 h for the water level to equilibrate in PZ-1, while in PZ-2 it took more than 2 d. Because of the addition of development water just before tagging, the water levels in these wells, combined with an unknown amount of water-level change before transducers were deployed, it was not possible to identify the true groundwater elevations for comparison.

Overall, a rising water-level trend was evident in the hydrographs throughout the monitoring period. There was no obvious explanation for the significant decline in water level and rebound observed between March 20 and 24.

Figure F-8.0-6 shows an expanded-scale plot of the two curves, highlighting their similarity around the time of the pumping test. Note that there are a number of anomalous water-level spikes in the hydrograph for PZ-2. The largest one is plotted on a further expanded scale on Figure F-8.0-7. The data indicated an apparent change in water level of half a foot in less than 1 min—clearly impossible based on the slow equilibration rate observed previously in PZ-2.

The anomalous spikes on the graph occurred only during the pumping period (i.e., when the pump was running). It is possible that they were caused either mechanically by pump vibration or electrically by the proximity of the pump cable to the transducer location. Similar “noise” in transducer signals has been detected in other pumping tests on the plateau in which the transducer was located adjacent to the pump cable rather than beneath the pump.

Figures F-8.0-8 and F-8.0-9 compare barometric pressure and water levels for PZ-1 and PZ-2, respectively. The times of the pumping test periods for the CdV-9-1(i) pumping tests are included in the figures for reference. There was no indication of a water-level response to pumping CdV-9-1(i).

Aside from the overall rise in water level observed in the hydrographs, there was a remarkable similarity in the shapes of the hydrographs and barometric pressure curve over the first half of the record displayed on the figures. However, the observed water-level fluctuations were *greater* rather than smaller than the barometric pressure changes as was expected. To illustrate this, the steady water level rise was mathematically removed from the hydrograph signal, and the magnitude of the barometric pressure fluctuations was increased in order to match the revised barometric pressure curve to the modified hydrograph.

Figure F-8.0-10 shows the resulting plot for PZ-1. Results for PZ-2, not shown, were similar. An optimum match was achieved for an assumed water level rise of 0.11 ft/d and an increase in the magnitude of the barometric pressure fluctuations of 80%. As shown on the figure, the resulting curves were remarkably similar. Inexplicably, this analysis would suggest a barometric efficiency for the PZ-1 and PZ-2 perched zones of 180%. Previously, anecdotal barometric efficiencies greater than 100% have been observed on the plateau (personal communication, Richard Koch), but only in basalts.

It is not known if the similarity in the curves on Figure F-8.0-10 is simply coincidental or if the water-level fluctuations were, in fact, caused by the barometric pressure changes. Conventional understanding of barometric efficiency is not consistent with efficiencies greater than 100%. Curiously, the correlation between water levels and barometric pressure was not as good for the data after March 20.

Well R-25b

Figure F-8.0-11 compares barometric pressure data and water-level data from well R-25b recorded with a vented transducer. The curves appeared similar, except that the magnitude of the fluctuations in the hydrograph was somewhat less than that in the barometric pressure curve.

The correlation between the two curves was emphasized in Figure F-8.0-12 by adjusting the hydrograph for a slight decline in water level and reducing the magnitude of the change in barometric pressure by an assumed barometric efficiency. An optimum match was achieved for a background water level decline of 0.005 ft/d and a barometric efficiency of 80%.

The data showed no effect in response to pumping CdV-9-1(i).

Well R-25

Figures F-8.0-13 through F-8.0-18 compare barometric pressure and apparent hydrographs recorded with nonvented transducers for R-25 screens 1, 2, 4, 6, 7, and 8, respectively. The hydrographs for screens 1, 2, 4, and 6 showed little barometric pressure response, suggesting high barometric efficiencies approaching 100%, while those for screens 7 and 8 showed a greater response of approximately 30% of the barometric pressure change implying barometric efficiencies of approximately 70%.

Small magnitude diurnal fluctuations of less than a tenth of a foot were evident in the graphs for screens 2, 7 and 8. It is likely that these are responses to Earth tides.

None of the R-25 screen zones showed a response to pumping CdV-9-1(i).

F-9.0 DATA ANALYSIS

This section presents the data obtained from the CdV-9-1(i) pumping tests and the results of the analytical interpretations. Data are presented for the step-drawdown test, the 72-h constant rate test, and the final week of well development and purging.

Figure F-9.0-1 shows water-level data recorded during the test period. The locations of the top and bottom of the screen zone are shown for reference on the graph. Note that water levels at times were pulled down to the pump intake, which was positioned just above the bottom of the well screen to provide maximum available drawdown.

CdV-9-1(i) was tested from March 5 to 19, 2015. On March 5, the pump was installed and operated long enough to fill the drop pipe and adjust the control valve to establish a suitable discharge rate. As indicated, this brief pumping pulled the water level slightly below the top of the well screen.

Beginning at 7:00 a.m. on March 6, a 4-h step-drawdown test was conducted at discharge rates ranging from 2.3 to 11.0 gpm. As shown on Figure F-9.0-1, the lowest water level observed during step-drawdown testing was around the middle of the well screen, slightly below a depth of 960 ft, at the maximum discharge rate of 11.0 gpm—the limiting capacity of the pumping equipment. Following shutdown, recovery/background data were recorded for 44 h until the start of the 72-h pumping test. It was evident that the water level had not yet recovered to the starting level before the 72-h test commenced.

Following background data collection, the 72-h pumping test was begun at 7:00 a.m. on March 8, at a discharge rate of 7.0 gpm. This rate was maintained for approximately 11 h before pump cavitation began to occur. At the time, it was surmised that the pumping water level had reached the pump intake. As indicated on the figure, that is what happened.

The discharge rate was reduced to 3.5 gpm, eliminating pump cavitation and restoring normal pump operation. Over the next 50 h, the discharge rate slowly declined to 3.4 gpm, a natural consequence associated with gradually increasing drawdown in the well. Over the final 11 h of pumping, the pumping rate declined more rapidly, suggesting that the pumping water level had reached the pump intake again, causing cavitation. The data graphed in the figure confirmed that the pumping water level had reached the pump intake late on March 11 and remained there for the duration of test. The final discharge rate at the end of the pumping test was approximately 3.1 gpm and was continuing to decline.

Following shutdown at 7:00 a.m. on March 11, recovery data were recorded for more than 8 d until 12:00 noon on March 19. After the first 24 h of recovery, the pump was pulled. At that point, the transducer was downloaded, reprogrammed to resume recording water levels, and rerun into the well. Thus, as shown in the figure, there was a gap in the recovery record, with monitoring being discontinued at 7:00 a.m. on March 12 and restarted at 6:00 p.m. that same day.

Figure F-9.0-2 shows an expanded-scale plot of the early recovery data recorded in CdV-9-1(i). Two straight lines of fit are included on the graph to illustrate the linear rate of water level rise in the well. This information was valuable in identifying the producing interval within the well screen.

Theoretically, the water level rise is expected to be steep initially and then flatten continuously, with a monotonically decreasing slope throughout the recovery period. The linear recovery rate actually observed indicated a constant, continuing flux of formation water into the well even though the residual drawdown was decreasing. This implied that the bottom portion of the well screen was unproductive (i.e., that all of the production was entering the well from above the water level). In essence, even though the pump had been shut off, production was continuing as the lower portion of the well screen and filter pack filled with water at a rate essentially equal to the antecedent discharge rate.

As shown in Figure F-9.0-2, the recovery rate was linear for 8 min, declined for 2 min, and then resumed the original linear rate for an additional 5 min. The transient flattening of the slope for 2 min likely indicated the presence of a borehole enlargement (washout). Indeed, the volume of filter pack required to backfill the annulus during well construction indicated an average borehole diameter of approximately 19 in. compared with the drilled diameter of 12.75 in. It is probable that the borehole is both oversized and irregular in diameter.

The linear refill rate persisted for 15 min until the water level rose to a depth of 974 ft, indicating no production below that depth. At that point, there was only a slight flattening of the slope for an additional 13 min until the water level rose to 963 ft. After that the slope of the curve showed significant change, suggesting that little production was provided by the sediments between 963 and 974 ft.

As a first approximation, it was assumed that most of the production to CdV-9-1(i) entered the well screen above 963 ft. In other words, the saturated zone was considered to be permeable and productive from the static water level to a depth of 963 ft and tight below that depth. Extrapolation of the recovery data, described below in section F-9.2, suggested a static water level of approximately 918 ft. Therefore, the permeable formation was assumed to be 45 ft thick originally, extending from 918 to 963 ft bgs.

F-9.1 Well CdV-9-1(i) Step-Drawdown Test

Brief step-drawdown testing was performed from 7:00 a.m. to 11:00 a.m. on March 6, 2015. Eight pumping steps were applied, with rates increasing from 2.3 to 11.0 gpm. Table F-9.1-1 summarizes the discharge rates and corresponding drawdown for each pumping step. Equation F-14 was used to compute a corrected drawdown for each step to account for formation dewatering. This equation was considered appropriate for the larger discharge rates and drawdown values. For the earlier steps, however, the correction was not strictly applicable because partial penetration effects were expected to dominate for small drawdown values. Finally, the corrected specific drawdown (s_c/Q) was computed for each data point at shown in the table.

Figure F-9.1-1 provides a graphical summary of discharge rates, drawdown values and corrected drawdown throughout the step-drawdown test. Note that the discharge rate was reduced to 7.0 gpm for a brief time at the end of the test to adjust the discharge valve setting for the subsequent 72-h pumping test.

The primary objective of the step-drawdown test was to identify zones of water contribution (permeable zones) within the saturated interval. The intention was to periodically increase the pumping rate and drawdown until the entire screen zone was dewatered to see how the well responded. Unfortunately, the capacity of the pump was not sufficient to dewater the entire well screen at short pumping times as shown previously on Figure F-9.0-1, with the maximum pumping water level just reaching the middle of the well screen. Nevertheless, the data proved useful in corroborating the estimated production interval estimated from the early recovery data as described in section F-9.0.

The corrected specific drawdown values were plotted versus discharge rate as shown on Figure F-9.1-2. Theoretically, for laminar flow conditions, the corrected specific drawdown is expected to be constant if the saturated thickness used in the calculations is selected appropriately. An erroneous assignment of saturated thickness would tend to skew the plotted data points in one direction or another. As shown on the plot, the computed corrected specific drawdown showed a fairly constant trend with minimal scatter. This confirmed the reasonableness of the selection of the 963-ft depth as the estimated practical base of the permeable interval. The first few data points on the graph showed somewhat lower specific drawdown (greater specific capacity) than the subsequent points, likely a function of the shorter total pumping time associated with the early data points.

F-9.2 Well CdV-9-1(i) 72-h Constant Rate Test

Figure F-9.2-1 shows a semilog plot of the drawdown data collected from the 72-h pumping test on CdV-9-1(i) at from March 8 to 11, 2015. The computed casing storage times are shown on the plot. The transmissivity value determined from the analysis was 410 gallons per day/foot (gpd/ft). The drawdown data were not corrected for dewatering because at minimal drawdown levels (when the pumping water level is well above the top of the well screen), partial penetration effects (not requiring correction) dominate over dewatering effects.

The static water level at the onset of starting the 72-h test was 920.6 ft making the saturated thickness at that time 40.8 ft, resulting in a calculated hydraulic conductivity value of 10.0 gpd/ft^2, or 1.34 ft/d. There was only a limited window of data available to support computation of formation transmissivity. Within the first half hour of pumping, the time-drawdown slope began to steepen in response to negative boundary conditions illustrating severe lateral limits to the saturated perched interval.

As the permeable zone was dewatered, the drawdown increased at an accelerated rate. Once the pumping level reached the estimated practical depth limit of the permeable saturated zone, the borehole was dewatered rapidly.

Reducing the discharge rate to 3.5 gpm restored the pumping water level to an elevation within the permeable zone. However, once the drawdown reached the base of the permeable zone again, rapid dewatering of the underlying portion of the borehole occurred.

Figure F-9.2-2 shows recovery data recorded for 8 d following cessation of pumping. Of note is the fact that the first half hour or recovery was considered to be part of the pumping period because water continued entering the well at a rate equal to the antecedent discharge rate as the lower portion of the well filled with water to the base of the permeable zone at a depth of 963 ft. Therefore, the recovery times and residual drawdown were recomputed to adjust for this. The revised recovery graph is shown in Figure F-9.2-3. The casing storage times are highlighted on the figure for reference.

