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Completion Report for Groundwater Extraction Well CrEX-1

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EXECUTIVE SUMMARY

This completion report describes the drilling, installation, well development, aquifer testing, and pumping system installation for chromium extraction well 1 (CrEX-1), located in Technical Area 05 at Los Alamos National Laboratory.

CrEX-1 was installed as a hydraulic control well at the southern edge of the known plume of contamination. The work plan for installation of this extraction well was approved by the New Mexico Environment Department (NMED) in July 2014.

The CrEX-1 borehole was drilled using fluid-assisted dual-rotary drilling methods and mud-rotary methods. Drilling fluid additives included potable water, a foaming agent, and bentonite-based drilling mud. The drilling work plan for CrEX-1 proposed completion of a single-screen extraction well in the regional aquifer; however, a two-screen well was installed after review of the geophysical logs indicated the potential for water production from the upper part of the screen was minimal. In keeping with the objective of hydraulic capture as close to the top of the aquifer as possible, a two-screen approach was proposed to, and approved by, NMED. The well contains an upper screen 50 ft in length and a lower screen 20 ft in length, separated by 30 ft of blank pipe with a mechanical packer set between the screens. CrEX-1 was completed per the NMED-approved well design.

Following development, it was determined that the upper screen alone could produce the required amounts of water. Therefore, a mechanical packer was set between the upper and lower screened intervals, and the pumping campaign continued using only the upper screen. The pumping of CrEX-1 produces about 6.2 m (~20 ft) drawdown at the well within the pumped screen. However, the pumping test data do not suggest that the pumping produces a significant drawdown in the aquifer adjacent to the screen.

Geologic formations encountered during drilling included, in descending stratigraphic order, Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff (including the Guaje Pumice Bed), upper Puye Formation, Cerros del Rio volcanic series, the lower Puye Formation, Miocene pumiceous sediments, and Miocene riverine deposits.

The regional water table occurs within Miocene pumiceous sand and gravel at a depth of 997.2 ft below ground surface as measured in the completed well with a packer between the upper and lower screens.

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Acronyms and Abbreviations

amsl	above mean sea level
API	American Petroleum Institute
APS	accelerator porosity sonde
bgs	below ground surface
Consent Order	Compliance Order on Consent
EP	Environmental Programs (Directorate)
ESH	Environment, Safety, and Health (Directorate)
gpm	gallons per minute
hp	horsepower
HNGS	hostile natural gamma spectroscopy
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MR	magnetic resonance
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
PVC	polyvinyl chloride
TA	technical area

TBD	to be determined
TD	total depth
VOA	volatile organic analysis

1.0 INTRODUCTION

This completion report summarizes the drilling, well construction, well development, aquifer testing, and pumping system installation for chromium extraction well 1 (CrEX-1). CrEX-1 was drilled and installed from July 4, 2014, to August 17, 2014, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

CrEX-1 is located within Technical Area 05 (TA-05) north of the narrow ridge that separates Mortandad and Cedro Canyons (Figure 1.0-1). The primary purpose of CrEX-1 is to attain hydraulic control of chromium-contaminated groundwater from beneath Mortandad Canyon and to prevent migration of this water farther southward towards San Ildefonso Pueblo. Water-quality and hydrologic data from CrEX-1 will also be used in conjunction with information from other wells in the area to assess where additional hydraulic control and source removal wells may be positioned in the future.

The work plan for installing CrEX-1 was approved by the New Mexico Environment Department (NMED) in its July 8, 2014, letter, "Approval Drilling Work Plan for Groundwater Extraction Well CrEX-1" (LANL 2014, 254824; NMED 2014, 525004). Earlier approval to begin work was received from NMED by e-mail on June 19, 2014 (Dale 2014, 600135). The approved work plan specified that a single screen up to 100 ft long would be installed in the regional aquifer. However, geophysical logging of the borehole indicated that the upper portion of the well might contribute only minimal water to the total well production. Therefore, a dual-screen design was proposed by the Laboratory and approved by NMED on August 8, 2014 (see Appendix A). The dual-screen design would allow for a packer to be inserted between the upper and lower screens if sufficient water production was achieved in the upper screen. The well screens were set between 1090 ft and 1070 ft below ground surface (bgs) and 1040 ft and 990 ft bgs. The water level was 997.2 ft bgs after development of both screens and placement of a packer between the upper and lower screened intervals.

Characterization during drilling included collection of cuttings samples at 10-ft intervals from ground surface to total depth (TD) for lithologic evaluation. Borehole logs included video and natural gamma logs conducted by the Laboratory and a full suite of geophysical logs conducted by Schlumberger.

Postinstallation activities included well development, aquifer testing, pumping system installation, and geodetic surveying. The aquifer testing demonstrated a relatively high permeability of the aquifer screened by CrEX-1. Future activities will include surface completion, site restoration, and continued 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 in the Laboratory's Electronic Document Management System. This report contains summary descriptions of activities and supporting figures, tables, and appendixes associated with the CrEX-1 well drilling and installation project.

2.0 ADMINISTRATIVE PREPARATION

The following documents were prepared to guide activities associated with the drilling, installation, and pumping of groundwater extraction well CrEX-1:

- "Drilling Work Plan for Groundwater Extraction Well CrEX-1" (LANL 2014, 254824)
- "Field Implementation Plan for Well CrEX-1" (LANL 2014, 600129)

- "[Integrated Work Document for] Implementation of the Drilling Work Plan for Groundwater Extraction Well CrEX-1" (Yellow Jacket Drilling 2014, 600131)
- "Spill Prevention Control and Countermeasures Plan for the ADEP Groundwater Monitoring Well Drilling Operations, Los Alamos National Laboratory, Revision 6" (North Wind Inc. 2011, 213292)
- "Waste Characterization Strategy Form for Chromium Well CrEX-1" (LANL 2014, 254859)
- "Application for Permit to Drill a Well with No Consumptive Use of Water" (OSE 2014, 600141)
- "Temporary Permission to Discharge, Treated Ground Water from Aquifer Testing at Pilot Pumping Well CrEX-1 (AI: 856, PRD20140007)" (NMED 2014, 600128)
- "Well Pump Tests Phase II in Sandia and Mortandad Canyons," U.S. Department of Energy Categorical Exclusion Determination Form (DOE 2014, 600140)

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and approach and provides a chronological summary of field activities conducted during the drilling of CrEX-1.

3.1 Drilling Approach

The CrEX-1 borehole was drilled using a Foremost DR-24HD dual-rotary drilling rig. The dual-rotary system allows for advancement of casing with the casing rotator while drilling with conventional air/mist/foam methods with the drill string. The Foremost DR-24HD drill rig was equipped with a 5.5-in.–outside diameter (O.D.) dual-wall reverse-circulation drill pipe, tricone bits, downhole hammer bits, and general drilling equipment. Casing sizes used in drilling activities included 20-in., 18-in., and 16-in. nominal diameters. Casing sizes were selected to ensure the required 3-in. minimum annular thickness of the filter pack would be achieved around an 8.62-in.-O.D. well screen, as recommended by the American Water Works Association for municipal well construction (standard A100). The dual-rotary and standard rotary (open-hole) techniques used filtered compressed air, fluid-assisted air, and bentonite-based drilling mud to evacuate cuttings from the borehole.

Drilling fluids, including compressed air, municipal water, and a mixture of municipal water with Baroid brand QUIK-FOAM foaming agent, were used as needed to advance the borehole to a depth of 820 ft bgs, just below the base of the Cerros del Rio volcanic series. The fluids were used to cool the bit and help lift cuttings from the borehole. At 820 ft bgs, the drilling subcontractor switched to a flooded reverse-circulation method using bentonite-based mud in an effort to drill the remainder of the borehole open hole. After trying to remedy lost circulation issues for several days, the drillers tried a modified flooded reverse-circulation system with the crossover subset in the drill string 50 ft above the bit. This approach was successful at advancing the borehole, maintaining borehole stability, returning cuttings to the surface, and achieving the planned TD of 1200 ft bgs.

3.2 Chronology of Drilling Activities

Decontamination of the drill rig and associated tools was performed before the crew arrived at the drill site. Drilling equipment and supplies were mobilized and prepared for drilling between June 30 and July 4, 2014. Drilling of the CrEX-1 borehole began on July 4, 2014, when a 20-in.-O.D. surface casing was installed with a 24-in.-diameter tricone bit and dual-rotary drilling method. The 24-in.-diameter borehole was advanced to 65 ft bgs. However, the 20-in.-O.D. casing could only be advanced to a depth of 35 ft bgs. The borehole was then filled from 65 ft to 35 ft bgs with cement grout, and the annular space between the 20-in. casing and the 24-in.-diameter borehole wall was filled. The surface casing was set in unit 1v of the Tshirege Member of the Bandelier Tuff.

A 19-in.-diameter borehole was drilled to 475 ft bgs (top of the Cerros del Rio volcanic series) using casing-advance methods, including the use of potable water and foam. This portion of the well was cased with 18-in.-O.D. casing. Five feet of this casing, including the casing shoe, was cut off and left in the borehole from 475 ft to 470 ft bgs.

A 17-in.-diameter borehole was advanced from 475 ft to 816 ft bgs (bottom of the Cerros del Rio volcanic series) using casing-advance methods, including the use of potable water and foam. This portion of the well was cased with 16-in.-O.D. casing. Five feet of this casing, including the casing shoe, was cut off and left in the borehole from 816 ft to 811 ft bgs.

At 816 ft bgs, the drilling method was switched to flooded reverse-circulation using mud. However, circulation was lost at this depth and several days were spent changing the mud mixture and adding circulation-restoring additives (Baroid products BENSEAL and AQUAGUARD) to the mixture. On July 31, 2014, 8 yd of neat cement was placed downhole, allowed to set up for 12 h, and then drilled through. This appeared to stabilize the borehole but did not restore circulation. On August 2, 2014, a revised bottom-hole assembly with the crossover subset only 50 ft above the drill bit was used to successfully drill ahead to 1035 ft bgs. This approach used a modified reverse-circulation method by pumping drilling mud at a controlled rate from the top instead of flooding the borehole. The borehole was completed to a TD of 1211 ft bgs on August 4, 2014.

The borehole was logged by Schlumberger on August 6 and 7, 2014. A proposed well design was submitted by the Laboratory to NMED for review on August 8, 2014, and was approved the same day (Appendix A).

Well construction began on August 12, 2014.

4.0 SAMPLING ACTIVITIES

The following sections describe the cuttings sampling activities for CrEX-1. No groundwater samples were collected during drilling. All sampling activities were conducted in general accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected at 10-ft intervals from the borehole beginning at 170 ft to the TD of 1211 ft bgs. At each interval, the drillers collected approximately 500 mL of bulk cuttings from the discharge cyclone, placed them in canvas or plastic bags, labeled them, and stored them on-site. Radiological control technicians screened cuttings before they were removed from the site, and screening measurements were within the range of background values. The cuttings were delivered to the Laboratory's Geology and Geochemistry Research Laboratory for binocular microscope analysis.

Section 5.1 of this report summarizes the stratigraphy encountered at well CrEX-1.

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at CrEX-1 is presented below. The Laboratory's geology task leader and geologists examined the cuttings to determine the geologic contacts and hydrogeologic conditions. Drilling observations, video logging, geophysics, and water-level measurements were used to characterize groundwater occurrences.

5.1 Stratigraphy

The stratigraphy and contacts presented below are based on lithologic descriptions of cuttings samples collected from the discharge cyclone, borehole geophysical logs, and video logs. Geologic units are described below in order of youngest to oldest geologic units. Figure 5.1-1 illustrates the stratigraphy at CrEX-1.

No cuttings were collected from 0 ft to 170 ft bgs, and no geophysical logs were run from 0 ft to 200 ft bgs, so contacts for the upper geologic units are based on depths predicted by the sitewide geologic model. Descriptions of these uncharacterized units are taken from nearby wells.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (0 ft to 62 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff consists of light and brownish-gray to dark yellowish-brown, poorly welded, crystal- and lithic-rich devitrified ash-flow tuff.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (62 ft to 122 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff consists of grayish-orange-pink to very pale orange to light brown, nonwelded to poorly welded vitric ash-flow tuff.

Cerro Toledo Interval, Qct (122 ft to 144 ft bgs)

The Cerro Toledo interval consists of light gray to light brownish-gray and pale red to light brown, poorly to well-sorted tuffaceous sedimentary deposits that occur between the Tshirege and Otowi Members of the Bandelier Tuff. The deposits are predominantly reworked tuff with minor silt, sands, granules, and gravels derived from Cerro Toledo rhyolites, Tschicoma dacites, and Otowi tuffs eroded from the Sierra de los Valles highlands west of the Pajarito Plateau. The formation commonly exhibits pervasive light pale orange to grayish-orange oxidation.

Otowi Member of the Bandelier Tuff, Qbo (144 ft to 433 ft bgs)

The Otowi Member of the Bandelier Tuff consists of white to light gray pumiceous, nonwelded to partly welded ash-flow tuff with vitric, fibrous pumices, phenocrysts, and lithic clasts that include a variety of pale brown and olive gray to brownish-gray intermediate-composition volcanic rocks.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (433 ft to 450 ft bgs)

The Guaje Pumice Bed is white to gray and reddish-gray and contains pumice fragments with subordinate amounts of volcanic lithics and quartz and sanidine phenocrysts. The presence of this unit was difficult to determine based on drill cuttings alone. The unit boundaries were determined based on the high borehole gamma-ray response commonly found in this unit in nearby wells.

Puye Formation, Tpf (450 ft to 460 ft bgs)

The Puye Formation consists of unconsolidated, light brown, fairly sorted, volcaniclastic sand with a silty matrix of glassy shards and clay. These deposits contain abundant quartz and feldspar and minor pumice and dacite clasts up to 0.5 cm in size.

Cerros del Rio Volcanic Series, Tb4 (460 ft to 809 ft bgs)

The Cerros del Rio volcanic series consists of dark to medium gray, massive to vesicular basaltic lava flows separated by porous zones of interflow breccias. The basalts are sparsely porphyritic with phenocrysts of pyroxene, plagioclase, and altered olivine. Thin intervals of pinkish-gray claystone are intercalated with basalt in the lower part of the unit.

Puye Formation, Tpf (809 ft to 1054 ft bgs)

The Puye Formation consists of moderate brown and grayish-orange to very dusky red, poorly to moderately sorted volcaniclastic sediments with subangular to subrounded boulders, cobbles, gravels, sands, and silts. Clasts in these sedimentary deposits consist of dacitic detritus shed from the Tschicoma Formation exposed in the Sierra de los Valles highlands west of the Pajarito Plateau.

Mixed Miocene Deposits, Tjfp and Tcar (1054 ft to 1070 ft bgs)

The mixed Miocene deposits are a mixture of pumiceous sediments and riverine deposits that contain characteristics of both the Tjfp and Tcar units. The pumiceous sediments are represented by clasts of white crystal-poor vitric pumice and light gray rhyolite lavas. Riverine components include well-rounded lithic sands and gravels made up of intermediate-composition volcanics and minor (<5%) quartzite. The riverine sediments also include intervals of fine-grained crystal sand.

Miocene Pumiceous Sediments, Tjfp (1070 ft to 1155 ft bgs)

Miocene pumiceous sediments form an unassigned unit that consists of light brown and very light gray to tan tuffaceous silty sand with multicolored rhyolitic and dacitic gravel. Cuttings from this unit contain abundant, reworked, subrounded, white vitric pumice and gray vitric and devitrified rhyolite lava clasts in a silty and sandy matrix of rhyolite ash and fine-grained felsic crystals. Milky perlite and obsidian are minor but ubiquitous clasts in these deposits. Pumice clasts contain sparse biotite phenocrysts.

Miocene Riverine Deposits, Tcar (1155 ft to 1211 ft bgs)

Miocene riverine deposits consist of medium brown and grayish-orange-pink silty sand with subrounded to rounded gravel composed of dacite and minor quartzite. The sand fraction includes fine sand and silt dominated by rounded and frosted quartz and coarse lithic sand made up of intermediate volcanics. These deposits are probably correlative with the Chamita Formation of the Santa Fe Group.

5.2 Groundwater

No perched water was encountered during the drilling of CrEX-1. On August 8, 2014, after the well was drilled to a depth of 1211 ft bgs, a water level for the regional aquifer inside the drill casing was measured at 988 ft bgs. The depth to water in the open borehole at TD before well construction was 997 ft bgs. On September 24, 2014, after development of the upper and lower screens, the composite depth to water was measured at 995.8 ft bgs on a video log. On October 3, 2014, following well installation, well development, installation of the packer between the upper and lower screens, and aquifer testing, the depth to water was 997.2 ft bgs in the completed well. The upper screen of CrEX-1 straddles the regional water table. This allows for effective assessment of the uppermost portion of the regional aquifer next to the regional water table where the highest contaminant concentrations are expected. The effective saturated thickness of the formation screened by the upper screen is approximately 43 ft (the bottom of the upper screen is 1040 ft bgs). The aquifer testing demonstrated a relatively high permeability of the aquifer screened by CrEX-1. The pumping of CrEX-1 produces about 6.2 m (~20 ft) drawdown at the well within the pumped screen. However, the pumping test data do not suggest that the pumping produces a significant drawdown in the aquifer adjacent to the screen. Potentially, borehole skin effects caused a substantial portion of the observed drawdown. Skin effect is an increase in the pressure drop at the pumping well when compared with aquifer pressure adjacent to the well. The increased pressure drop is thought to be caused by extra flow resistance near the wellbore because of imperfect hydraulic connection between the well and the aquifer.

5.2.1 Regional Aquifer Groundwater Elevations

Based upon the depth to water of 997.2 ft bgs measured on October 3, 2014, at CrEx-1 after installation, initial development, and aquifer testing, the water-level elevation was approximately 5834.13 ft above mean sea level ([amsl] the ground surface elevation is 6831.33 ft, and the water level in the well is 997.2 bgs). This elevation is approximately 1 ft to 1.5 ft lower than the expected elevation of about 5835 ft for CrEx-1 based on the current groundwater flow conditions in the aquifer. For example, the groundwater elevation at R-50 screen 1 was approximately 5834.6 ft when the CrEx-1 water level was measured. The general structure of groundwater flow is presented in Figure 5.2-1; the water-level contours in the figure are based on circa 2011 water-level data. (Note: There is a documented 0.6-ft average annual water-level decline in the area.) Based on the general groundwater flow direction, it is expected that the water-level elevation at R-50 screen 1 would be lower, not higher, than the water-level elevation at CrEX-1. The water level for CrEx-1 measured after well installation and hydraulic testing is a preliminary value, and the water level may fluctuate as pressures equilibrate in the newly installed well.

Water levels at CrEX-1 will continue to be monitored, and data will be incorporated in periodic updates of the water-table elevation map.

6.0 BOREHOLE LOGGING

The following sections describe the borehole logging conducted at CrEX-1. Table 6.0-1 presents a summary of all logging.

6.1 Video Logging

Laboratory personnel ran a video survey of the borehole from the surface to 750 ft bgs on July 30, 2014. The purpose of this survey was to observe the lost circulation zone at about 820 ft bgs. The survey was stopped at 750 ft bgs as a result of lost visibility because of highly turbid borehole fluids.

Laboratory personnel ran a video log of the CrEX-1 well after construction to confirm locations of the well screens. The video log was recorded on September 24, 2014, from ground surface to 1110.9 ft bgs to observe the screen locations and depth to water. Table 6.0-1 provides a description of the log. The video log is provided on DVD as Appendix B of this report.

6.2 Geophysical Logging

On August 6 to 7, 2014, Schlumberger ran a suite of geophysical logs in the upper (cased) part of the borehole from ground surface to 810 ft bgs, which included the following:

- accelerator porosity sonde (APS),
- natural gamma spectrometer,
- litho scanner elemental spectroscopy, and
- array induction tool.

For the lower (open) part of the borehole, the geophysical suite consisted of the following:

- microcylindrically focused log,
- magnetic resonance (MR) scanner,
- fullbore formation microimager,
- APS,
- natural gamma spectrometer, and
- litho scanner elemental spectroscopy.

On September 24, 2014, the Laboratory ran a natural gamma ray survey in the constructed CrEX-1 well from 945 ft to 1112 ft bgs to confirm the placement locations of the bentonite and filter-pack materials. Table 6.0-1 shows the depths of coverage for each type of log. The Laboratory and Schlumberger geophysical logs are included as Appendix C of this report (on CD).

7.0 WELL INSTALLATION

The CrEX-1 well was installed between August 12 and 17, 2014. The following sections summarize the well design and well construction activities.

7.1 Well Design

The CrEX-1 well was designed in accordance with the objectives and steps outlined in the field implementation plan (LANL 2014, 600129). The drill cuttings and drillers logs were reviewed and the results of the downhole geophysics were also reviewed, as well as the depth to water. The objectives in setting the screen were to

- establish a capture zone within the plume of elevated chromium concentrations in the upper 70 ft to 100 ft of the aquifer,
- optimize the removal of only chromium-contaminated water,
- reach downgradient towards R-50 during pumping if possible, and
- avoid drawing chromium contamination downwards within the aquifer.

Because the geophysical logs indicated that the upper part of the saturated zone may not be capable of producing the required volume of water needed for a successful extraction well as described in the work plan (i.e., 100 gallons per minute [gpm]), the design was revised to include a second zone, deeper within the aquifer, that was more likely to produce the required volumes of water. The two zones were to be separated by a removable packer. A two-screen design was submitted to NMED on August 8, 2014, and approved later that day. The final CrEX-1 design and the NMED approval are included as Appendix A.

7.2 Well Construction

The CrEX-1 well was constructed of nominal 8-in.–inside diameter (I.D.)/8.62-in.-O.D. passivated type 304L stainless-steel welded casing fabricated to American Society for Testing and Materials standard A312. Figure 7.2-1 illustrates the final well construction details. The screened intervals consist of a 50-ft length of nominal 8-in.-I.D. rod-based, 0.040-in. slot, wire-wrapped well screen from 1040 ft to 990 ft bgs and a 20-ft length of nominal 8-in.-I.D. rod-based, 0.040-in. slot, wire-wrapped well screen from 1090 ft to 1070 ft bgs. Casing and screen were provided by the subcontractor and were steam-pressure washed before installation. A 2.5-in.-O.D. steel, flush-threaded tremie pipe string, also decontaminated before use, was used to deliver annular fill materials and potable water downhole during well construction.

The well was installed on August 12, 2014, and the screened intervals were placed at depths of 1090 ft to 1070 ft bgs and 1040 ft to 990 ft bgs. Before the well was constructed, the bottom of the borehole was measured at a depth of 1211 ft bgs. From a depth of 1211 ft to 1096.2 ft bgs, 3/8-in. bentonite chips were added to the borehole via tremie pipe and allowed to hydrate.

The primary filter pack for the lower screen (consisting of 10/20 sand) was emplaced via tremie pipe beginning on August 12. The filter pack was installed at depths of 1096.2 ft to 1066 ft bgs and swabbed to promote settling of the sand pack. The secondary filter pack consisting of 20/40 sand was emplaced via tremie pipe from depths of 1066 ft to 1063 ft bgs. A seal between the two screened intervals consisting of hydrated 3/8-in. bentonite chips was emplaced via tremie pipe at depths of 1063 ft to 1048 ft bgs and allowed to hydrate for 4 h. The primary filter pack for the upper screen (consisting of 10/20 sand) was emplaced via tremie pipe beginning on August 13. The filter pack was installed at depths of 1048 ft to 985.3 ft bgs and swabbed. The secondary filter pack consisting of 20/40 sand was emplaced via tremie pipe from depths of 985.3 ft to 979.3 ft bgs.

Additional bentonite was emplaced above the secondary filter pack from 816 ft to 979.3 ft bgs in multiple 10- to 20-ft-thick lifts and allowed to hydrate. The 16-in. drill casing was then removed from the borehole. Five feet of this casing, including the cutting shoe, were left behind in the borehole from 816 ft to 811 ft bgs. More bentonite was emplaced from 816 ft to 475 ft bgs in multiple lifts and allowed to hydrate. The 18-in. drill casing was then removed from the borehole. Five feet of this casing, including the cutting shoe, was left behind in the borehole from 475 ft to 470 ft bgs. More bentonite was then emplaced from 475 ft to 59.8 ft bgs in multiple lifts. A mixture consisting of 92% cement and 8% bentonite was emplaced from a depth of 59.8 ft to 4 ft bgs.

A summary of the annual fill materials is presented in Table 7.2-1.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation at CrEX-1, the well was developed and tested, and the pumping system was installed. The well head and surface pad will be completed when weather permits. A geodetic survey will be completed on the surface pad, well head, and survey marker. Survey data will be sent to NMED in a separate submittal. 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

Well development was conducted from August 25 to September 30, 2014. Well development began with swabbing and air-lifting to remove formation fines in the upper and lower filter packs and sump. AQUA-CLEAR was used from August 27 to August 29 in an effort to break down the bentonite wall cake and improve water delivery rates to the surface, which remained at about 1.5 gpm. AQUA-CLEAR and PENETROL were used together for the same purpose on August 30.

On September 1, 2014, the subcontractor decided that submergence of the tremie pipe was not adequate for effective air-lifting of water. Therefore, the decision was made to remove the tremie pipe and install a 10-horsepower (hp), 30-gpm pump to develop the well. The smaller-capacity pump was used because there was still no indication that the well could produce more than 1.5 gpm. Pumping and "rawhiding" with the 30-gpm pump was continued from September 1 to September 10 on both screened intervals of the well. At that point, the specific capacity had improved from 0.5 gpm/ft to 7.0 gpm/ft, and the well was producing 30 gpm. Rawhiding is the practice of removing the check valves in the riser pipe and pump, filling the riser pipe with water by pumping, then turning off the pump and allowing the water in the riser pipe to fall back down the riser pipe, through the pump, and into the filter pack—in effect back-flushing the screened intervals of the well.

On September 10, the 30-gpm pump was removed. On September 13, a 100-gpm pump was installed in the well, and the well was found to be capable of producing up to 168 gpm from the two screens. On September 14, the cuttings pit was full of development water, and pumping had to stop until the plumbing was complete to transfer the water to a treatment system located at nearby monitoring well R-28. Pumping resumed on September 17 and continued at near 100 gpm while the pump was moved up and down through the water column from the water table down to the sump. On September 23, the 100-gpm pump was removed from the well. On September 24, a video and gamma log was made of the entire well to confirm the placement of the well screens and the filter packs before a TAM single-set packer was inserted in the blank pipe between the screens.

On September 26, a TAM packer was installed in the well, and the 100-gpm development pump was put back into the well for additional, focused development of the upper screen. The upper screen was pumped at 60 gpm to 100 gpm from September 28 to September 30.

8.1.1 Well Development Field Parameters

The field parameters of turbidity, temperature, and pH were monitored via a flow-through cell at CrEX-1 during each phase of well development. The field parameter measurements at the end of development of both screens on September 22, 2014, were pH of 7.46, temperature of 19.3°C, and turbidity of 0.02 nephelometric turbidity units (NTU). Field parameters measured during the development of screen 1 alone were pH of 7.41, temperature of 19.21°C, and turbidity of 0.75 NTU on September 28, 2014. Field water-quality parameters are presented in Table 8.1-1.