The transmissivity computed from the line of fit shown on the plot was 245 gpd/ft, substantially less than that obtained from the time-drawdown graph. This is because later data were used to determine the transmissivity given the greater storage time during recovery vis-à-vis pumping. During pumping, only the well casing provided storage, whereas during recovery both the casing and drained filter pack contributed to storage delays. By the time storage effects had subsided, the cone of impression exhibited boundary effects that steepened the curve and led to the lower computed value of transmissivity. Thus, the transmissivity obtained from the recovery data was not considered valid.

Extrapolation of the late recovery data to arbitrarily large recovery times (not shown) suggested an equilibrated static water level of 918 ft bgs.

F-9.3 Well CdV-9-1(i) Final Purging

Figure F-9.3-1 shows a water level plot recorded during the final week of purging the drilling water from CdV-9-1(i). Pumping was performed every day through February 25, 2015, after which the pump was removed and water levels were allowed to recover before pumping test activities began. Note that the asymptotic position of the water level recovery curve at late time was not inconsistent with the extrapolated estimate of a static water level of 918 ft bgs determined later from the pumping test data.

Figure F-9.3-2 shows an expanded-scale plot of the pumping periods along with the average discharge rate for each day of pumping. The pump was operated for less than an hour on February 20 but for longer periods after that. The pump intake was installed approximately 7 ft above the bottom of the well screen to provide for maximum available drawdown. The data showed that intermittent pumping at approximately 5 gpm for 8 to 10 h each day was sufficient to cause cavitation, with the water level reaching the pump intake. Subsequent data, obtained during test pumping, showed that for longer pumping time the discharge rate declined to as low as 3.1 gpm and was continuing to decline steadily. The water-level data in Figure F-9.0-2 showed that the rebound in water levels each day was less than the previous day at the withdrawal rates shown, exhibiting a steady downward trend in overall level.

This information, along with the pumping test data, suggested that the potential steady-state yield capacity of CdV-9-1(i) would be limited. The purging data were used to try to quantify the achievable steady-state discharge rate. It was assumed that replenishment of water to the areally limited perched zone would be driven by the difference in head between the lowered water level within the perched zone and the surrounding area-wide static water level—presumably 918 ft bgs.

Data from the extensive purging from February 21 to 25 were examined first. February 20 data were not included because of the brief pumping duration on that day. Over the 5 d beginning February 21, a total water volume of 12,930 gal. was pumped. This averages out to 1.8 gpm. During this time, the flux of groundwater into the perched zone from adjacent and/or overlying sediments must have been less than 1.8 gpm because water levels continued to decline as evidenced by successively lower rebound positions of the water table from one day to the next.

Ostensibly, this would suggest a maximum sustained yield from the perched zone of strictly less than 1.8 gpm. However, during the idle periods between pumping events, water-level recovery within the perched zone reduced the driving head between it and the surrounding sediments. This meant that had pumping continued for 24 h/d, the head in the perched zone would have been maintained at a slightly lower elevation and, thus, the flux into the perched zone from surrounding sediments would have been somewhat greater than that observed.

A more apt description of the yield potential is that it would be “strictly less than some number that is slightly greater than 1.8 gpm.” It is expected that the magnitude of the correction to the estimate of 1.8 gpm would not be large. As shown in Figure F-9.3-2, following the last couple of pumping cycles, water levels returned quickly to about 942 ft bgs and then crept up slowly from there. From that point on, it was surmised that the water level in the well would be approximately representative of that in the perched zone. (Data from the pumping test showed the arrival of boundary effects soon after the onset of pumping, indicating a severely limited perched area and suggesting rapid equilibration between the water level in the well and that in the perched zone.) During the recovery period up to the next pumping cycle, the water levels in the perched zone averaged approximately 938 ft bgs versus the approximately 942-ft level that would have been maintained had pumping continued. Comparing these values with the estimated static water level of 918 ft bgs meant that the driving head bringing water into the perched zone averaged 20 ft (938 minus 918) instead of 24 ft (942 minus 918) during recovery. Thus, had pumping continued, the flux into the perched zone would have been about 20% greater than what actually occurred during the recovery period. Assuming that recovery constituted about two-thirds of the total time, this suggested that the upper bound flux estimate of 1.8 gpm might be underestimated by about 13% and implying a revised upper bound limit of about 2 gpm.

Data from the final pumping step on February 25 provided another estimate of the yield capacity for the perched zone. Figure F-9.3-3 shows recovery data measured following the step-drawdown test, the 72-h pumping test and the last 3 d of purging on February 23, 24, and 25. Remarkably, the recovery trends were nearly identical following the February 24 and 25 pumping events. This suggested that the February 25 pumping event caused no incremental dewatering of the perched zone and, therefore, that the volume of water removed during this last pumping cycle was equal to the volume of water entering the perched zone between the February 24 shutdown and the February 25 shutdown—a duration of 1109 min. On February 25, a volume of 1863 gal. was pumped from CdV-9-1(i). This suggested an average influx rate of groundwater into the perched zone of 1863 gal. in 1109 min, or 1.7 gpm. As discussed above, this rate might have been approximately 13% greater under continuous pumping conditions resulting in a potential steady flux rate of perhaps 1.9 gpm.

The foregoing flux estimates were consistent—an upper limit rate of 2 gpm and an estimated actual potential rate of 1.9 gpm. However, these yield potential estimates were applicable to pumping times of just a few days. Under continuous pumping (months or years), it is probable that lowering of water levels in the adjacent sediments could eventually reduce the driving head bringing water into the local perched zone. Therefore, it would be reasonable to expect that the long-term pumping capacity might be significantly less than 2 gpm. The pumping potential also could vary in response to temporal changes in recharge in the area.

F-9.4 Well CdV-9-1(i) Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by CdV-9-1(i). This was done to provide a frame of reference for evaluating the time-drawdown analysis.

The total saturated thickness of permeable sediments was estimated at 40.8 ft at the time the 72-h pumping test was conducted (static water level of 922.2 ft bgs and base of the permeable zone of 963 ft bgs). A saturated well screen length of 25.6 ft was used in the partial penetration calculations—the distance from the top of the screen at 937.4 ft bgs to the base of the permeable zone.

Before boundary conditions were encountered, CdV-9-1(i) produced 7.0 gpm with 11.54 ft of drawdown for a specific capacity of 0.607 gpm/ft after 20 min of pumping. In addition to specific capacity and pumping time, other input values used in the calculations included assigned storage coefficient values ranging from 0.01 to 0.2 and a borehole radius of 0.80 ft (inferred from the volume of filter pack required to backfill the screen zone).

Applying the Brons and Marting method to these inputs yielded the lower-bound transmissivity estimates shown on Figure F-9.4-1. Depending on the assumed storage coefficient value, the calculated lower-bound hydraulic transmissivity values ranged from approximately 350 to 600 gpd/ft^2, encompassing and consistent with the value of 410 gpd/ft^2 obtained from the time-drawdown analysis.

F-9.0 SUMMARY

Constant rate pumping tests were conducted on CdV-9-1(i) to gain an understanding of the hydraulic characteristics of the screened interval and get a sense for the yield potential of the saturated perched zone for possible pump and treat remediation.

Several observations were made using the data obtained from the pumping test and the final week of antecedent purging data.

1. A comparison of barometric pressure and CdV-9-1(i) screen 1 water-level data showed a highly barometrically efficient screen zone. Large changes in barometric pressure caused almost no change in the apparent hydrograph obtained from the well.
2. Well R-25b and R-25 screens 1, 2, 4, 6, 7, and 8 showed high barometric efficiencies—typically 70% to 100%. R-25 screens 2, 7, and 8 showed distinct fluctuations caused by Earth tides.
3. Water-level responses to barometric pressure in PZ-1 and PZ-2 were identical, suggesting the Otowi Member of the Bandelier Tuff and the upper portion of the Puye Formation respond as a single hydraulic unit. However, because development water had been added to the piezometers just before tagging the water levels and because of the differences in equilibration rates in the two zones (PZ-2 took 2 d to equilibrate), it was not possible to determine the true water level elevations to determine if they were identical. Retagging the water levels in the piezometers would be a worthwhile task to identify the actual groundwater elevations.
4. Inexplicably, water levels in PZ-1 and PZ-1 were consistent with computed barometric efficiencies of about 180% for the first 2 wk of monitoring and then showed poor correlation to barometric pressure the following 2 wk.
5. R-63i showed little movement of the water level, except for a steady decline of 0.014 ft/d. This ostensibly would suggest a low barometric efficiency—a condition not observed in any other wells on the plateau. It is more likely that the zone is simply tight or plugged, preventing water from moving readily in and out of the screened zone.
6. None of the aforementioned wells showed any response to pumping CdV-9-1(i) screen 1.
7. The data indicated that the bulk of the formation transmissivity in the 937.4- to 992.4-ft screen zone was concentrated above a depth of 963 ft bgs, with little production below that depth.
8. The step-drawdown test data were consistent with the idea of the production being concentrated in the upper half of the screen zone and showed largely laminar flow conditions at all discharge rates from 2.3 to 11 gpm.
9. The perched zone in which CdV-9-1(i) is completed is laterally limited with boundary effects showing up in the response within the first half hour of pumping and becoming severe. While CdV-9-1(i) can produce in excess of 10 gpm for short periods (hours), the yield declines quickly. By the end of the 72-h pumping test, the maximum capacity had fallen to 3.1 gpm and was continuing to decline rapidly.
10. The purging data corroborated this idea and indicated a maximum sustainable yield less than 2 gpm for moderate pumping times (days). It is expected that long-term pumping could be restricted to even lower rates than this.
11. Time-drawdown data indicated a local transmissivity of 410 gpd/ft, corresponding to a calculated hydraulic conductivity value of 10.0 gpd/ft^2, or 1.34 ft/d.
12. Specific capacity data were consistent with this and indicated a lower-bound transmissivity of 350 to 600 gpd/ft, depending on the assumed value of storage coefficient.

F-10.0 REFERENCES

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

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

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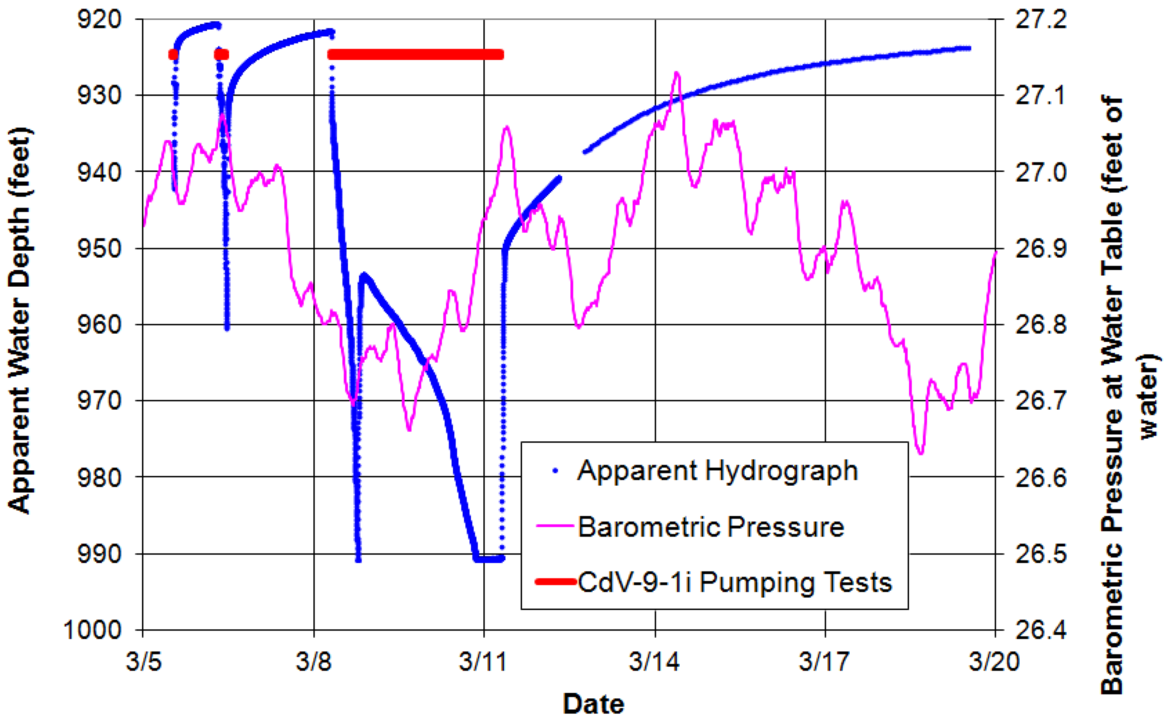