8.2 Aquifer Testing

Aquifer pumping tests, including a step test and a 24-h test, were conducted at CrEx-1 between October 1 and 4, 2014, by Yellow Jacket Drilling, Inc. (Table 8.2-1). The aquifer testing was performed while pumping water from the upper 50-ft screen only; the lower screen was separated using a TAM packer. A 50-hp, 6-in.-diameter Grunfos submersible pump was used to perform the aquifer tests.

Five short-duration pumping intervals (steps), without recovery in between, were conducted on October 1. The primary objective of the short-duration step tests was to assess the hydraulic behavior of the system and properly determine the optimal pumping rate for the 24-h test. The step tests demonstrated that the specific capacity of the well does not seem to depend on the pumping rate, which suggests the well is well developed. During the step tests, the specific capacity varied between 100 m^2/d and 120 m^2/d (5.5 gpm/ft and 6.6 gpm/ft). The pumping at the highest rate (96 gpm) produced about 5 m (~16 ft) drawdown at the well within the pumped screen. However, the well's specific capacity did not decline with the increase of the pumping rate (Appendix D). This suggests that borehole skin effects (imperfect hydraulic connection between the aquifer and the well) caused a portion of the drawdown. Nevertheless, the pumping caused a decline in the regional water table, and it is likely that vadose zone groundwater flow impacted the drawdowns observed in CrEx-1. Therefore, unconfined (phreatic) groundwater flow is occurring near the pumped well. However, the observed drawdowns are still small compared with the aquifer thickness (much greater than 100 ft), so it is acceptable to use analyses that interpret the groundwater flow as confined. In addition, analyses accounting for unconfined groundwater flow were also performed. The confined and unconfined analyses produced similar estimates for effective aquifer transmissivity and hydraulic conductivity.

A 24-h aquifer test was completed on October 4. The test was conducted at a pumping rate of 517.6 m^3/d (94.9 gpm). The 24-h aquifer test analyses suggested a formation transmissivity of approximately 490 m^2/d (40,000 gallons per day/ft). This transmissivity value is very similar to the estimate obtained by a recent R-28 aquifer test analysis conducted in 2014 (LANL 2014, 255110).

The saturated thickness corresponding to the transmissivity value is not known to estimate hydraulic conductivity. The saturated thickness is impacted by the pumping because the pumping causes a decline in the regional water table. Assuming the saturated thickness is the length of the initial saturated screened interval (~43 ft before the pumping started) minus half the observed drawdown (~10 ft), the estimated average hydraulic conductivity is about 49 m/d or 161 ft/d. This estimate is uncertain, but the value of hydraulic conductivity is consistent with the estimate obtained for R-28 (~120 ft/d).

The CrEX-1 transmissivity and hydraulic conductivity estimates suggest that the well is tapping a highly permeable zone of the regional aquifer. This helps achieve the CrEX-1 objective of hydraulic capture of contaminated groundwater.

8.3 Dedicated Pumping System Installation

A dedicated pumping system for CrEX-1 was initially installed on October 11, 2014. The system uses a single 50-hp Franklin Electric motor and 6-in. Grundfos submersible pump. The pump riser pipe consists of 3-in. threaded and coupled American Petroleum Institute (API) 5L galvanized steel. Two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) tubes are installed along with, and banded to, the pump column. A dedicated In-Situ Level Troll 500 transducer will be installed in one of the tubes, and the second tube will be used for manual water-level measurements. Both PVC tubes are equipped with a 0.5-ft section of 0.010-in. slotted screen and a closed bottom.

During electrical acceptance testing by Laboratory electricians, it was determined that the motor was initially functioning correctly but little water was delivered to the surface, and the system failed the test. In addition, it was found that the PVC transducer tubes were obstructed at a point about 50 ft above the water table. The pumping system and tubes were removed from the well on October 25, 2014. The problem was determined to be that the pump and transducer tubes had been set 100 ft above the water table. Once any water in the riser pipe had been pumped to the surface, the pump and motor overheated and were destroyed. Using the 50-hp, 6-in.-diameter Grundfos submersible pump from the development phase, the pump and motor were replaced on October 25, 2014, and the system retested. All systems worked correctly and the system was accepted.

Figure 8.3-1a shows details of the dedicated sampling system. Figure 8.3-1b presents technical notes describing the sampling system components. Figure 8.3-1c shows the Grundfos pump performance curve.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 24 ft × 9 in. thick, will be installed at the CrEX-1 wellhead when weather permits. The concrete pad will be slightly elevated above ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A protective tent will be erected over the well. A brass monument marker will be embedded in the northwest corner of the pad. A 16-in.-O.D. steel protective casing will be installed around the stainless-steel well riser. A 0.25-in. weep hole will be drilled near the base of the protective casing to prevent water accumulation inside the protective casing. Pea gravel will be emplaced between the protective casing and well casing to a height of 1 ft above the weep hole. Six steel bollards, covered by high-visibility plastic sleeves, will be set at the outside edges of the pad to protect the well from accidental vehicle damage. They are designed for easy removal to allow access to the well. Figure 8.3-1a shows details of the proposed wellhead completion.

8.5 Geodetic Survey

A licensed professional land surveyor will conduct a geodetic survey once the wellhead is completed. The survey data will 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 will be expressed relative to New Mexico State Plane Coordinate System Central Zone 83 (North American Datum [NAD] 83); elevation will be expressed in feet amsl using the National Geodetic Vertical Datum of 1929. Survey points will include ground-surface elevation near the concrete pad, the top of the monument marker in the concrete pad, the top of the well casing, and the top of the protective casing.

8.6 Waste Management and Site Restoration

Waste generated from the CrEX-1 project includes drilling fluids and mud, purged groundwater, drill cuttings, decontamination water, and contact waste. A summary of the waste characterization samples collected during drilling, construction and development of the CrEX-1 well is presented in Table 8.6-1. All waste streams produced during drilling and development activities were sampled in accordance with the "Waste Characterization Strategy Form for Chromium Well CrEx-1" (LANL 2014, 254859). Development water was land-applied under a Temporary Permission to Discharge (NMED 2014, 600128).

Fluids produced during drilling and containerized in the pit will be evaporated on site. Evaporation activities began in October 2014.

Analytical results for fluids produced during well development and pump testing will be reviewed with the goal of land application. Data will be reviewed manually and within the automated waste disposition program per the waste characterization strategy form and ENV-RCRA-QP-010.3, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criteria for land application, the drilling fluids will be reevaluated for treatment and disposal at one of the Laboratory's wastewater treatment facilities or other authorized disposal facility. If analytical data indicate the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be either treated on-site or disposed of at an authorized facility.

Drilling mud was collected in a lined mud pit on the drill pad. This mud will be sampled in the spring once associated fluids are evaporated and a representative waste sample can be taken. Analytical results will be evaluated for waste characterization, and this mud will be disposed of at a Laboratory-approved off-site disposal facility.

Cuttings produced during drilling were sampled, and analytical results will be reviewed with the goal of land application. A sample submitted for volatile organic analysis (VOA) (sample ID WST05-14-84406) was damaged en route to the analytical laboratory. Once the fluids are evaporated or removed from the pit in the spring, a composite VOA sample of the cuttings will be taken and evaluated against land-application criteria (ENV-RCRA-QP-011.2, Land Application of Drill Cuttings). If cuttings meet land-application criteria, materials will be spread across the pad area and the site reseeded as required for site reclamation.

Decontamination fluids used for cleaning the well steel were containerized and staged at the CrEX-1 well pad. This fluid waste will be sampled, and a waste profile form will be completed. This decontamination waterwaste will be shipped for disposal at a Laboratory-approved off-site disposal facility.

Characterization of contact waste will be based upon acceptable knowledge, referencing the analyses of the waste samples collected from the drilling fluids, drill cuttings, and decontamination fluids. A waste profile form will be completed, and the contact wastes will be removed from the site following land application of the pit-contained drill cuttings. The pit liner will be included in the contact waste disposal materials.

Site restoration activities are conducted by Maintenance and Site Services personnel at the Laboratory. Activities include evaporating drilling fluids, removing cuttings from the pit, and managing the development/pump test fluids in accordance with applicable procedures. The polyethylene liner will be removed following land application of the cuttings, and the containment area berms will be removed and leveled. Activities also include backfilling and regrading the containment area, as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, construction, and development were performed in general accordance with the “Field Implementation Plan for Well CrEX-1” (LANL 2014, 600129). Two significant deviations from the plan occurred.

The first deviation from the plan was changing the design from a single 100-ft-long screen to an upper 50-ft-long screen and a lower 20-ft-long screen separated by 30 ft of blank pipe. The change was made because the upper part of the well appeared on the geophysical logs to be significantly less productive than the lower part of the well. To address one of the main objectives of the well, collecting chromium-contaminated water from the top of the regional aquifer and not drawing contaminated water down into the regional aquifer, the two-screen approach was proposed to, and approved by, NMED. Once the upper screen demonstrated that it could produce the required amounts of water, a packer was set between the screens.

The second deviation from the plan was the loss of 14 d of pumping because the pump was set above the water table; the completion rig left the site before acceptance testing could be conducted, and the rig could not return to the Laboratory for 13 d.

10.0 ACKNOWLEDGMENTS

Yellow Jacket Drilling drilled the CrEX-1 borehole, installed the well, and conducted the well development and aquifer testing.

Laboratory personnel ran downhole video and natural gamma logging equipment.

Schlumberger ran a suite of geophysical logs.

Laboratory personnel analyzed the data for the aquifer testing (Appendix D).

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

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

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

Dale, M., June 19, 2014. FW: Extraction Well CrEX-1 start up notification. E-mail message to H. Shen (NMED) and D. Katzman (LANL) from M. Dale (NMED), Santa Fe, New Mexico. (Dale 2014, 600135)

DOE (U.S. Department of Energy), May 19, 2014. "Well Pump Tests Phase II in Sandia and Mortandad Canyons," U.S. Department of Energy Categorical Exclusion Determination Form, Los Alamos Site Office, Los Alamos, New Mexico. (DOE 2014, 600140)

LANL (Los Alamos National Laboratory), February 28, 2014. "Waste Characterization Strategy Form for Chromium Well CrEx-1," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2014, 254859)

LANL (Los Alamos National Laboratory), March 2014. "Drilling Work Plan for Groundwater Extraction Well CrEX-1," Los Alamos National Laboratory document LA-UR-14-21478, Los Alamos, New Mexico. (LANL 2014, 254824)

LANL (Los Alamos National Laboratory), March 2014. "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2," Los Alamos National Laboratory document LA-UR-14-21642, Los Alamos, New Mexico. (LANL 2014, 255110)

LANL (Los Alamos National Laboratory), June 2014. "Field Implementation Plan for CrEX-1," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2014, 600129)

NMED (New Mexico Environment Department), July 8, 2014. “Approval, Drilling Work Plan for Groundwater Extraction Well CrEX-1,” New Mexico Environment Department letter to P. Maggiore (DOE-NA-LA) and J.D. Mousseau (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2014, 525004)

NMED (New Mexico Environment Department), August 8, 2014. “Temporary Permission to Discharge, Treated Ground Water from Aquifer Testing at Pilot Pumping Well CrEX-1 (AI: 856, PRD20140007),” New Mexico Environment Department letter to A. Dorries (LANL) and G. Turner (DOE) from J. Schoeppner (NMED-GWQB), Santa Fe, New Mexico. (NMED 2014, 600128)

North Wind Inc., July 2011. “Spill Prevention Control and Countermeasures Plan for the ADEP Groundwater Monitoring Well Drilling Operations, Los Alamos National Laboratory, Revision 6,” plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (North Wind, Inc., 2011, 213292)

OSE (New Mexico Office of the State Engineer), July 21, 2014. “Application for Permit to Drill a Well with No Consumptive Use of Water,” OSE File No. RG 94875, Santa Fe, New Mexico. (OSE 2014, 600141)

Yellow Jacket Drilling, June 27, 2014. “Integrated Work Document for Drilling and Installation of LANL Well [CrEX-1],” Gilbert, Arizona. (Yellow Jacket Drilling 2014, 600131)

11.2 Map Data Sources

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

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

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

Inactive Outfalls; Los Alamos National Laboratory, Water Quality and Hydrology Group of the Environmental Stewardship Division at Los Alamos National Laboratory Los Alamos New Mexico; 01 September 2003.

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

Penetrations; Los Alamos National Laboratory, Environment and Remediation Support Services, ER2006-0664; 1:2,500 Scale Data, 01 July 2006.

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

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

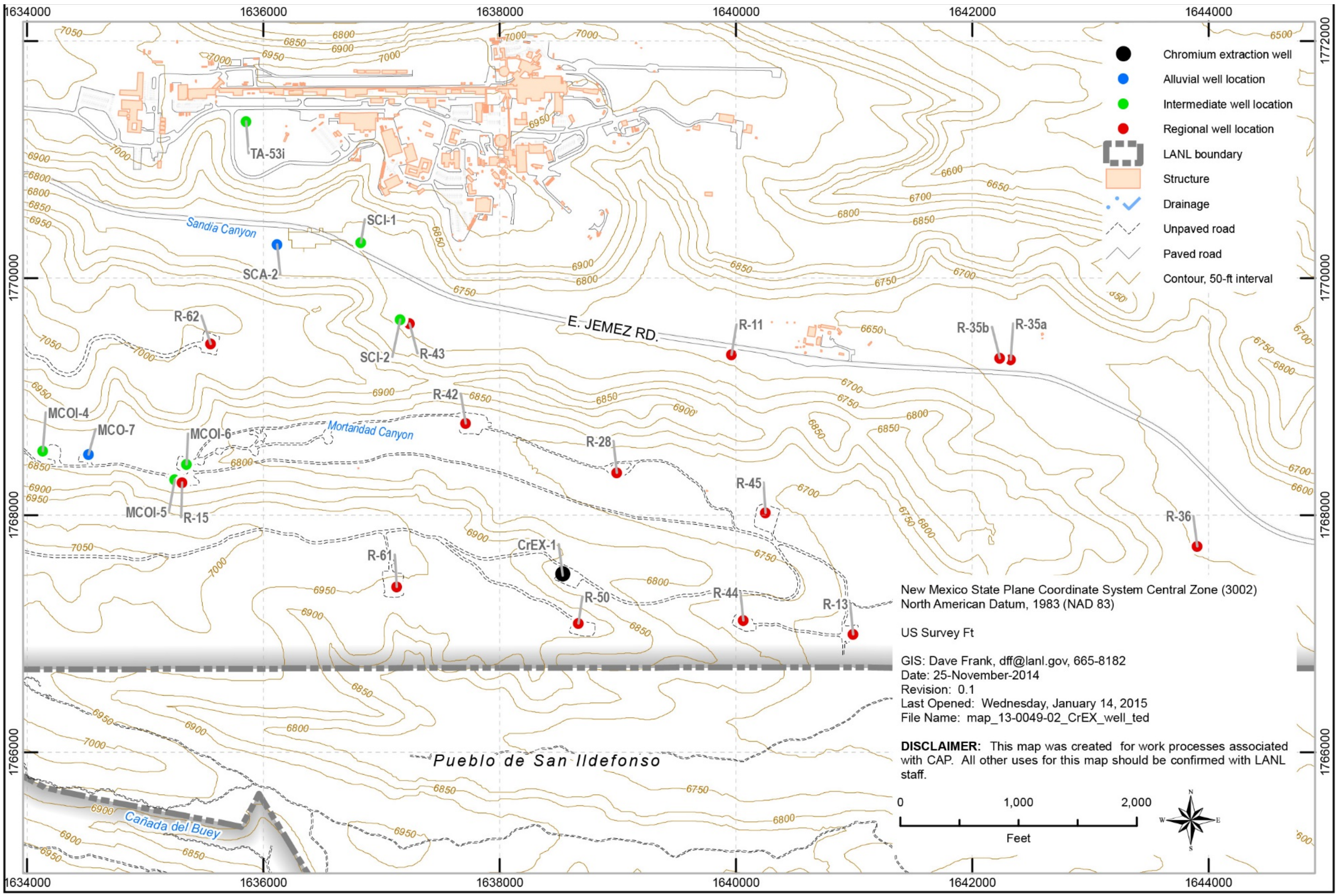


Figure 1.0-1 Location of well CrEX-1

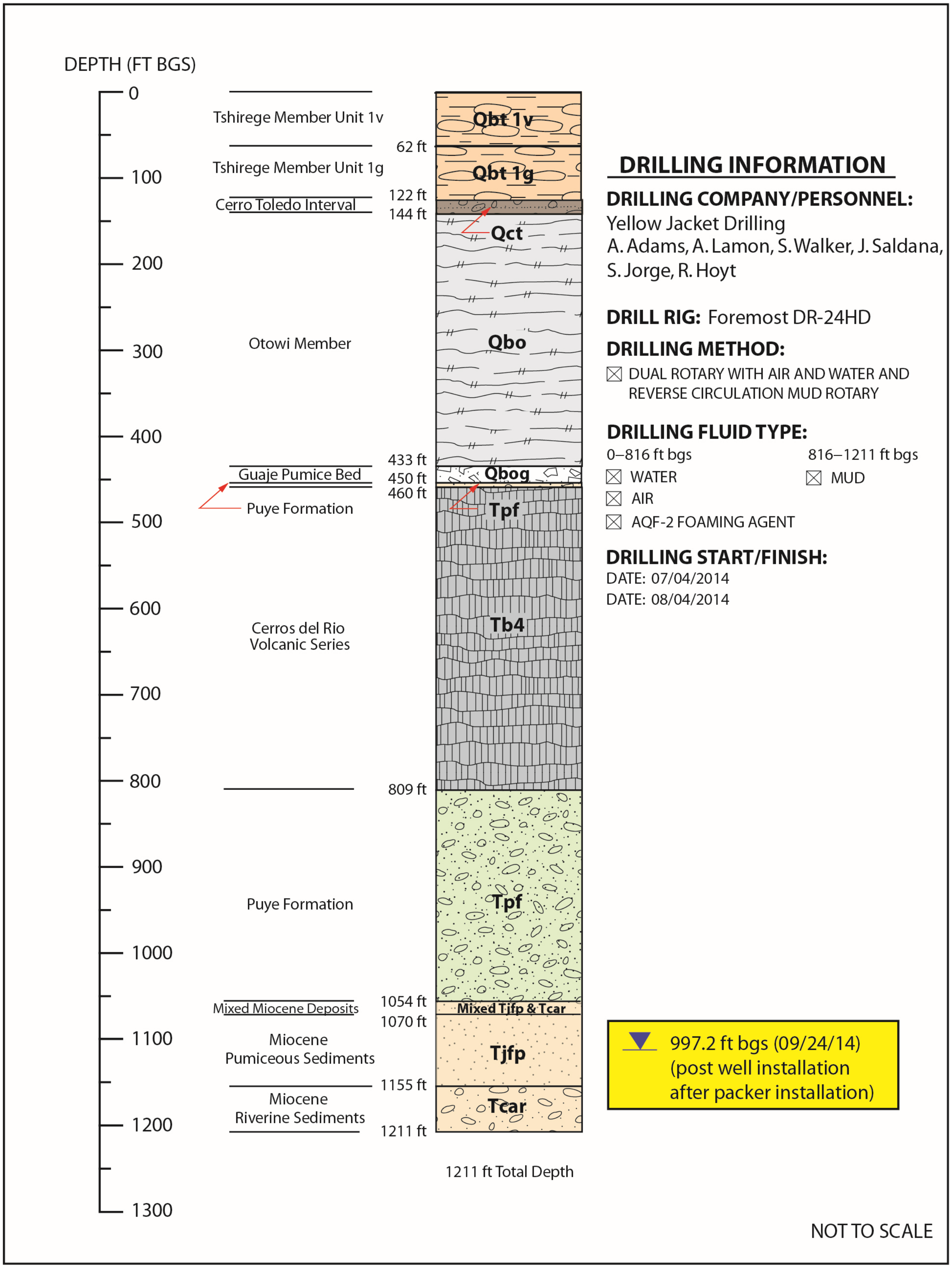


Figure 5.1-1 CrEX-1 borehole stratigraphy

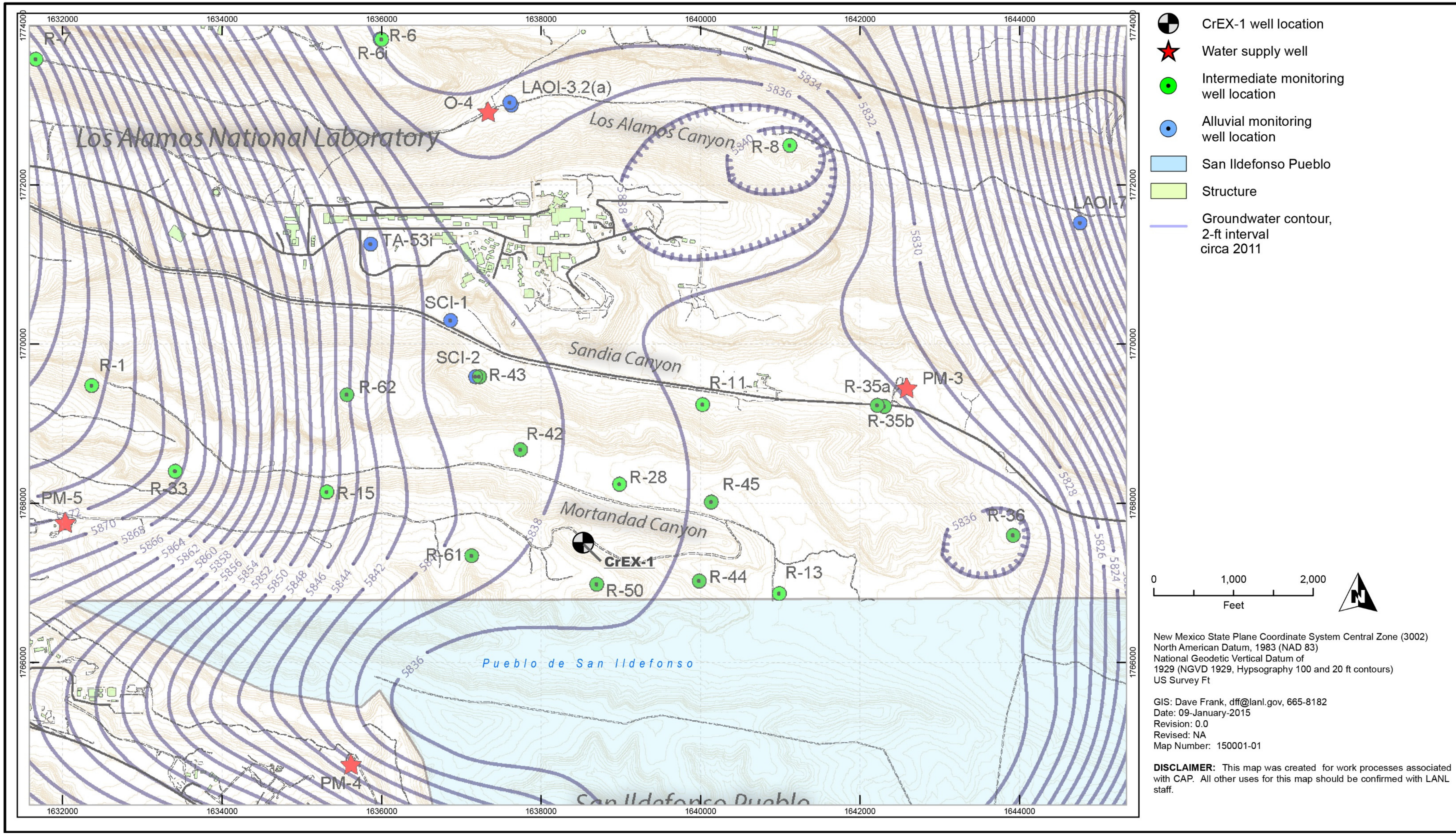


Figure 5.2-1 Regional aquifer groundwater elevations

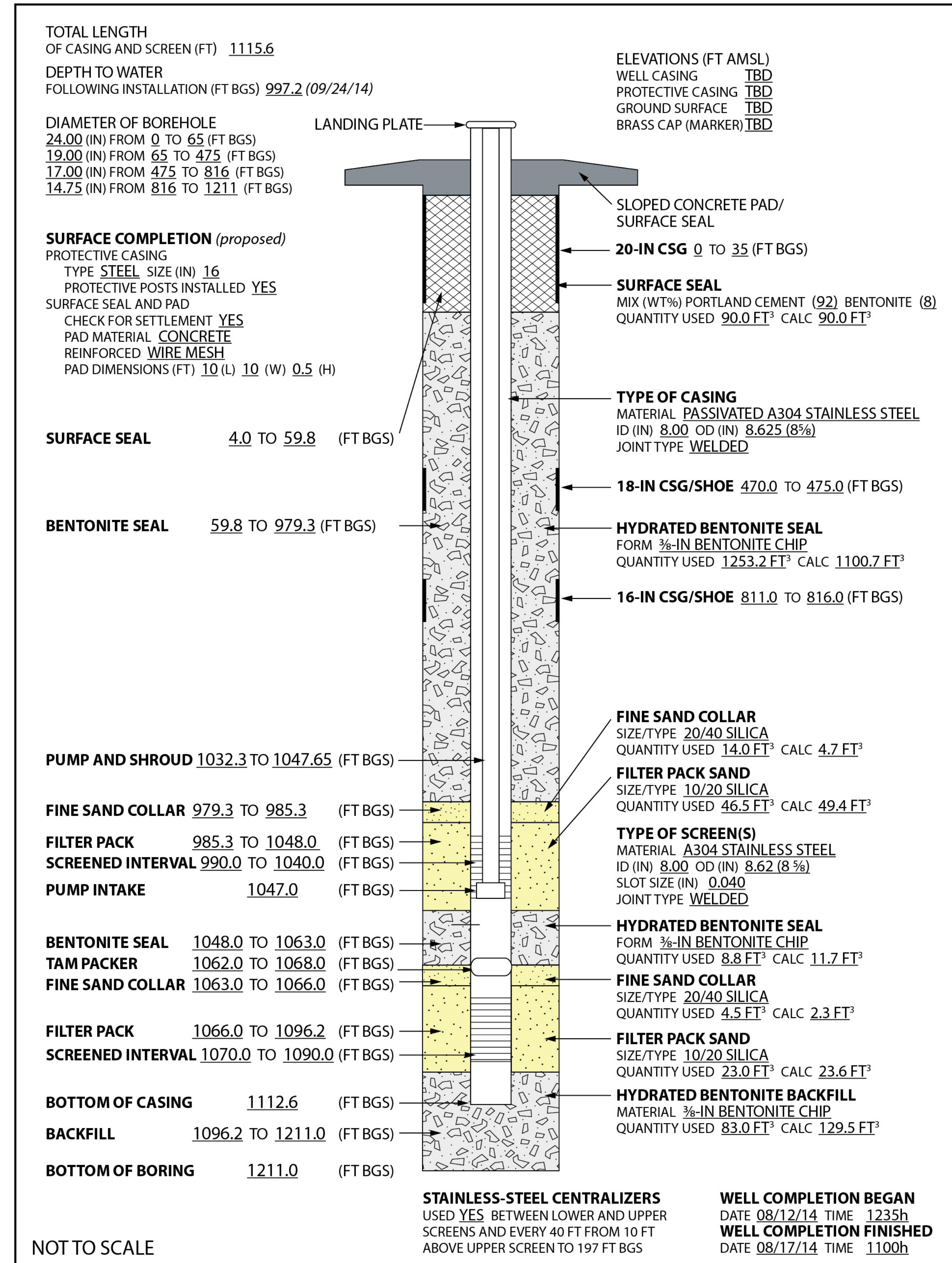


Figure 7.2-1 As-built construction diagram for well CrEX-1

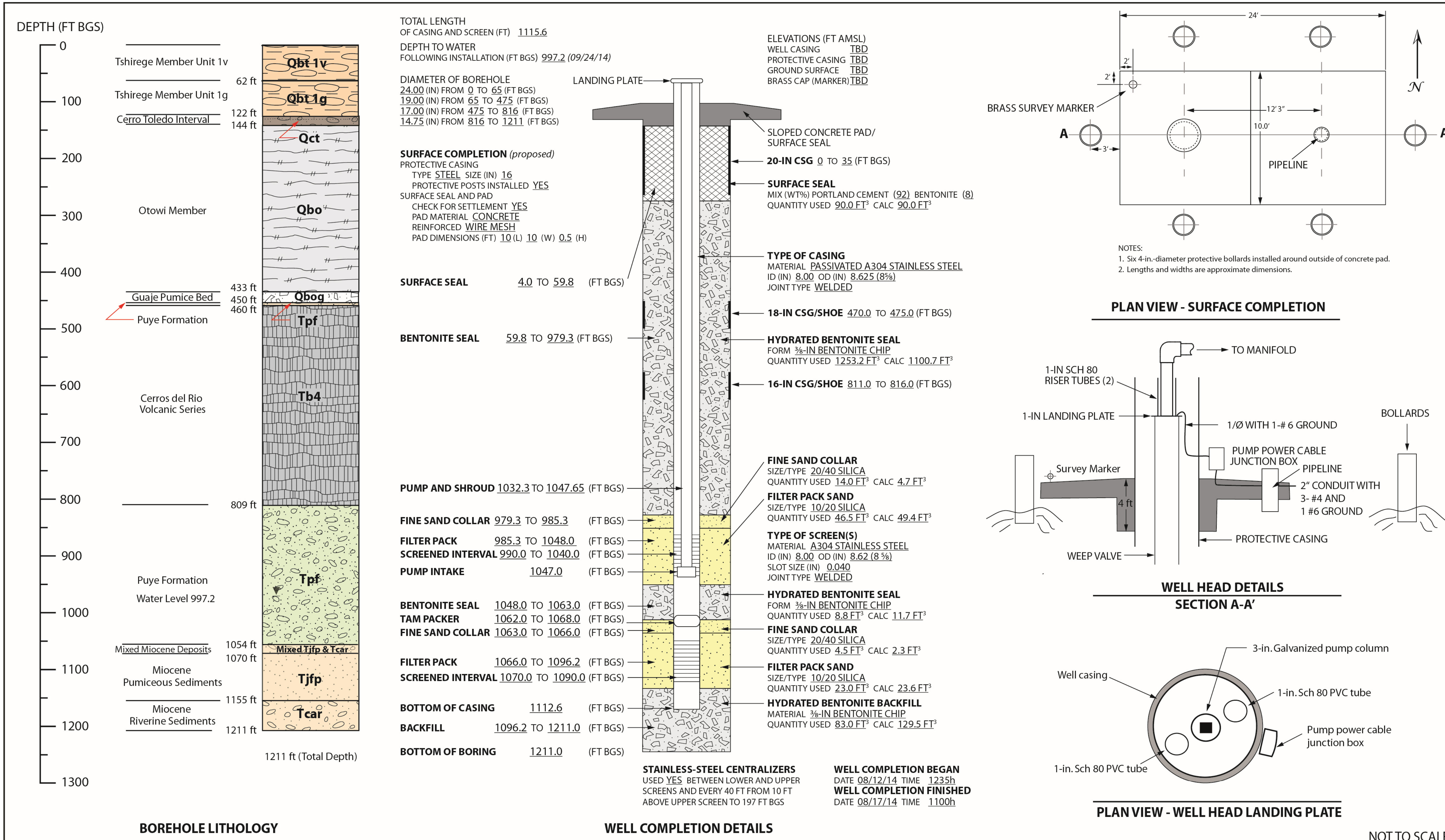


Figure 8.3-1a As-built schematic for well CrEX-1

CrEX-1 TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker
Northing: TBD
Easting: TBD
Elevation: TBD

Well Casing (top of stainless steel)
Northing: TBD
Easting: TBD
Elevation: TBD

BOREHOLE GEOPHYSICAL LOGS

LANL: Natural gamma ray, induction
Schlumberger: APS, FMI, natural gamma ray, litho scanner, MR scanner, array induction

DRILLING INFORMATION

Drilling Company
Yellow Jacket Drilling, Inc.

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual rotary foam-assisted air rotary and flooded reverse mud rotary,

Drilling Fluids
Air, potable water, AQF-2 Foam (to 810 ft bgs)
Potable water, soda ash, QUIK-TROL, bentonite (810 ft bgs to TD)

MILESTONE DATES

Drilling
Start: 07/04/2014
Finished: 08/04/2014

Well Completion
Start: 08/12/2014
Finished: 08/17/2014

Well Development
Start: 08/25/2014
Finished: 09/30/2014

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, air-lifting, and pumping
Total Volume Purged: 178,090 gal.

Parameter Measurements (Final)
pH: 7.41
Temperature: 19.21°C
Specific Conductance: Not available
Turbidity: 0.75 NTU

AQUIFER TESTING

24-h Constant-Rate Pumping Test
Water Produced: 173,670 gal.
Average Flow Rate: 94.94 gpm
Performed on: 10/3/14–10/4/14

DEDICATED SAMPLING SYSTEM

Pump (Shrouded)
Make: Grundfos
Model: 150S500-28

Motor
Make: Franklin Electric
Model: Submersible Sand Fighter
50 hp, 3 phase, 460 V

Pump Column
Flomatic model # 80DI check valves at 760 and 1030 ft bgs

Transducer Tubes
2 × 1.0-in. flush threaded schd. 80 PVC tubing
0.020-in. slot screens at 1031.0–1031.5 ft bgs

Transducer
Make: In-Situ Level TROLL
Model: LT 500
PSIG range: Max 100 PSI / 231 ft
S/N: 379843

NOTE:
* 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.

Figure 8.3-1b Technical notes for well CrEX-1

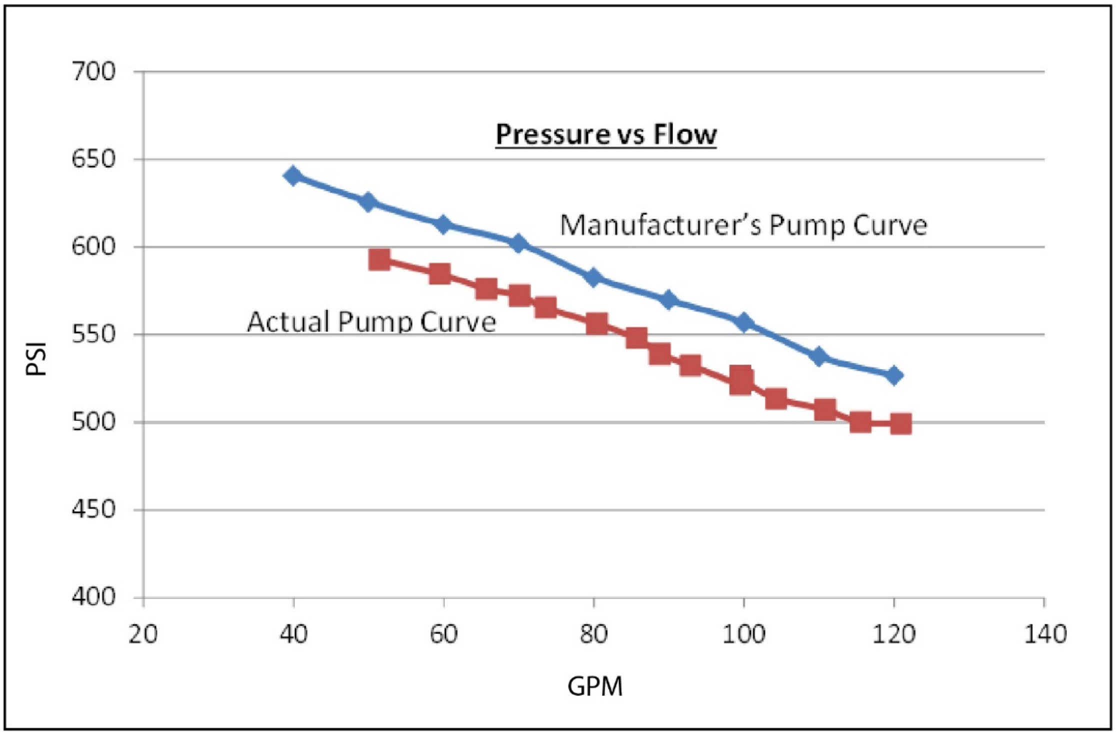


Figure 8.3-1c Pump performance curve

Table 6.0-1
Logging Runs

Date(s)	Type of Log	Depth (ft bgs)	Description
7/30/14	Video	0–750	LANL video from ground surface to 750 ft bgs. Attempted to observe lost circulation zone, thought to be above water table. However, muddy water remained in the borehole at 750 ft bgs, and survey was stopped before reaching the depth of interest.