Figure F-8.0-1 Well CdV-9-1(i) apparent hydrograph and barometric pressure

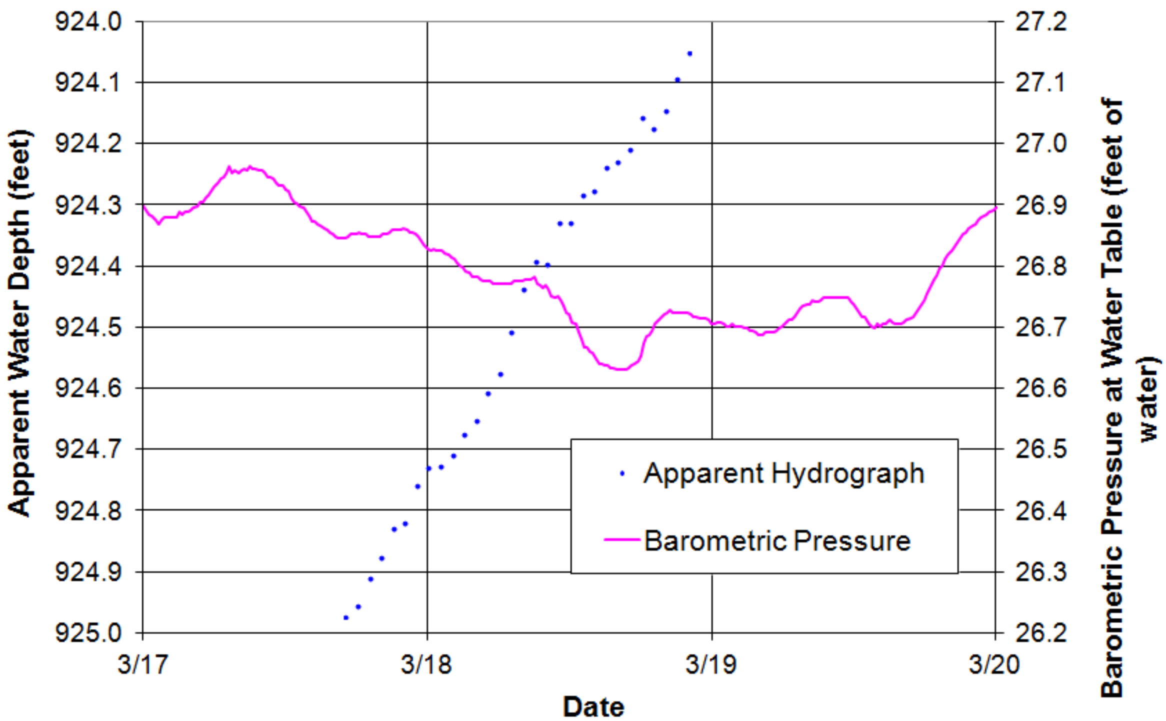

Figure F-8.0-2 Well CdV-9-1(i) apparent hydrograph—expanded scale

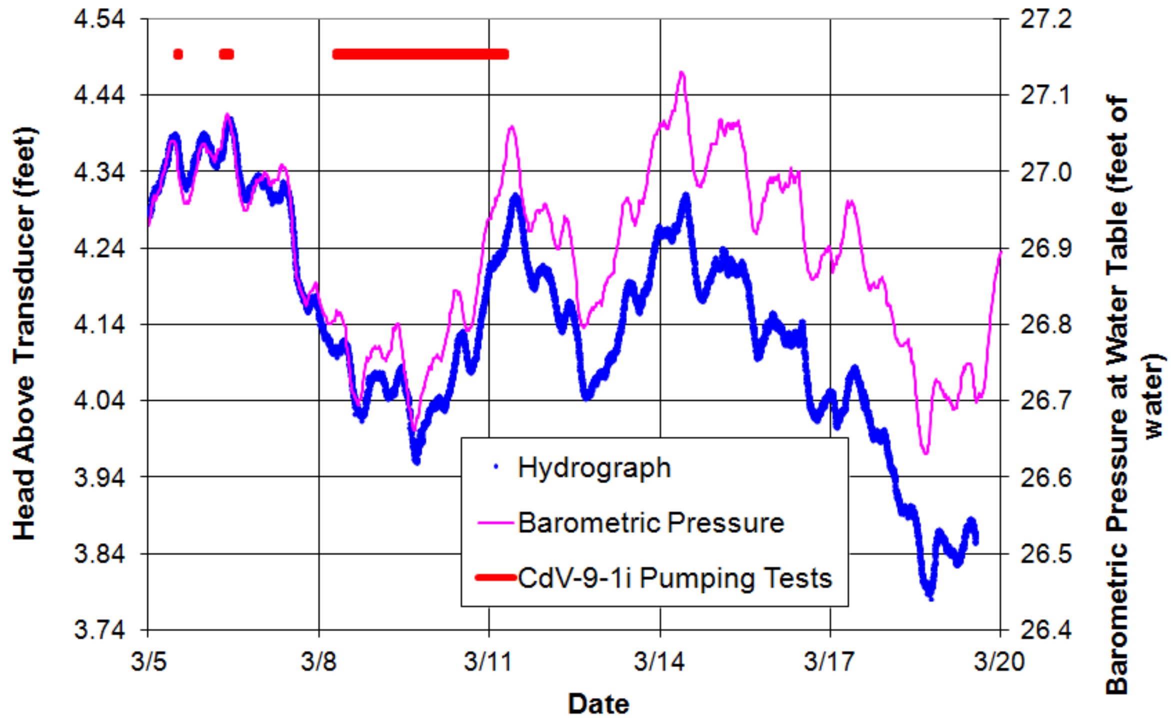

Figure F-8.0-3 Well R-63i apparent hydrograph

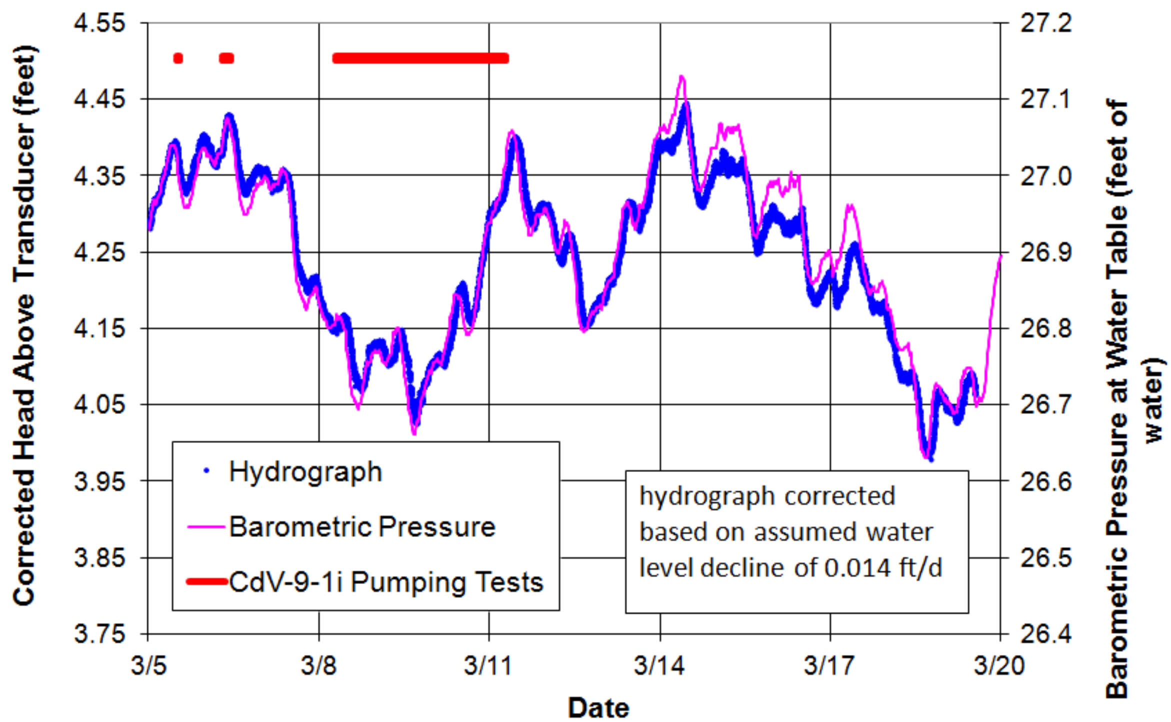

Figure F-8.0-4 Well R-63i corrected apparent hydrograph

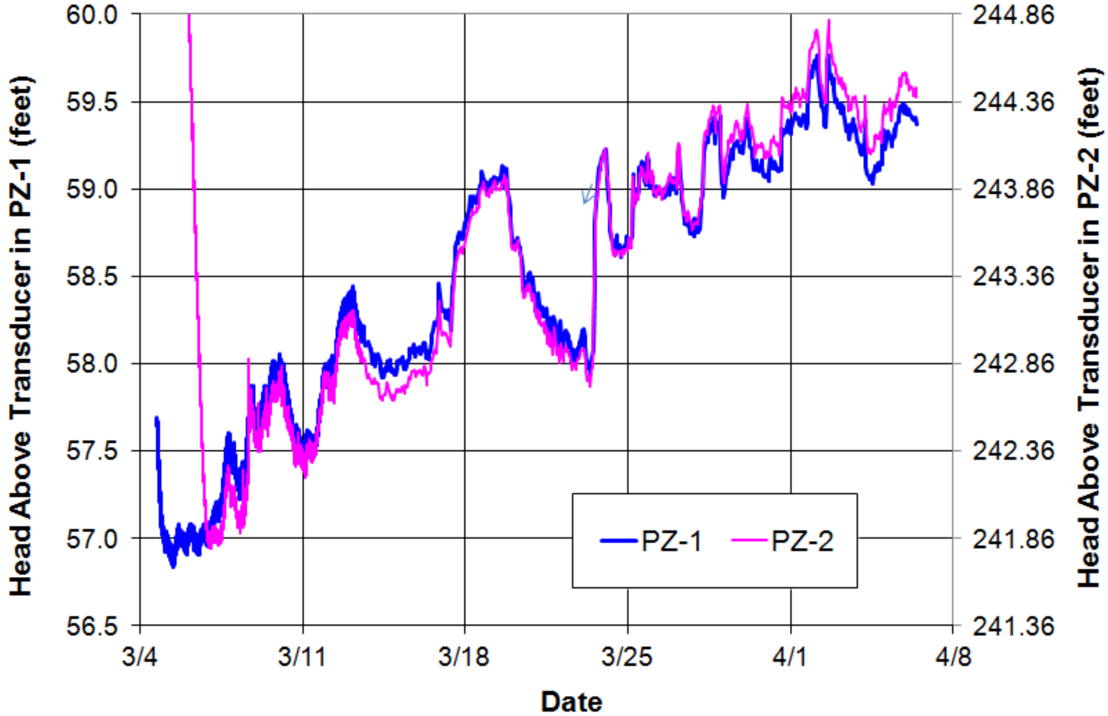

Figure F-8.0-5 Well CdV-9-1(i) PZ-1 and PZ-2 hydrographs

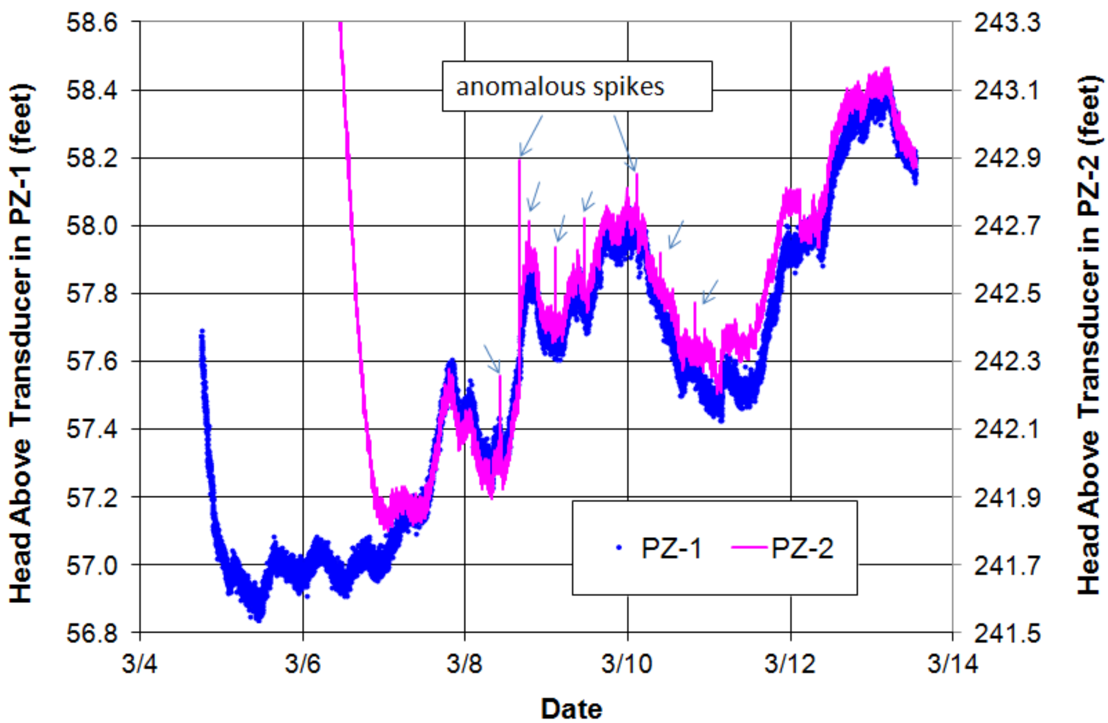

Figure F-8.0-6 Well CdV-9-1(i) PZ-1 and PZ-2 hydrographs—expanded scale

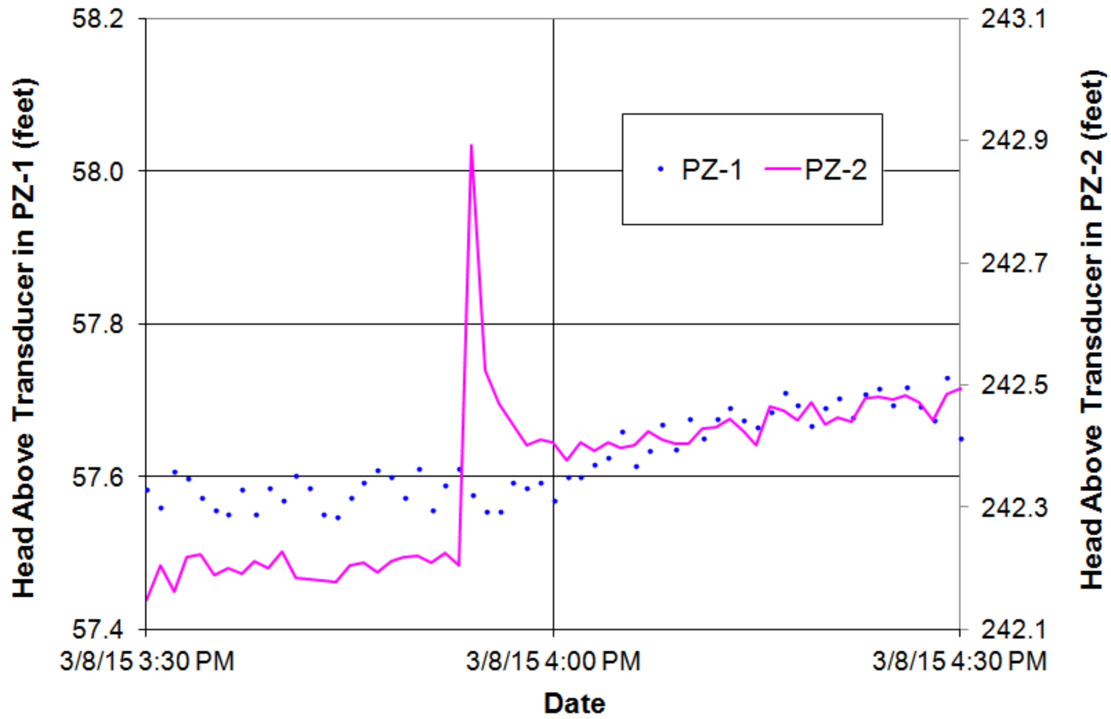

Figure F-8.0-7 Well CdV-9-1(i) PZ-2 hydrograph anomaly

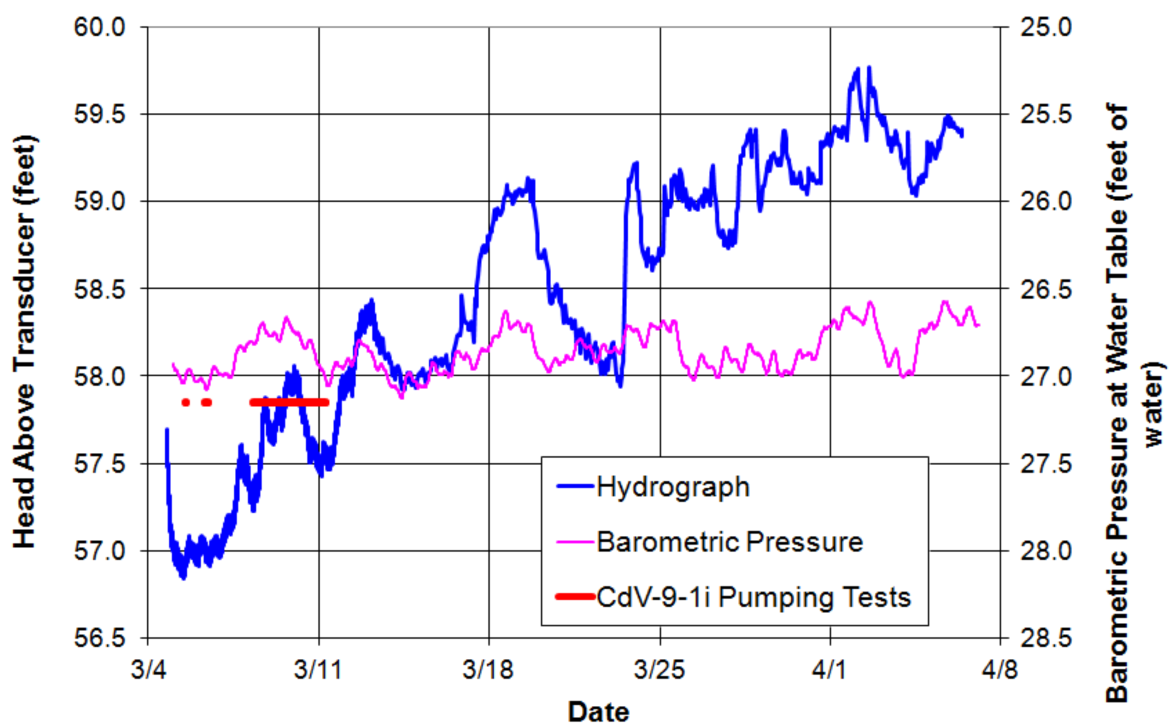

Figure F-8.0-8 Well CdV-9-1(i) PZ-1 hydrograph

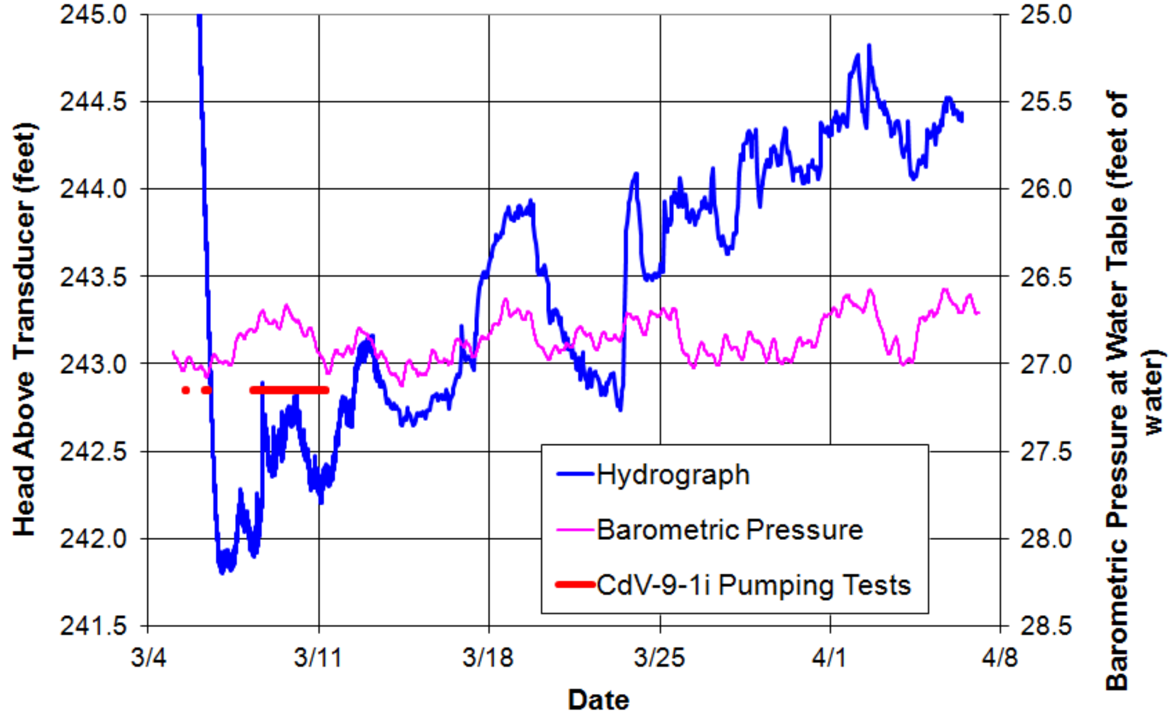

Figure F-8.0-9 Well CdV-9-1(i) PZ-2 hydrograph

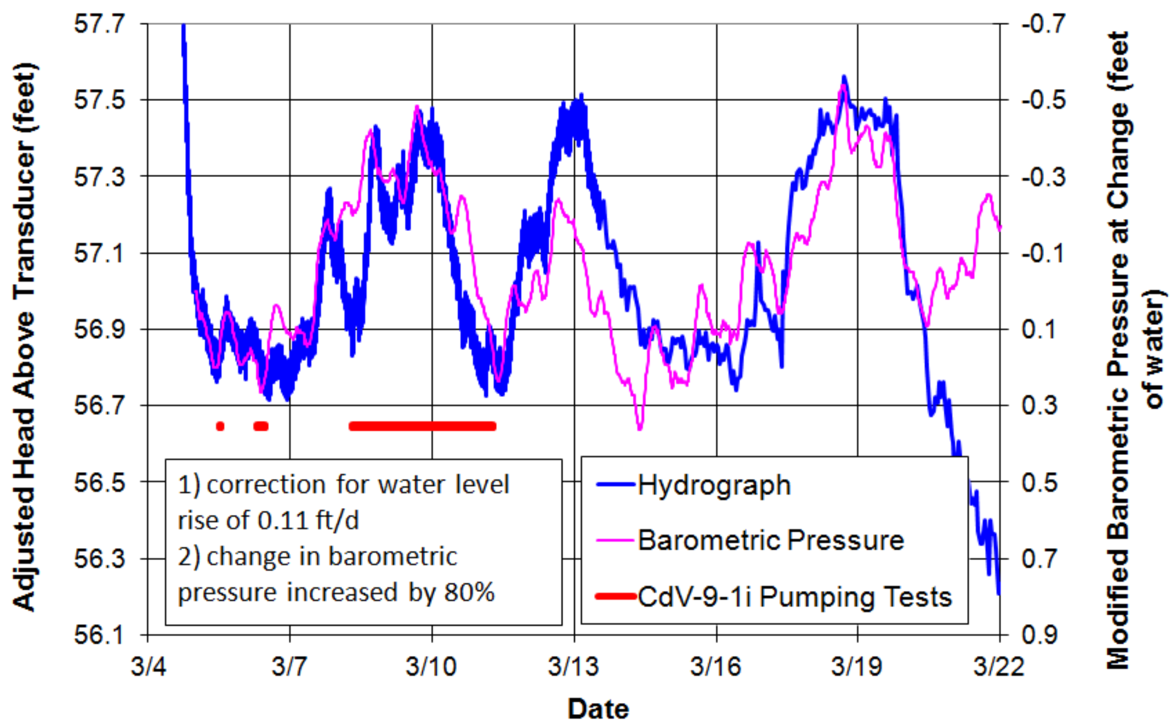

Figure F-8.0-10 Well CdV-9-1(i) PZ-1 modified hydrograph—early time

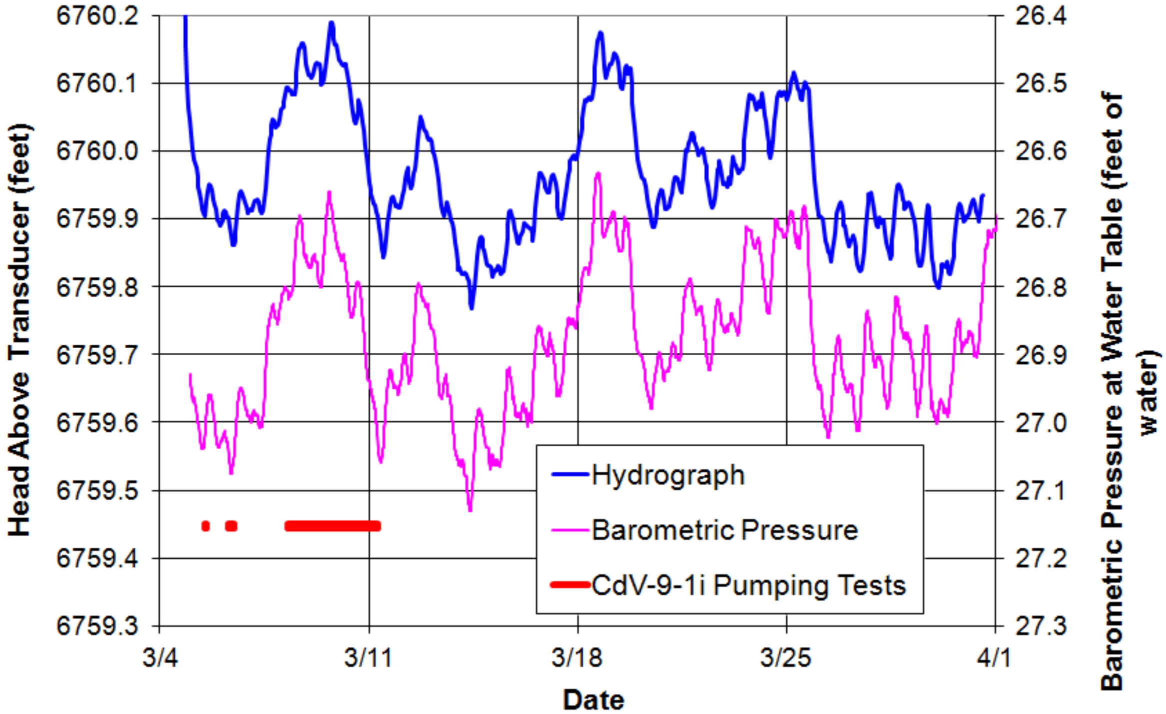

Figure F-8.0-11 Well R-25b hydrograph