8/6/14–8/7/14	APS	200–1208	Schlumberger geophysical log
8/6/14–8/7/14	Natural gamma/HNGS*	200–1208	Schlumberger geophysical log
8/6/14–8/7/14	Litho scanner	200–1180	Schlumberger geophysical log
8/6/14–8/7/14	Array induction tool	200–1180	Schlumberger geophysical log
8/6/14–8/7/14	Microcylindrically focused log	816–1211	Schlumberger geophysical log
8/6/14–8/7/14	MR scanner	858–1196	Schlumberger geophysical log
8/6/14–8/7/14	Fullbore formation microimager	840–1210	Schlumberger geophysical log
9/24/14	Video	0–1111	LANL video to confirm well screen placement and condition and water level
9/24/14	Gamma log	945–1112	LANL gamma log to confirm position of bentonite backfill and sand pack materials

*HNGS = Hostile natural gamma spectroscopy.

Table 7.2-1
CrEX-1 Annular Fill Materials

Material	Volume (ft^3)
Surface seal: 92% Portland cement, 8% bentonite	90.0
Upper seal: 0.375-in. bentonite chips	1253.2
Upper screen transition sand collar: 20/40 silica sand	14.0
Upper screen primary filter pack sand: 10/20 silica sand	46.5
Separating seal: 0.375-in. bentonite chips	8.8
Lower screen transition sand collar: 20/40 silica sand	4.5
Lower screen primary filter pack sand: 10/20 silica sand	23.0
Lower seal: 0.375-in. bentonite chips	83.0

Table 8.1-1
Field Water-Quality Parameters and Well Performance for Development of Well CrEX-1

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Cumulative Purge Volume (gal.)	pH	Specific Capacity (gpm/ft)	Turbidity (NTU)	Temp (°C)
9/19/14										
On	1 & 2	9:45	n/a[a]	990.63	n/a	0	n/a	n/a	n/a	n/a
		9:50	150	1012.13	21.5	920	na[b]	6.98	29.9	21.5
		9:55	150	1012.63	22	1260	na	6.82	10.72	22
		10:00	150	1012.43	21.8	920	na	6.88	9.32	21.8
		10:15	150.4	1012.03	21.4	4,240	na	7.03	6.92	21.4
		10:30	142.6	1012.93	22.3	6380	na	6.39	4.16	22.3
		11:00	143	1012.83	22.2	10,670	na	6.44	3.43	22.4
		11:30	148	1013.03	22.4	15,110	na	6.61	0.39	22.4
Off	1 & 2	12:00	135	1012.83	22.2	19,180	na	6.08	0.92	22.2
9/22/14										
On	1 & 2	10:15	n/a	989.66	0.00	54,880	n/a	n/a	n/a	n/a
		10:30	na	1009.56	19.90	57,060	7.22	0	1.18	19.15
		10:45	147.33	1009.69	20.03	61,450	7.3	7.36	1.25	19.17
		11:00	146	1009.72	20.06	68,030	7.35	7.28	0	19.46
		11:15	147	1009.8	20.14	69,210	7.36	7.30	0	19.68
		11:30	149	1009.82	20.16	70,320	7.37	7.39	0.03	19.28
		11:45	148	1009.83	20.17	71,640	7.38	7.34	0.02	19.45
		12:00	138	1009.82	20.16	73,180	7.39	6.85	0.02	19.24
		12:15	158	1009.76	20.10	74,950	7.41	7.86	0.02	19.38
		12:30	149.33	1009.76	20.10	76,940	7.4	7.43	0.03	19.28
		13:05	147.42	1009.74	20.08	79,450	7.42	7.34	0.04	19.27
		13:30	148.8	1009.82	20.16	82,340	7.46	7.38	0.03	19.32