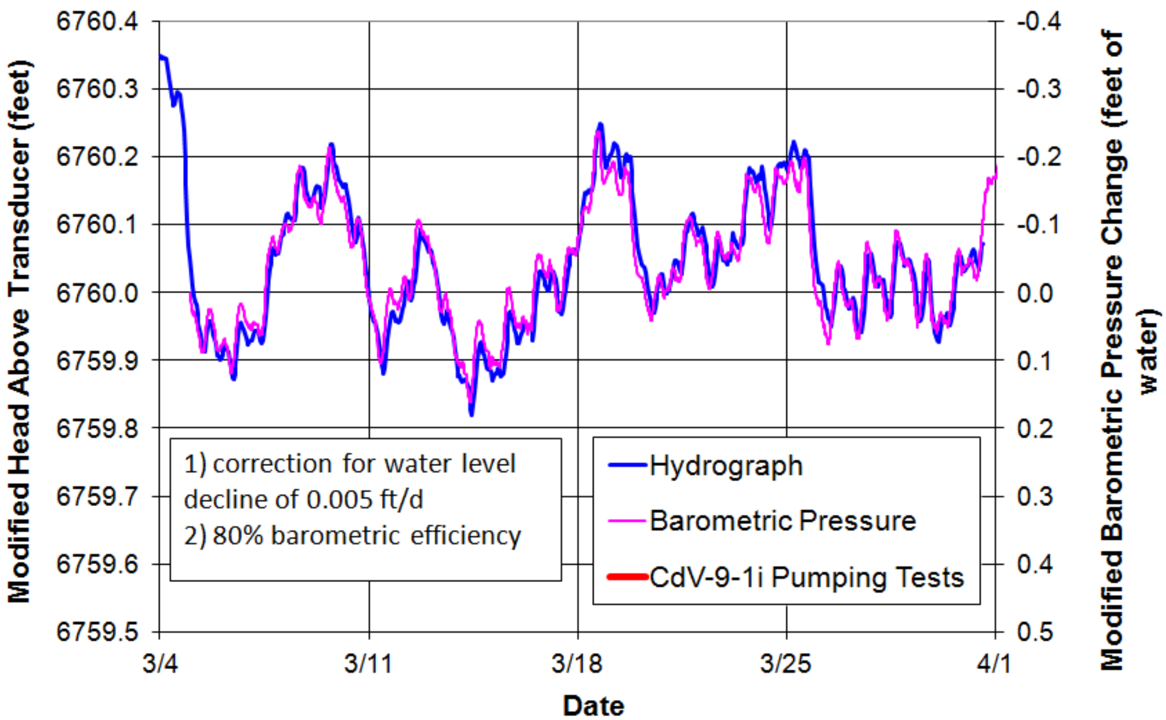

Figure F-8.0-12 Well R-25b hydrograph and barometric pressure correlation

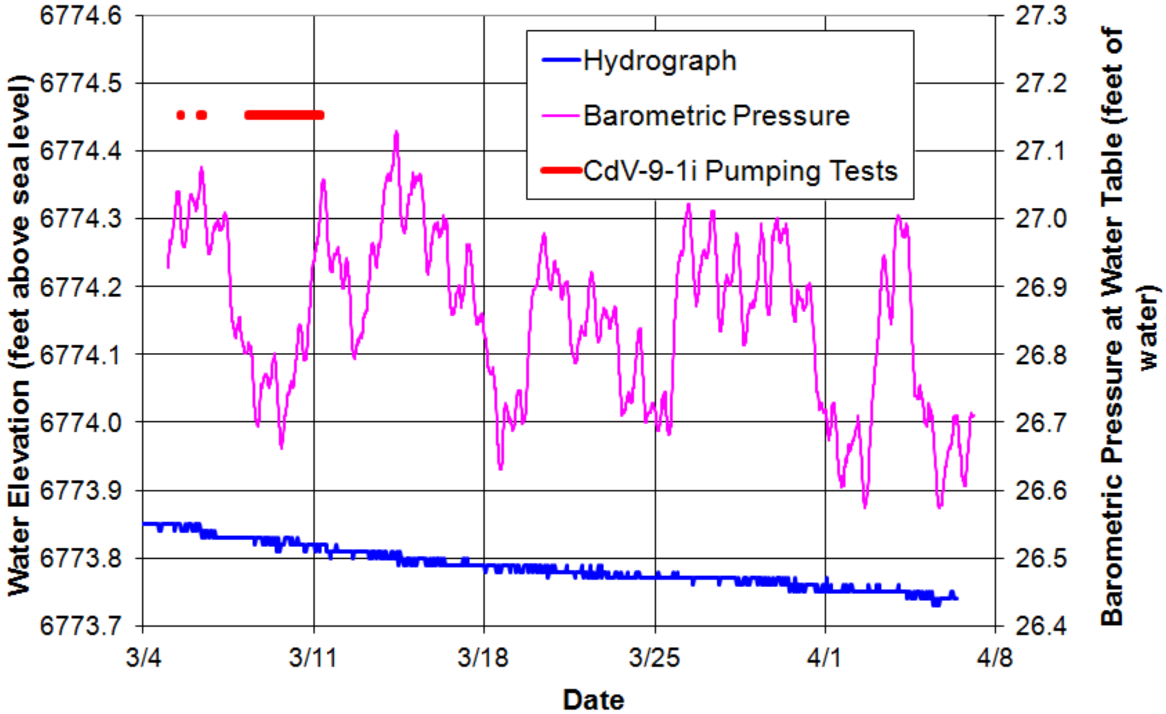

Figure F-8.0-13 Well R-25 screen 1 apparent hydrograph

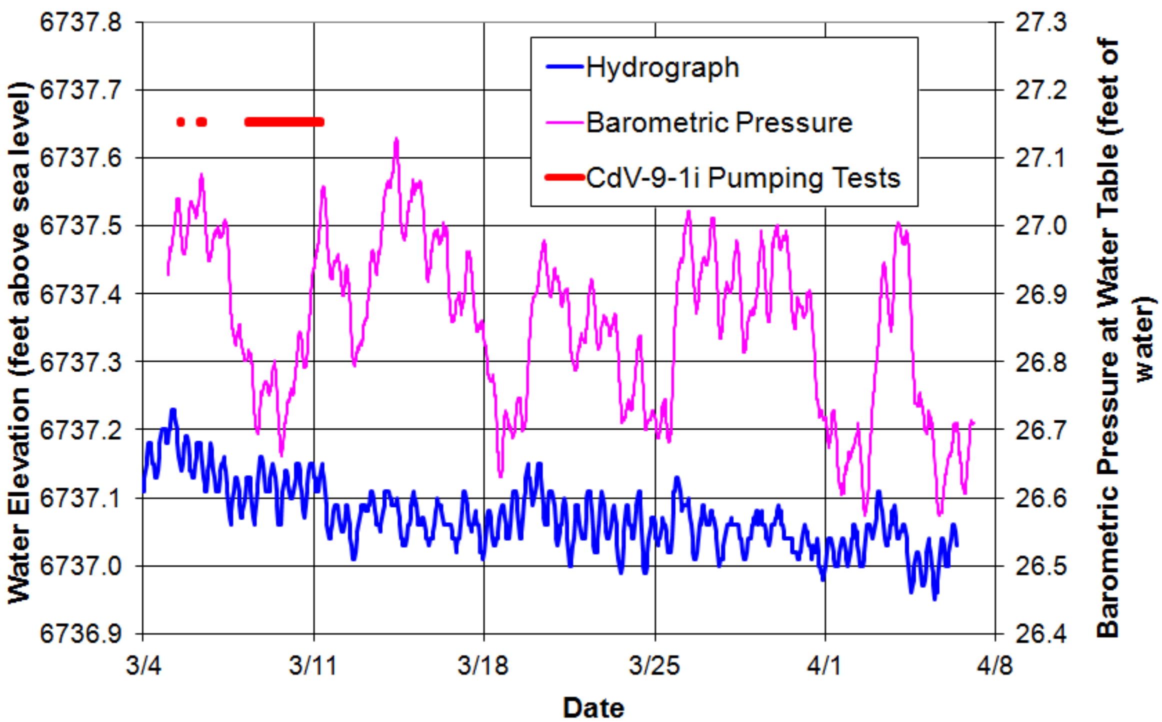

Figure F-8.0-14 Well R-25 screen 2 apparent hydrograph

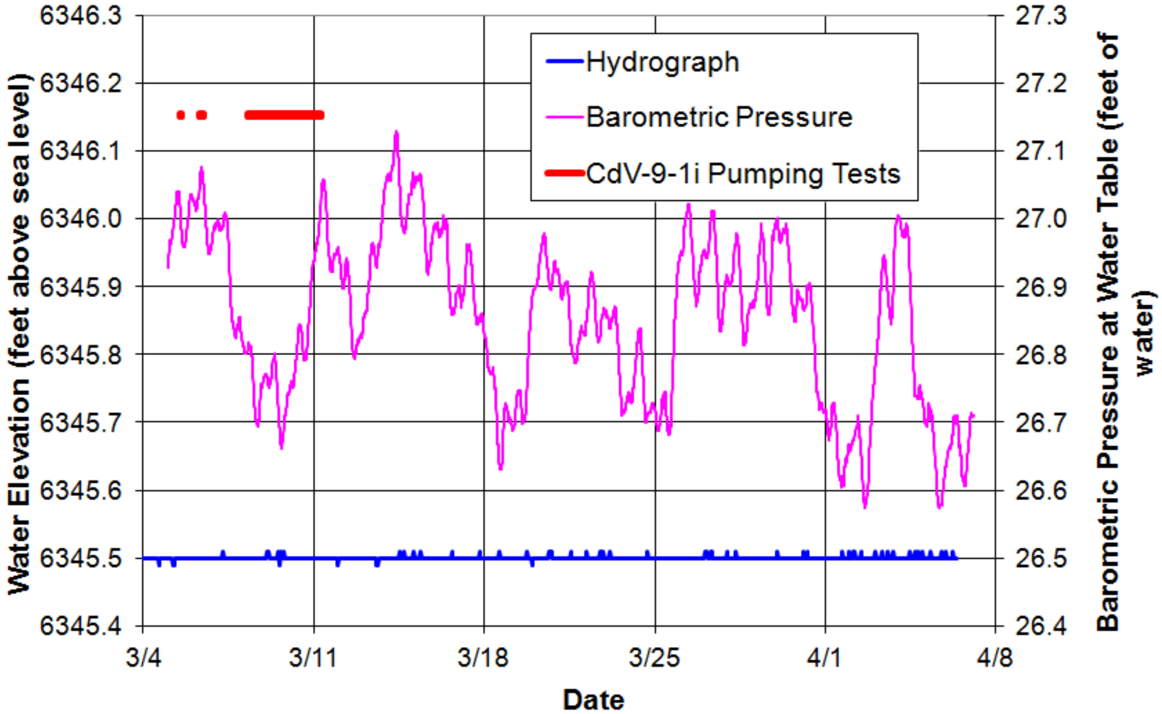

Figure F-8.0-15 Well R-25 screen 4 apparent hydrograph

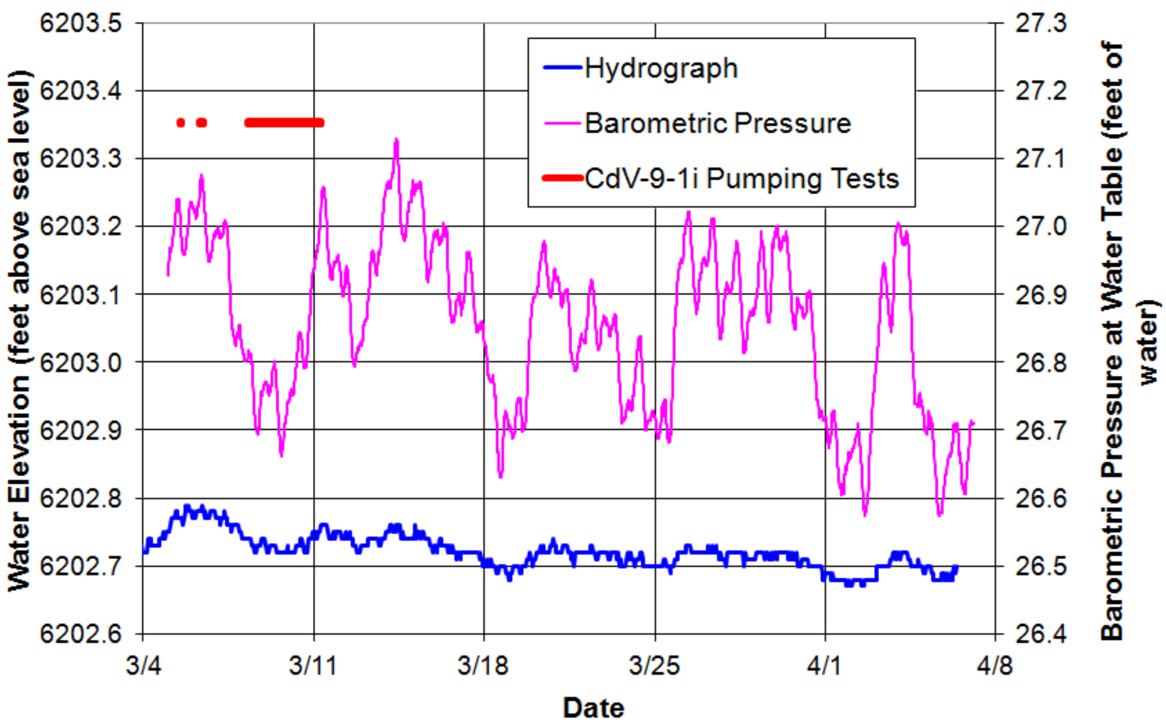

Figure F-8.0-16 Well R-25 screen 6 apparent hydrograph

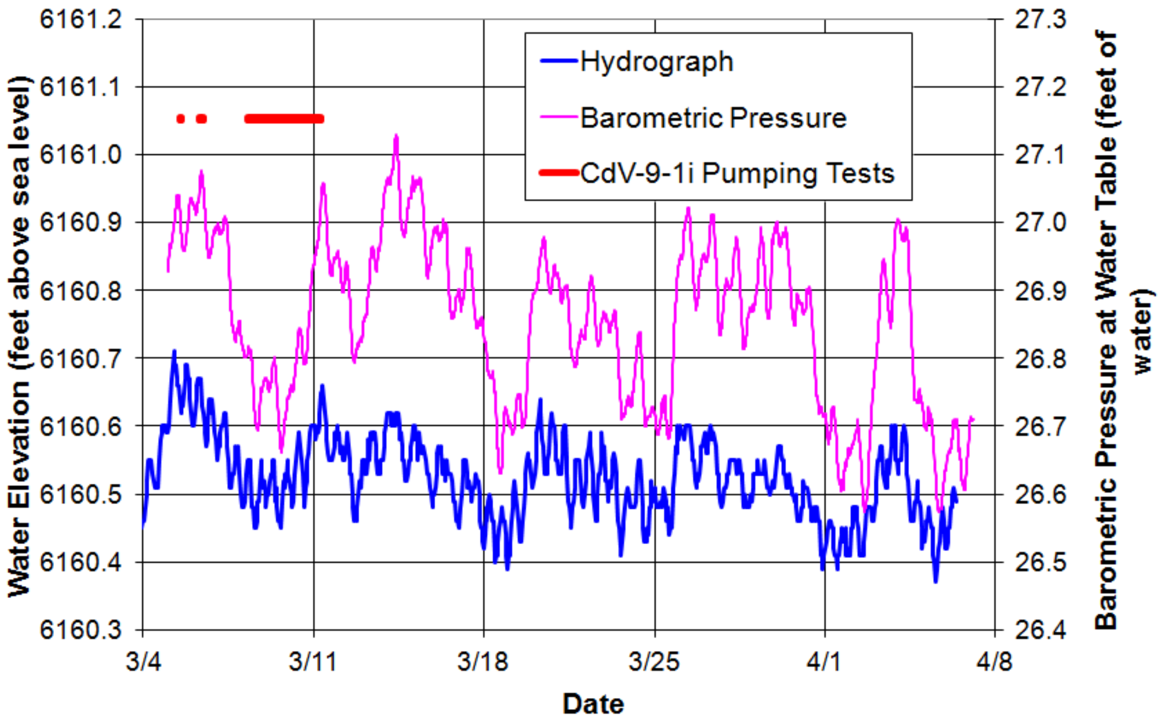

Figure F-8.0-17 Well R-25 screen 7 apparent hydrograph

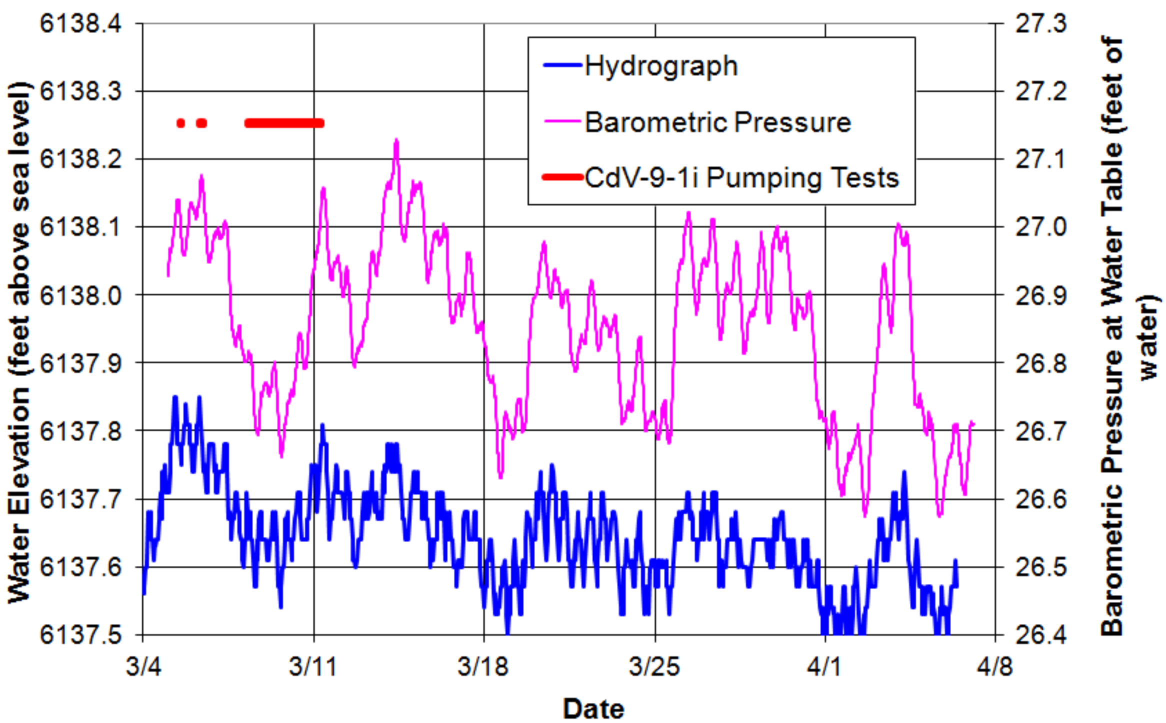

Figure F-8.0-18 Well R-25 screen 8 apparent hydrograph

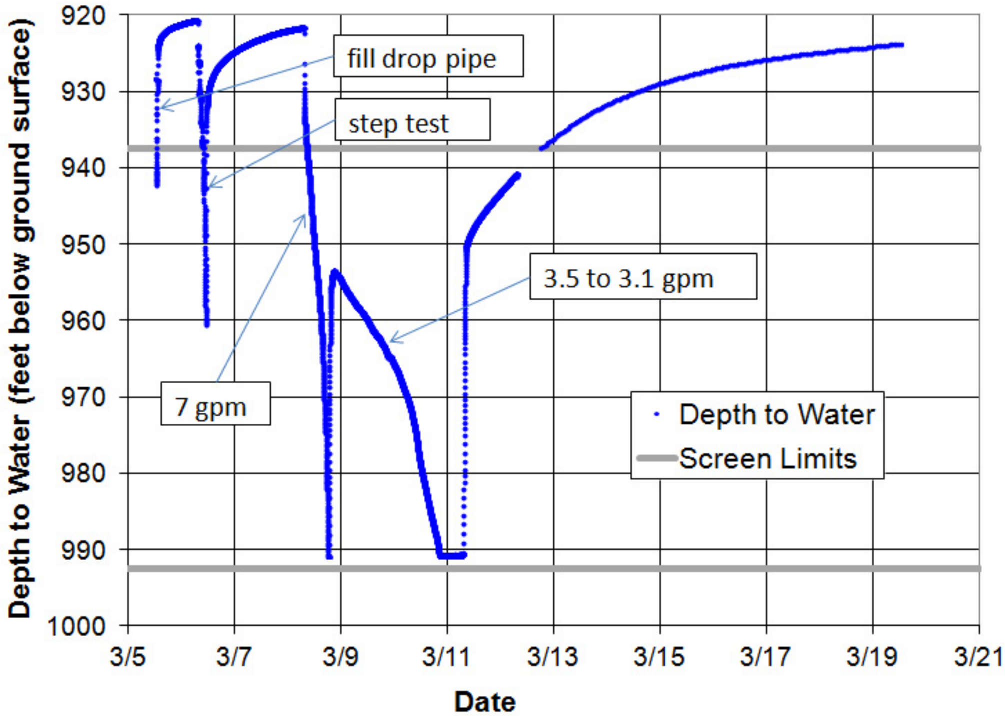

Figure F-9.0-1 Well CdV-9-1(i) screen 1 apparent hydrograph

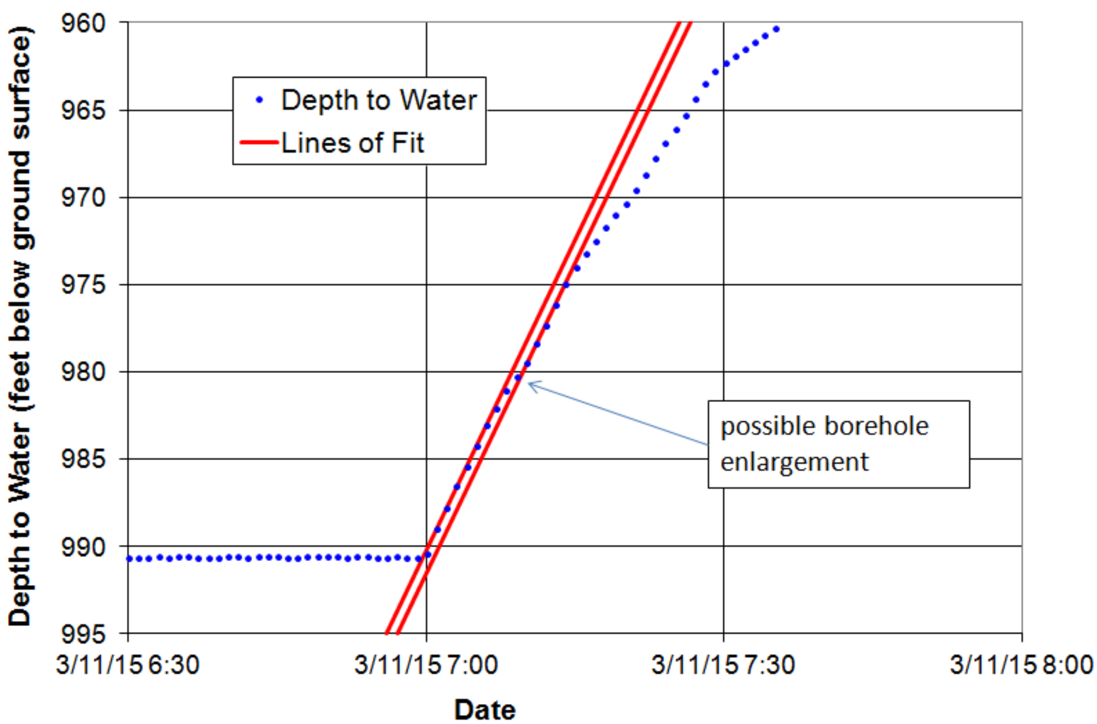

Figure F-9.0-2 Well CdV-9-1(i) screen 1 early recovery

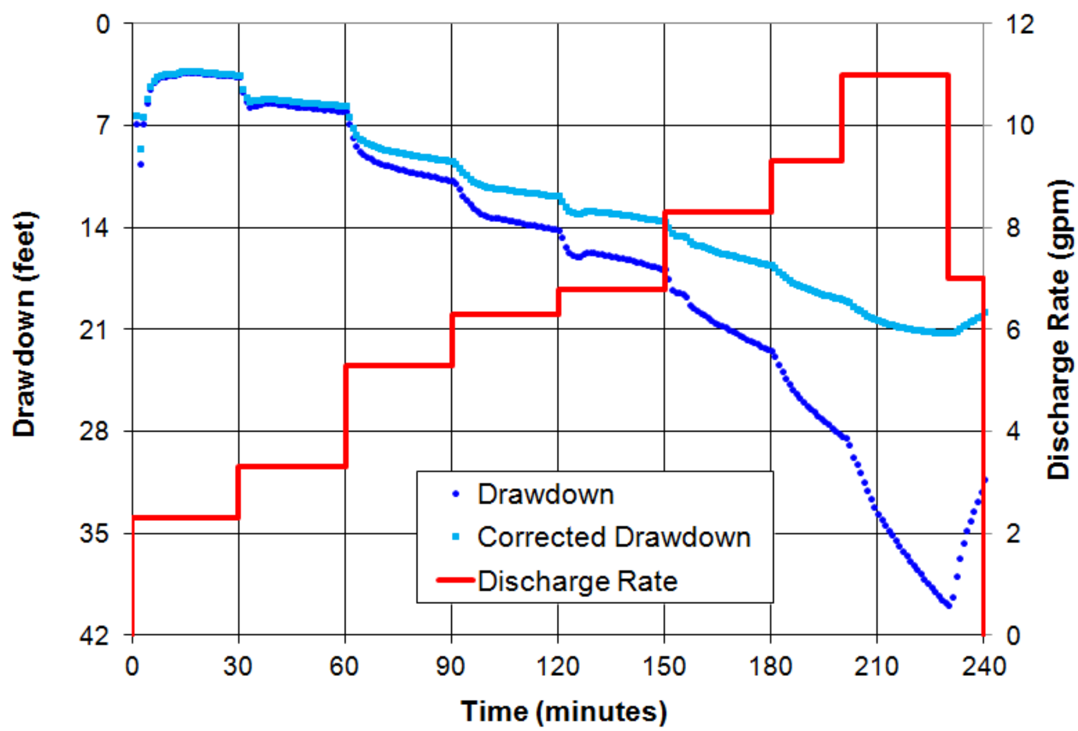

Figure F-9.1-1 Well CdV-9-1(i) screen 1 step-drawdown test

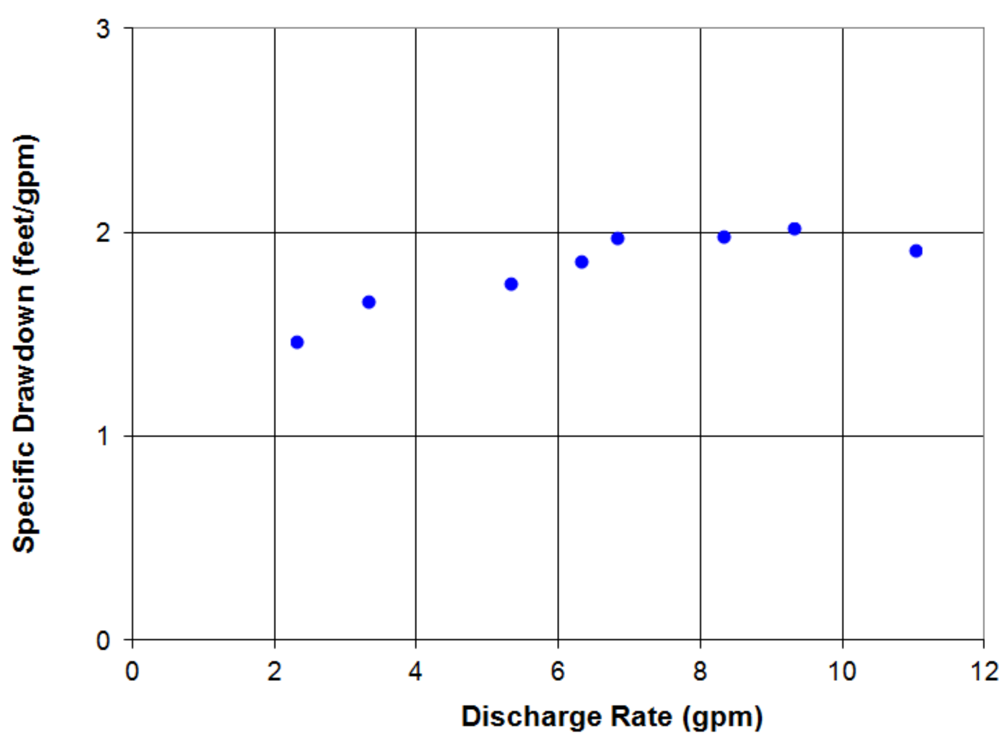