Table 8.1-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Cumulative Purge Volume (gal.)	pH	Specific Capacity (gpm/ft)	Turbidity (NTU)	Temp (°C)
		14:00	147.67	1009.74	20.08	85,660	4.46	7.35	0.03	19.3
		14:30	148.33	1009.77	20.11	89,430	7.45	7.38	0.02	19.31
		15:00	148	1009.81	20.15	93,650	7.46	7.34	0.02	19.3
		15:30	147.33	1009.81	20.15	101,450	7.46	7.31	0.02	19.31
Off	1 & 2	16:00	148.33	1009.81	20.15	105,900	7.46	7.36	0.02	19.3
9/28/14										
On	1	8:45	n/a	986.83	0	116,180	n/a	n/a	n/a	n/a
		9:00	100	1008.28	21.45	117,770	7.19	4.66	19.6	18.99
		9:15	100	1006.43	19.6	119,120	7.28	5.10	2.26	19.35
		9:32	94.68	1007.28	20.45	120,590	7.33	4.63	1.01	19.38
		9:45	101.54	1007.43	20.6	121,910	7.35	4.93	0.3	19.12
		10:00	94	1007.58	20.75	123,320	7.36	4.53	na	19.25
		10:15	93.33	1007.63	20.8	124,720	7.37	4.49	na	19.49
		10:30	94	1007.68	20.85	126,130	7.38	4.51	na	19.21
Off	1	10:45	94.67	1007.73	20.9	127,550	7.38	4.53	na	19.18
On	1	11:00	n/a	986.83	0	127,590	n/a	n/a	n/a	n/a
		11:15	86.67	1006.58	19.75	128,890	7.41	4.39	0.75	19.21
		11:30	95.33	1006.73	19.9	130,320	7.39	4.79	na	19.22
		11:45	96.67	1006.83	20	131,770	7.4	4.83	na	19.5
		12:00	97.33	1006.83	20	133,230	7.4	4.87	na	19.64
		12:15	96.67	1006.83	20	134,680	7.44	4.83	na	19.4
		12:31	95	1006.83	20	136,200	7.46	4.75	na	19.55
Off	1	13:00	100	1006.83	20	137,600	7.44	5.00	na	19.53

Table 8.1-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Cumulative Purge Volume (gal.)	pH	Specific Capacity (gpm/ft)	Turbidity (NTU)	Temp (°C)
On	1	13:30	n/a	986.83	0	137,720	n/a	n/a	n/a	n/a
		13:45	76	986.83	0	138,860	na	na	3.35	na
		14:00	86	986.83	0	140,160	na	na	0.85	na
		14:15	73	986.83	0	141,260	na	na	na	na
		14:30	66	997.73	10.9	142,250	na	6.06	na	na
		14:45	65	997.73	10.9	143,230	na	5.96	na	na
		15:00	64	997.63	10.8	144,200	na	5.93	na	na
		15:15	64	997.73	10.9	145,170	na	5.87	na	na
		15:30	65	997.73	10.9	146,150	na	5.96	na	na
		15:45	64	997.73	10.9	147,120	na	5.87	na	na
		16:00	65	997.73	10.9	148,100	na	5.96	na	na
		16:15	64	997.73	10.9	149,070	na	5.87	na	na
Off	1	16:30	65	997.73	10.9	150,050	na	5.96	na	na
9/29/14										
On	1	9:30	n/a	986.8	0	150,080	n/a	n/a	n/a	n/a
		9:45	80	1003.8	17	151,280	na	4.71	na	na
		10:00	95	1004.1	17.3	152,710	na	5.49	na	na
		10:15	95	1004.3	17.5	154,140	na	5.43	na	na
		10:30	95	1004.3	17.5	155,570	na	5.43	na	na
		10:45	95	1004.3	17.5	157,000	na	5.43	na	na
		11:00	95	1004.3	17.5	158,430	na	5.43	na	na
		11:15	95	1004.3	17.5	159,860	na	5.43	na	na
		11:30	95	1004.4	17.6	161,290	na	5.40	na	na
		12:00	95	1004.5	17.7	164,160	na	5.37	na	na
		12:30	95	1004.5	17.7	167,030	na	5.37	na	na
		13:00	95	1004.5	17.7	169,900	na	5.37	na	na

Table 8.1-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Cumulative Purge Volume (gal.)	pH	Specific Capacity (gpm/ft)	Turbidity (NTU)	Temp (°C)
Off	1	13:30	95	1004.4	17.6	172,750	na	5.40	na	na
Off	1	15:30	0	985.8	0	174,410	na	na	na	na
On	1	15:40	82	1016.8	31	175,230	na	2.65	na	na
		15:50	143	1017	31.2	176,660	na	4.58	na	na
Off	1	16:00	n/a	n/a	n/a	178,090	na	na	na	na

Note: Cumulative purge volumes on September 19 are biased low because of clogging of the flow meter from high initial sediment load in water.

[a] n/a = Not applicable.

[b] na = Not available.

Table 8.2-1
Aquifer Pumping Test Results for Well CrEX-1

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
Step Test								
10/1/14								
On at 20% max	1	8:15	19	997.08	0	0	0	na[a]
		8:20	19	1003.33	6.25	20	20	3.04
		8:25	16	1002.33	5.25	80	100	3.05
		8:30	20	1000.53	3.45	100	200	5.80
		8:35	18	1000.73	3.65	90	290	4.93
		8:40	20	1000.73	3.65	100	390	5.48
		8:45	26	1000.73	3.65	130	520	7.12
		8:50	16	1000.73	3.65	80	600	4.38
		8:55	22	1000.73	3.65	110	710	6.03
		9:00	20	1000.63	3.55	100	810	5.63
		9:05	22	1000.73	3.65	110	920	6.03
		9:10	22	1000.73	3.65	110	1030	6.03
		9:15	22	1000.73	3.65	110	1140	6.03
		9:25	22	1000.63	3.55	220	1360	6.20
		9:35	23	1000.63	3.55	230	1590	6.48
		9:45	21	1000.73	3.65	210	1800	5.75
		9:55	20	1000.73	3.65	200	2000	5.48
		10:05	21	1000.73	3.65	210	2210	5.75
		10:15	20	1000.73	3.65	200	2410	5.48

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
Change rate to 40% max	1	10:20	na	1003.03	5.95	190	2600	na
		10:25	36	1002.93	5.85	180	2780	6.15
		10:30	36	1002.93	5.85	180	2960	6.15
		10:35	38	1002.88	5.8	190	3150	6.55
		10:40	36	1002.83	5.75	180	3330	6.26
		10:45	36	1002.83	5.75	180	3510	6.26
		10:50	38	1002.83	5.75	190	3700	6.61
		10:55	36	1002.78	5.7	180	3880	6.32
		11:00	36	1002.78	5.7	180	4060	6.32
		11:05	36	1002.78	5.7	180	4240	6.32
		11:10	38	1002.78	5.7	190	4430	6.67
		11:15	36	1002.83	5.75	180	4610	6.26
		11:20	36	1002.78	5.7	180	4790	6.32
		11:30	37	1002.78	5.7	370	5160	6.49
		11:40	36	1002.78	5.7	360	5520	6.32
		11:50	37	1002.78	5.7	370	5890	6.49
		12:00	37	1002.78	5.7	370	6260	6.49
		12:10	36	1002.78	5.7	360	6620	6.32
		12:20	37	1002.78	5.7	370	6990	6.49

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
Change rate to 60% max	1	12:25	57	1007.33	10.25	290	7280	5.56
		12:30	62	1007.33	10.25	310	7590	6.05
		12:35	60	1007.33	10.25	300	7890	5.85
		12:40	60	1007.33	10.25	300	8190	5.85
		12:45	60	1007.33	10.25	300	8490	5.85
		12:50	60	1007.38	10.3	300	8790	5.83
		12:55	60	1007.38	10.3	300	9090	5.83
		13:00	62	1007.43	10.35	310	9400	5.99
		13:05	62	1007.43	10.35	310	9710	5.99
		13:10	58	1007.43	10.35	290	10,000	5.60
		13:15	60	1007.43	10.35	300	10,300	5.80
		13:20	60	1007.43	10.35	300	10,600	5.80
		13:25	62	1007.43	10.35	310	10,910	5.99
		13:35	60	1007.43	10.35	600	11,510	5.80
		13:45	60	1007.43	10.35	600	12,110	5.80
		13:55	61	1007.43	10.35	610	12,720	5.89
		14:05	60	1007.43	10.35	600	13,320	5.80
		14:15	67	1007.43	10.35	670	13,990	6.47
		14:25	55	1007.43	10.35	550	14,540	5.31

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
Change rate to 80% max	1	14:30	na[a]	1008.13	11.05	360	14,900	na
		14:35	74	1008.23	11.15	370	15,270	6.64
		14:40	74	1008.23	11.15	370	15,640	6.64
		14:45	74	1008.33	11.25	370	16,010	6.58
		14:50	74	1008.33	11.25	370	16,380	6.58
		14:55	74	1008.33	11.25	370	16,750	6.58
		15:00	74	1008.33	11.25	370	17,120	6.58
		15:05	76	1008.33	11.25	380	17,500	6.76
		15:10	74	1008.38	11.3	370	17,870	6.55
		15:20	74	1008.38	11.3	380	18,250	6.55
		15:25	76	1008.38	11.3	750	19,000	6.73
		15:30	74	1008.38	11.3	370	19,370	6.55
		15:40	76	1008.38	11.3	760	20,130	6.73
		15:50	75	1008.38	11.3	750	20,880	6.64
		16:00	75	1008.43	11.35	750	21,630	6.61
		16:10	76	1008.43	11.35	760	22,390	6.70
		16:20	75	1008.43	11.35	750	23,140	6.61
		16:30	76	1008.43	11.35	760	23,900	6.70

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
Change rate to 100% max	1	16:35	na	1013.23	16.15	470	24,370	na
		16:40	96	1013.23	16.15	480	24,850	5.94
		16:45	96	1013.23	16.15	480	25,330	5.94
		16:50	94	1013.23	16.15	470	25,800	5.82
		16:55	98	1013.23	16.15	490	26,290	6.07
		17:00	96	1013.23	16.15	480	26,770	5.94
		17:05	96	1013.23	16.15	480	27,250	5.94
		17:10	96	1013.23	16.15	480	27,730	5.94
		17:15	98	1013.23	16.15	490	28,220	6.07
		17:20	96	1013.23	16.15	480	28,700	5.94
		17:25	98	1013.23	16.15	490	29,190	6.07
		17:30	94	1013.23	16.15	470	29,660	5.82
		17:35	96	1013.23	16.15	480	30,140	5.94
		17:45	96	1013.23	16.15	960	31,100	5.94
		17:55	96	1013.23	16.15	960	32,060	5.94
		18:05	96	1013.23	16.15	960	33,020	5.94
		18:15	96	1013.23	16.15	960	33,980	5.94
		18:25	96	1013.23	16.15	960	34,940	5.94
Off	1	18:35	97	1013.23	16.15	970	35,910	6.01

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
24-h Constant Rate Test								
10/3/14								
On	1	8:05	0	997.33	0	10	35,920	na
		8:08	Water to surface	n/a[b]	n/a	n/a	n/a	n/a
		8:10	40	1016.9	19.57	200	36,120	2.04
		8:15	100	1016.65	19.32	500	36,620	5.18
		8:20	96	1016.65	19.32	480	37,100	4.97
		8:25	92	1016.8	19.47	460	37,560	4.73
		8:30	108	1016.9	19.57	540	38,100	5.52
		8:35	80	1016.9	19.57	400	38,500	4.09
		8:50	102	1017	19.67	1530	40,030	5.19
		9:05	89.33	1017.1	19.77	1340	41,370	4.52
		9:20	100	1017.15	19.82	1500	42,870	5.05
		9:35	96.67	1017.2	19.87	1450	44,320	4.87
		10:05	95	1017.25	19.92	2850	47,170	4.77
		10:35	96.33	1017.3	19.97	2890	50,060	4.82
		11:05	96.33	1017.35	20.02	3180	53,240	4.81
		11:30	96.52	1017.37	20.04	2220	55,460	4.82
		12:00	95.33	1017.37	20.04	2860	58,320	4.76
		12:30	96.33	1017.38	20.05	2890	61,210	4.80
		13:00	97	1017.38	20.05	2910	64,120	4.84
		13:30	96.67	1017.38	20.05	2900	67,020	4.82
		14:00	97	1017.38	20.05	2910	69,930	4.84
		14:30	96.86	1017.39	20.06	3390	73,320	4.83
		15:00	94.8	1017.39	20.06	2370	75,690	4.73

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
	1	15:30	95.15	1017.42	20.09	3140	78,830	4.74
		16:00	99.26	1017.42	20.09	2680	81,510	4.94
		16:30	96.33	1017.42	20.09	2890	84,400	4.79
		17:00	96.33	1017.45	20.12	2890	87,290	4.79
		17:30	96.33	1017.46	20.13	2890	90,180	4.79
		18:00	96.33	1017.48	20.15	2890	93,070	4.78
		18:30	96	1017.49	20.16	2880	95,950	4.76
		19:00	97.77	1017.49	20.16	2640	98,590	4.85
		19:30	95.66	1017.49	20.16	2870	101,460	4.75
		20:00	95.66	1017.51	20.18	2870	104,330	4.74
		20:30	95.66	1017.51	20.18	2870	107,200	4.74
		21:00	96	1017.51	20.18	2880	110,080	4.76
		21:30	95.66	1017.51	20.18	2870	112,950	4.74
		22:00	95.66	1017.55	20.22	2870	115,820	4.73
		22:30	95.66	1017.53	20.2	2870	118,690	4.74
		23:00	95.66	1017.55	20.22	2870	121,560	4.73
		23:30	95.66	1017.57	20.24	2870	124,430	4.73
		24:00	95.66	1017.6	20.27	2870	127,300	4.72
		0:30	96	1017.63	20.3	2880	130,180	4.73
		1:00	95.33	1017.63	20.3	2860	133,040	4.70
		1:30	95.66	1017.65	20.32	2870	135,910	4.71
		2:00	96	1017.65	20.32	2880	138,790	4.72
		2:30	95.33	1017.65	20.32	2860	141,650	4.69
		3:00	95.66	1017.63	20.3	2870	144,520	4.71
		3:30	95.66	1017.65	20.32	2870	147,390	4.71

Table 8.2-1 (continued)

Status	Screen	Time	Pumping Rate (gpm)	Depth to Water (ft bgs)	Draw Down (ft)	Purge Volume (gal.)	Cumulative Purge Volume (gal.)	Specific Capacity (gpm/ft)
	1	4:00	95.33	1017.66	20.33	2860	150,250	4.69
		4:30	95.66	1017.65	20.32	2870	153,120	4.71
		5:00	95.33	1017.65	20.32	2860	155,980	4.69
		5:30	95.66	1017.65	20.32	2870	158,850	4.71
		6:00	95.66	1017.65	20.32	2870	161,720	4.71
		6:30	96.66	1017.69	20.36	2900	164,620	4.75
		7:00	94.66	1017.7	20.37	2840	167,460	4.65
		7:30	95.33	1017.7	20.37	2860	170,320	4.68
Off	1	8:05	na	1017.7	20.37	3350	173,670	na

[a] na = Not available.