Figure F-9.1-2 Well CdV-9-1(i) screen 1 corrected specific drawdown

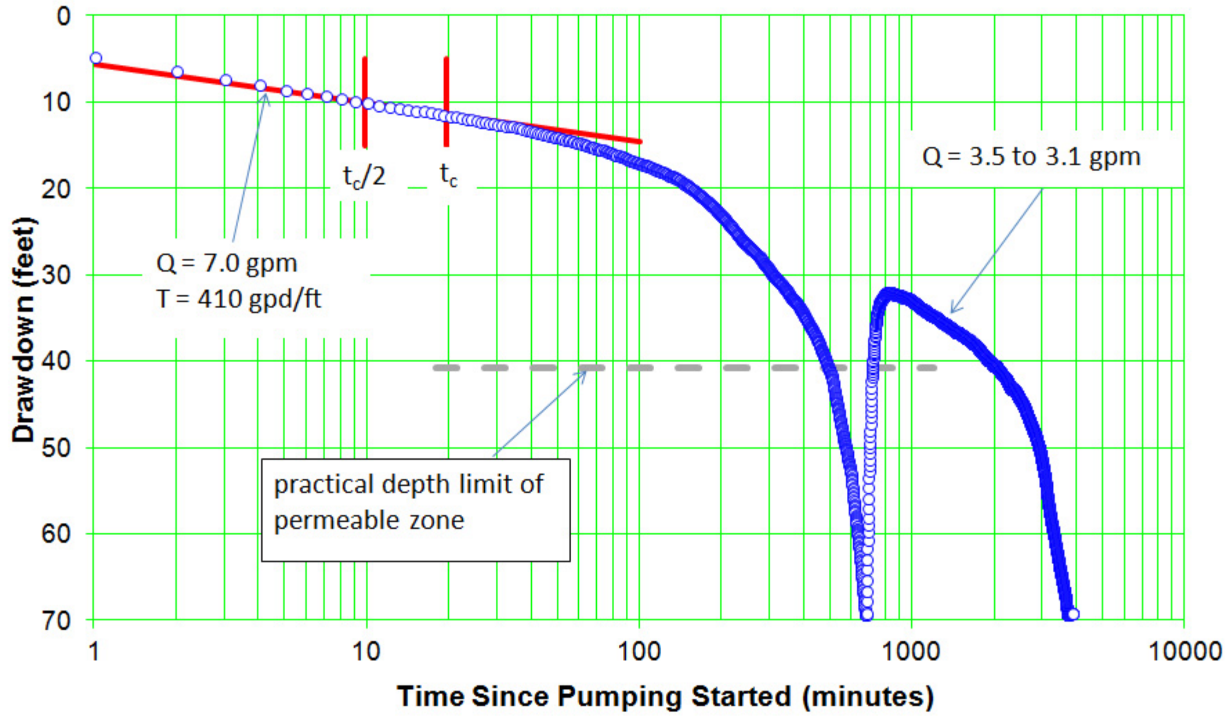

Figure F-9.2-1 Well CdV-9-1(i) screen 1 drawdown

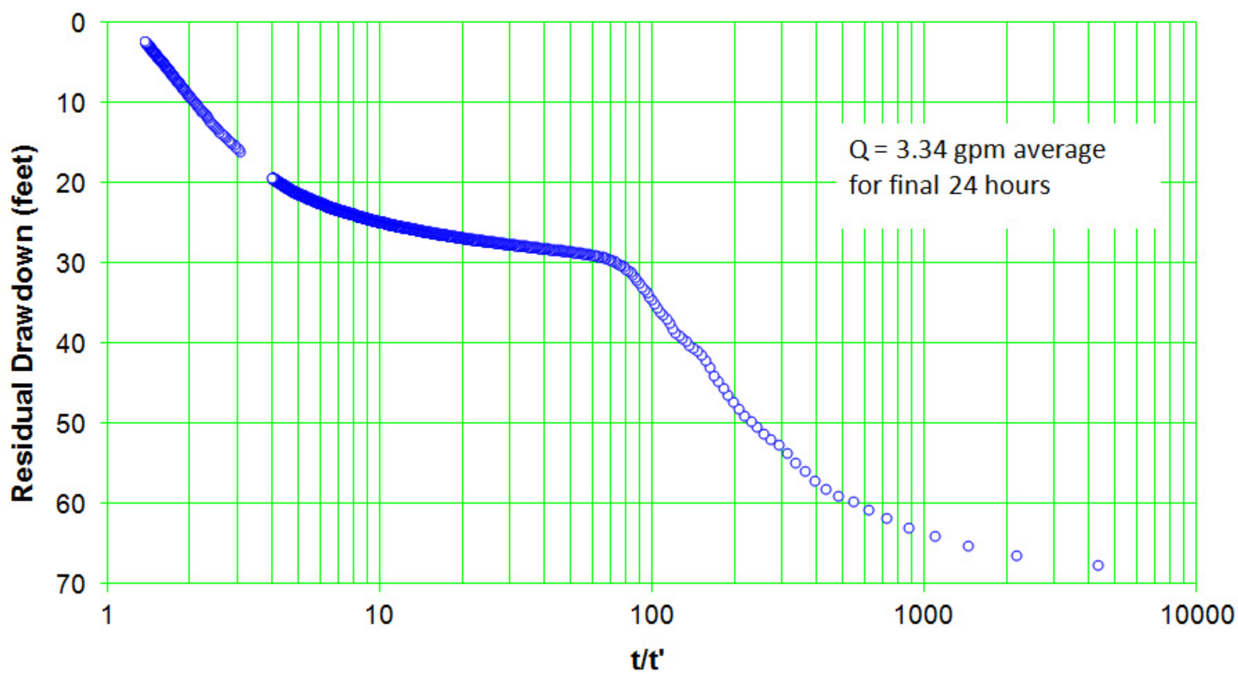

Figure F-9.2-2 Well CdV-9-1(i) screen 1 recovery

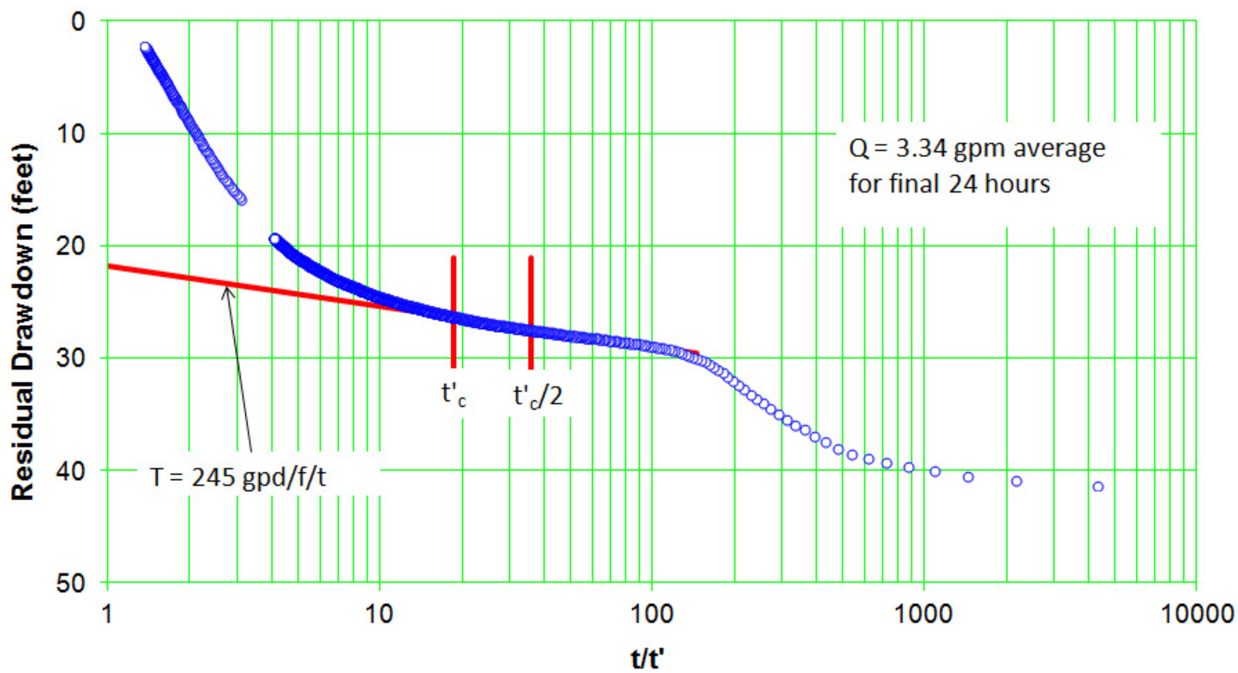

Figure F-9.2-3 Well CdV-9-1(i) screen 1 modified recovery

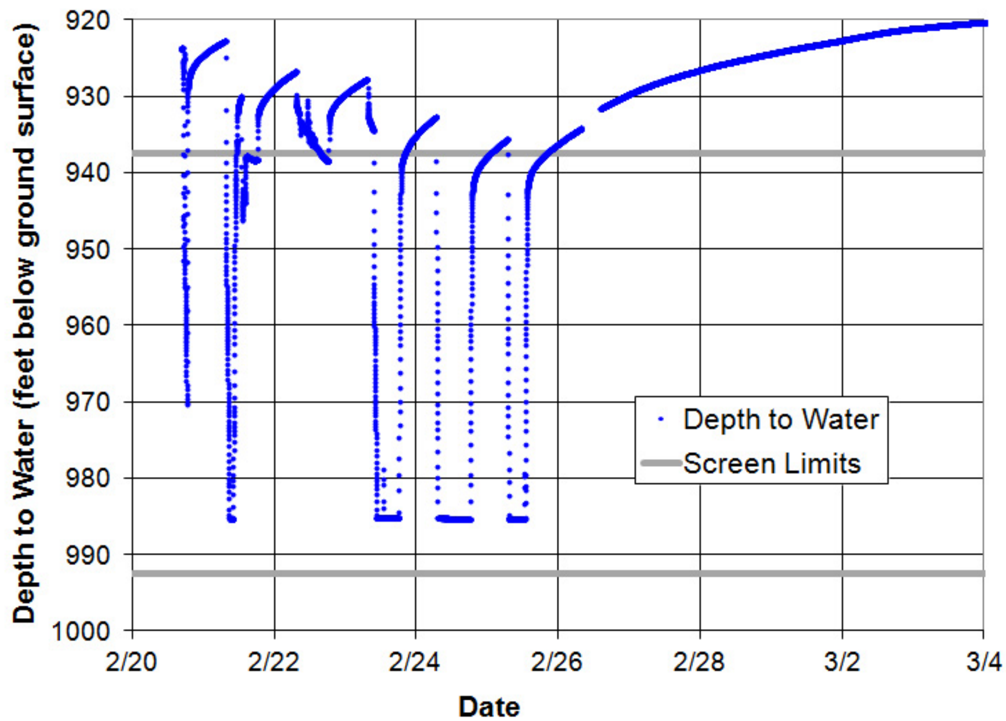

Figure F-9.3-1 Well CdV-9-1(i) screen 1 final purging

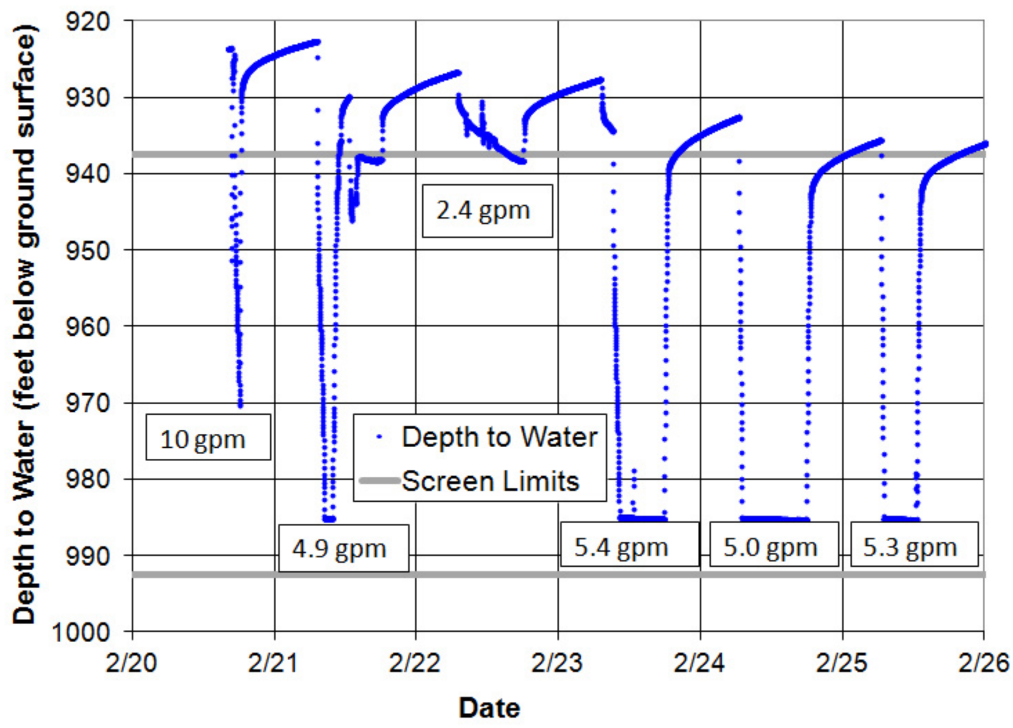

Figure F-9.3-2 Well CdV-9-1(i) screen 1 final purging—expanded scale

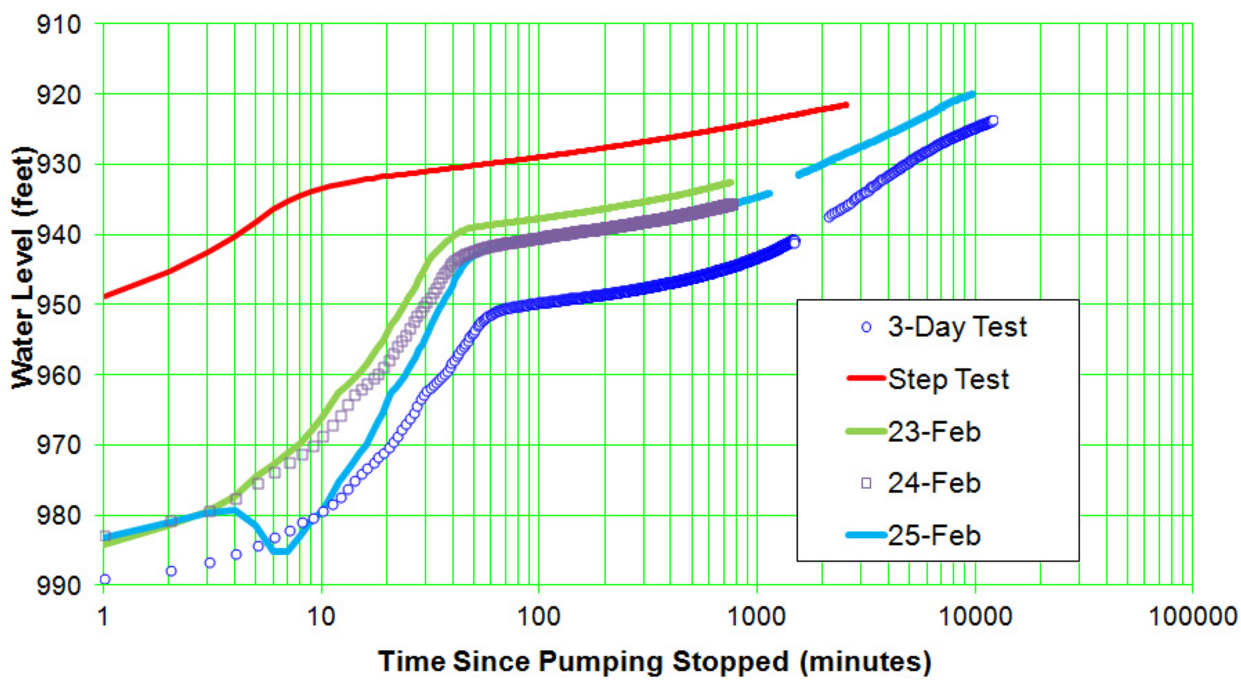

Figure F-9.3-3 Well CdV-9-1(i) screen 1 recovery for multiple tests

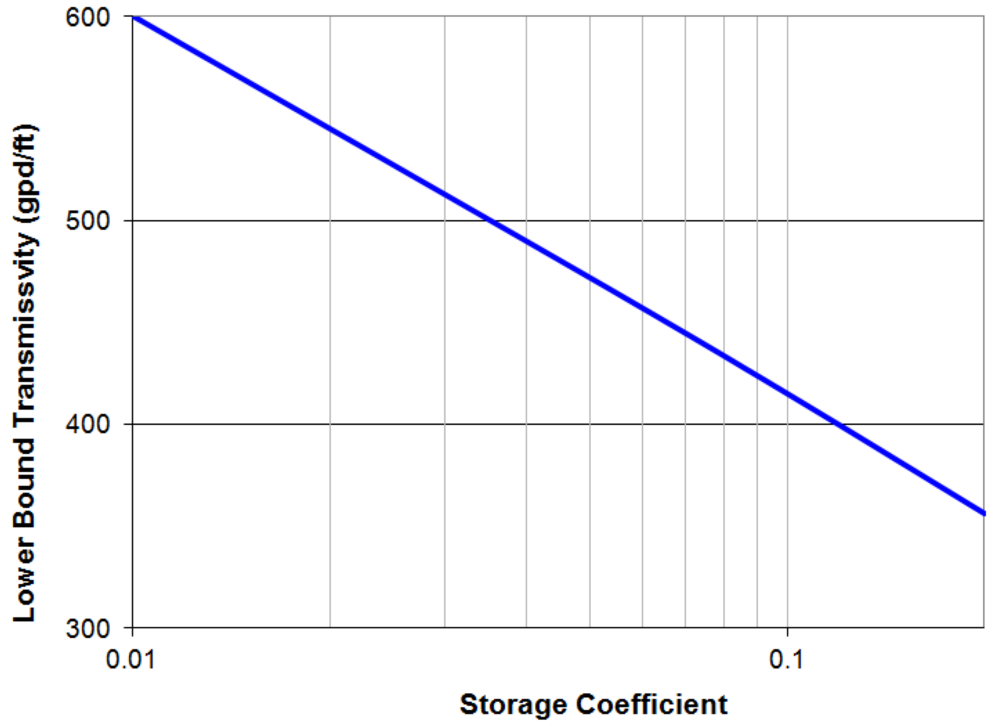

Figure F-9.4-1 Well CdV-9-1(i) screen 1 lower-bound transmissivity

Table F-9.1-1
Step-Drawdown Test Data

Step	Q (gpm)	s_a (ft)	s_c (ft)	s_c/Q (ft/gpm)
1	2.3	3.53	3.38	1.47
2	3.3	5.93	5.52	1.67
3	5.3	10.67	9.33	1.76
4	6.3	14.08	11.74	1.86
5	6.8	16.78	13.46	1.98
6	8.3	22.37	16.47	1.98
7	9.3	28.22	18.84	2.03
8	11.0	39.89	21.14	1.92