[b] n/a = Not applicable.

Table 8.6-1
Summary of Waste Characterization Samples Collected during Drilling, Construction, and Development of CrEX-1

Event ID	Sample ID	Date Collected	Description	Sample Matrix
5765	WST05-14-84406	07/08/14	CrEx-1 drill cuttings (top)	Solid
5765	WST05-14-84409	07/08/14	CrEx-1 drill cuttings trip blank	Solid
5765	WST05-14-84407	07/21/14	CrEx-1 drill cuttings(middle)	Solid
5765	WST05-14-84411	07/21/14	CrEx-1 drill cuttings trip blank	Solid
5765	WST05-14-85767	08/04/14	CrEx-1 drill cuttings (bottom)	Solid
5765	WST05-14-85765	08/04/14	CrEx-1 drill cuttings trip blank	Solid
5764	WST05-14-84405	09/03/14	CrEX-1 drill cuttings	Solid
5766	WST05-14-84414	07/08/14	CrEx-1drilling fluids (top)	Liquid
5766	WST05-14-84418	07/08/14	CrEx-1drilling fluids trip blank	Liquid
5766	WST05-14-84415	07/08/14	CrEx-1 drilling field dup	Liquid
5766	WST05-14-84413	07/21/14	CrEx-1 drilling fluid	Liquid
5766	WST05-14-84419	07/21/14	CrEx-1 drilling fluid trip blank	Liquid
5766	WST05-14-84417	07/21/14	CrEx-1 drilling fluid dup	Liquid
5766	WST05-14-84414	08/04/14	CrEx-1 drilling fluid	Liquid
5766	WST05-14-84420	08/04/14	CrEx-1 drilling fluid trip blank	Liquid
5766	WST05-14-84416	08/04/14	CrEx-1 drilling fluid dup	Liquid
5761	WST05-14-84269	10/27/14	CrEx-1 drilling fluid	Liquid
5761	WST05-14-84270	10/27/14	CrEx-1 drilling fluid dup	Liquid
5761	WST05-14-84403	10/27/14	CrEx-1 drilling fluid	Liquid
6869	WST05-14-86626	TBD*	CrEx-1 decon water	Liquid

*TBD = To be determined.

Appendix A

Final Well Design and New Mexico Environmental Department Approval

From: Everett, Mark Capen
Sent: Friday, August 08, 2014 12:39 PM
To: Jerzy Kulis (jerzy.kulis@state.nm.us); Wear, Benjamin, NMENV (Benjamin.Wear@state.nm.us); Michael Dale (Michael.Dale@state.nm.us)
Cc: Shen, Hai; Rodriguez, Cheryl L; Woodworth, Woody; Swickley, Stephani Fuller; Katzman, Danny; Ball, Ted; Douglass, Craig R
Subject: CrEX-1 proposed well design

Jerzy,

Here is the CrEX-1 proposed well design which includes a narrative, two diagrams depicting the proposed design, and a Schlumberger geophysical log montage for discussion. We will be in touch around 1:15.

Thanks,

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

From: Kulis, Jerzy, NMENV [mailto:jerzy.kulis@state.nm.us]
Sent: Friday, August 08, 2014 2:48 PM
To: Katzman, Danny; Wear, Benjamin, NMENV
Cc: Ball, Ted; Everett, Mark Capen; Shen, Hai; Cobrain, Dave, NMENV; Dale, Michael, NMENV
Subject: RE: CrEX-1 well design narrative (2)

Danny,

NMED hereby approves the installation of the chromium extraction well CrEX-1 as proposed in your e-mail below and in the e-mail sent by Mark Everett on August 8, 2014 at 12:39 PM. This approval is based on information available to NMED at the time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design proposed in the above-mentioned e-mails, and any additional information relevant to the installation of CrEX-1 as soon as such data or information becomes available. LANL must perform installation of CrEX-1 and its subsequent development in the manner the minimizes communication between the upper and lower screens and possible cross-contamination.

Please let me know if you have any questions.

Jerzy Kulis
Environmental Scientist
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Bldg 1
Santa Fe, NM 87505-6303
Phone: 505-476-6039
Fax: 505-476-6030

From: Katzman, Danny [mailto:katzman@lanl.gov]
Sent: Friday, August 08, 2014 2:15 PM
To: Kulis, Jerzy, NMENV; Wear, Benjamin, NMENV
Cc: Ball, Ted; Everett, Mark Capen; Shen, Hai
Subject: CrEX-1 well design narrative (2)

Jerzy, Ben- following on our discussion, here's an updated well-design rationale sheet for CrEX-1. Please review and provide a response at your earliest convenience.
Thanks again for facilitating such an efficient review.
Danny

CrEX-1

Key objectives that guide design:

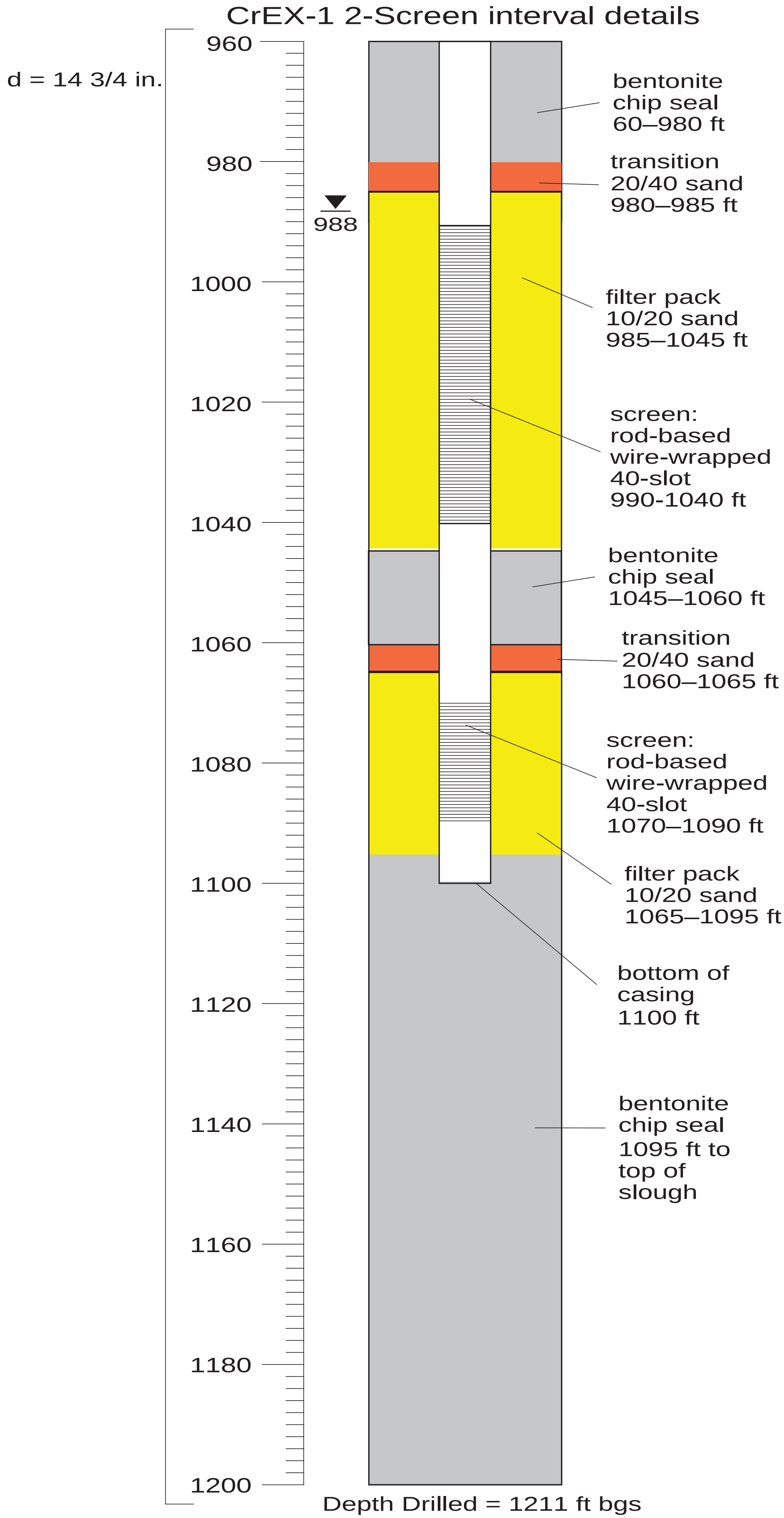
- Establish capture zone within the plume which is in the upper 70-100 ft of aquifer
- Optimize removal of only chromium contaminated water
- Reach downgradient towards R-50 if possible
- Avoid drawing chromium contamination downward

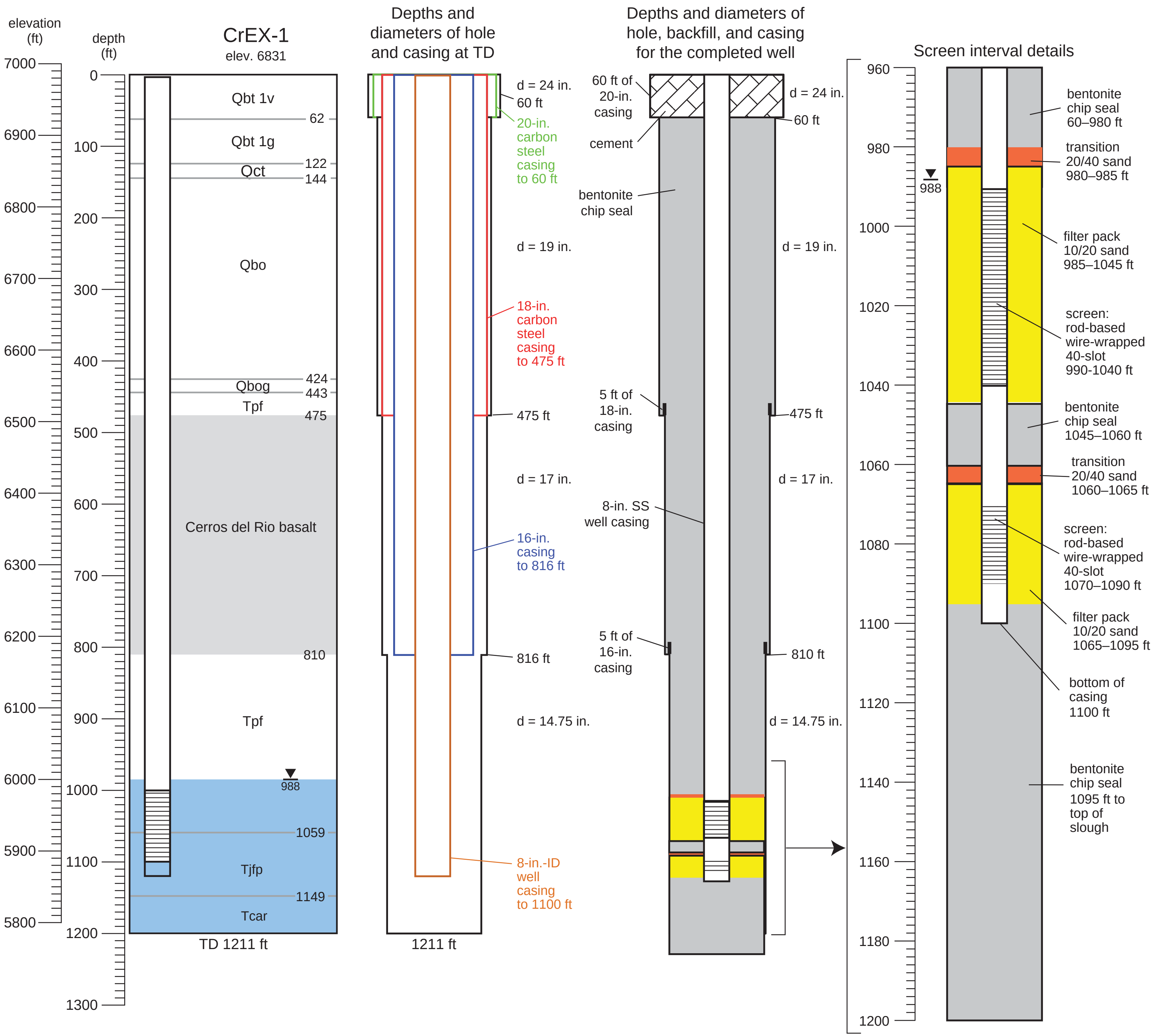
Key observations from geophysics:

- Water table is at approximately 990' bgs
- Contact between Puye formation and Miocene Pumiceous Unit is at ~1052' bgs
- Good probability of production from water table to ~1050' bgs
- Very high conductivity/free water/production zone between 1050 – 1150 (appears to correlate with Miocene pumiceous unit)

Recommendation:

- Build a two-screen well with a 50' screen starting at water table (990' – 1040' bgs), a 30' blank section, and a 20' lower screen set from 1070 – 1090' bgs
- The "water table" screen has a higher likelihood of reaching downgradient because it would be in a lower transmissivity zone than a deeper screen.
- A screen set exclusively in the deeper high production zone might not propagate capture towards the upper 75' of the aquifer where the chromium is present.
- The lower screen would be packed off and only used if the upper screen does not produce the hydraulic response necessary for an optimized capture zone.
- Development would occur over the entire screen interval, then again in the upper screen after being packed off


CrEX-1 2-Screen interval details
d = 14 3/4 in.
960
980
1000
1020
1040
1060
1080
1100
1120
1140
1160
1180
1200
988
bentonite chip seal 60–980 ft
transition 20/40 sand 980–985 ft
filter pack 10/20 sand 985–1045 ft
screen: rod-based wire-wrapped 40-slot 990-1040 ft
bentonite chip seal 1045–1060 ft
transition 20/40 sand 1060–1065 ft
screen: rod-based wire-wrapped 40-slot 1070–1090 ft
filter pack 10/20 sand 1065–1095 ft
bottom of casing 1100 ft
bentonite chip seal 1095 ft to top of slough
Depth Drilled = 1211 ft bgs



CrEX-1
elev. 6831
elevation (ft)
depth (ft)
Qbt 1v
62
Qbt 1g
122
Qct
144
Qbo
424
Qbog
443
Tpf
475
Cerros del Rio basalt
810
Tpf
988
1059
Tjfp
1149
Tcar
TD 1211 ft
Depths and diameters of hole and casing at TD
d = 24 in.
60 ft
20-in. carbon steel casing to 60 ft
d = 19 in.
18-in. carbon steel casing to 475 ft
475 ft
d = 17 in.
16-in. casing to 816 ft
816 ft
d = 14.75 in.
8-in.-ID well casing to 1100 ft
1211 ft
Depths and diameters of hole, backfill, and casing for the completed well
60 ft of 20-in. casing
cement
bentonite chip seal
5 ft of 18-in. casing
8-in. SS well casing
5 ft of 16-in. casing
d = 24 in.
60 ft
d = 19 in.
475 ft
d = 17 in.
810 ft
d = 14.75 in.
Screen interval details
bentonite chip seal 60–980 ft
transition 20/40 sand 980–985 ft
988
filter pack 10/20 sand 985–1045 ft
screen: rod-based wire-wrapped 40-slot 990-1040 ft
bentonite chip seal 1045–1060 ft
transition 20/40 sand 1060–1065 ft
screen: rod-based wire-wrapped 40-slot 1070–1090 ft
filter pack 10/20 sand 1065–1095 ft
bottom of casing 1100 ft
bentonite chip seal 1095 ft to top of slough

Schlumberger

MR Scanner
Pc / Sw Evaluation
Composite Log

COMPANY:	Los Alamos National Laboratory
WELL:	CrEX−1
FIELD:	LANL
State:	New Mexico
COUNTRY:	USA

Date Processed:	07−Aug−2014	Date Logged:	07−Aug−2014
Job Number:		Processed at:	
Well Location:	Mortandad Canyon		
Latitude:	35deg 51' 28" N	Longitude:	106deg 15' 23" W
Elevations:	KB:	DF:	GL:

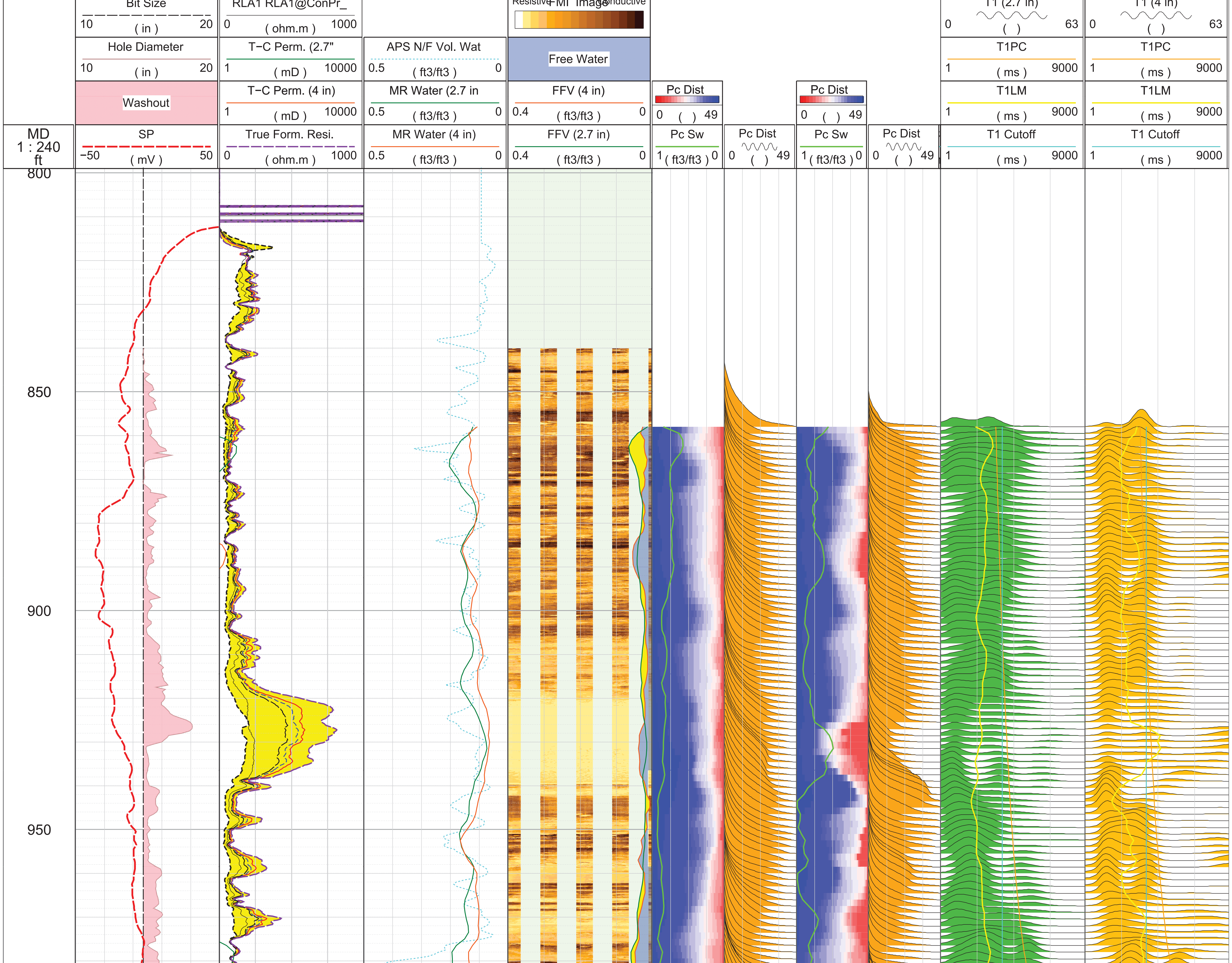
MRX advanced processing

FOLD HERE The well name, location and borehole reference data were furnished by the customer.

Mud Invasion

Curve	Min	Unit	Max
RXO_HRLT RXO_HRL	0	(ohm.m)	1000
RLA5 RLA5@ConPr_	0	(ohm.m)	1000
RLA4 RLA4@ConPr_	0	(ohm.m)	1000
RLA3 RLA3@ConPr_	0	(ohm.m)	1000

ConPr_R3L8Up_S02
Horizontal Scale: 1 : 28.134
Straight Image
0 120 240 360



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RLA1 RLA1@ConPr_
0 (ohm.m) 1000
Resistive FMI Image Conductive
T1 (2.7 in)
0 ( ) 63
T1 (4 in)
0 ( ) 63
Hole Diameter
10 (in) 20
T-C Perm. (2.7"
1 (mD) 10000
APS N/F Vol. Wat
0.5 (ft3/ft3) 0
Free Water
T1PC
1 (ms) 9000
T1PC
1 (ms) 9000
Washout
T-C Perm. (4 in)
1 (mD) 10000
MR Water (2.7 in
0.5 (ft3/ft3) 0
FFV (4 in)
0.4 (ft3/ft3) 0
Pc Dist
0 ( ) 49
Pc Dist
0 ( ) 49
T1LM
1 (ms) 9000
T1LM
1 (ms) 9000
MD
1 : 240
ft
SP
-50 (mV) 50
True Form. Resi.
0 (ohm.m) 1000
MR Water (4 in)
0.5 (ft3/ft3) 0
FFV (2.7 in)
0.4 (ft3/ft3) 0
Pc Sw
1 (ft3/ft3) 0
Pc Dist
0 ( ) 49
Pc Sw
1 (ft3/ft3) 0
Pc Dist
0 ( ) 49
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T1 Cutoff
1 (ms) 9000
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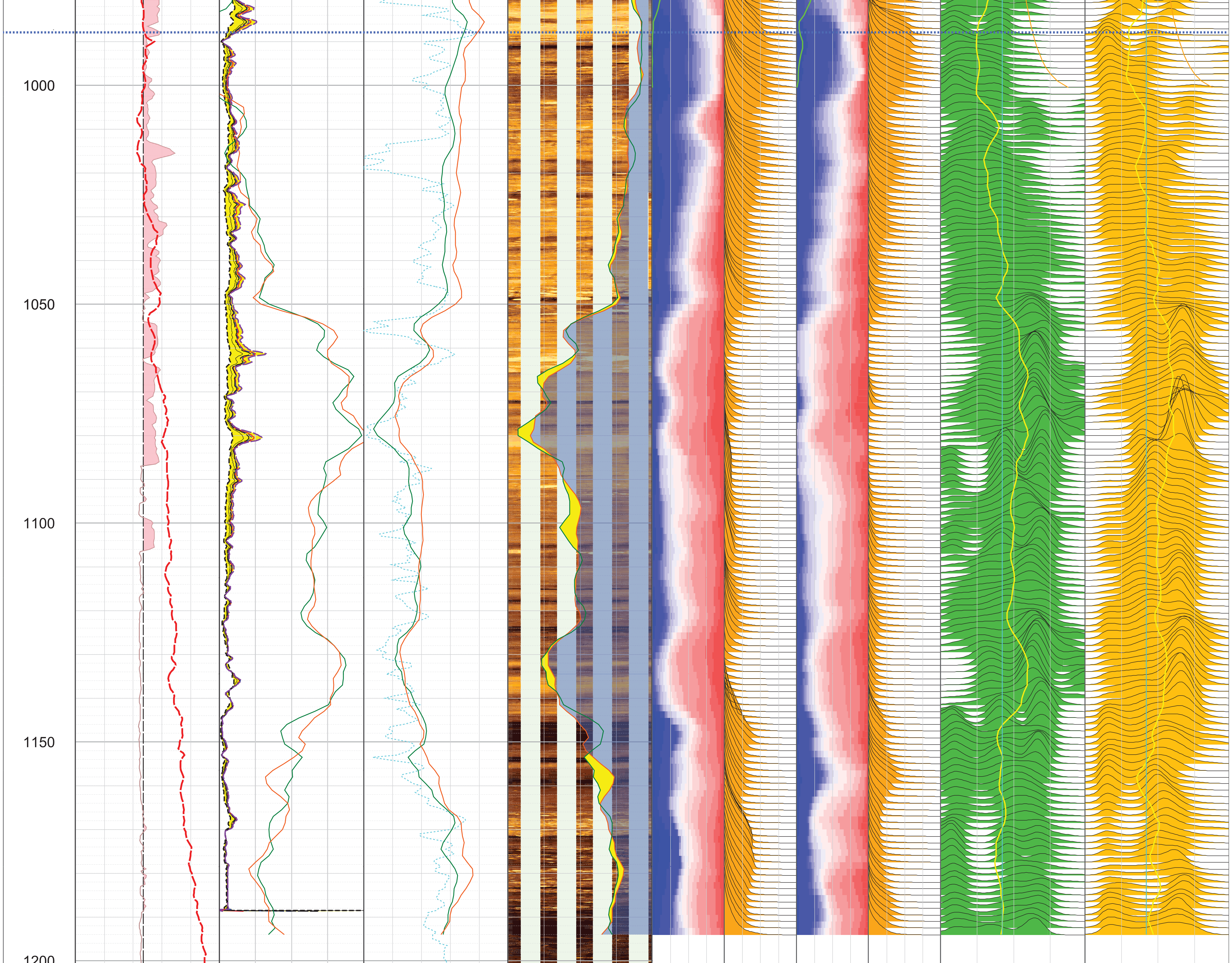
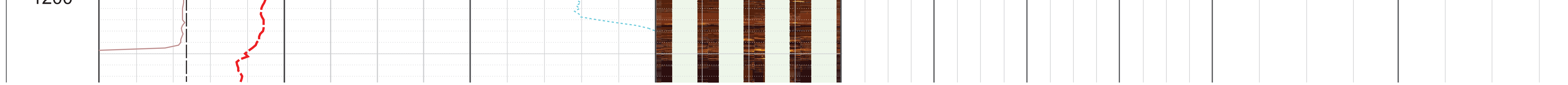
850
900
950



1000
1050
1100
1150
1200



Appendix B

Borehole Video Logging
(on DVD included with this document)

Appendix C

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

Appendix D

Aquifer Testing Report

D-1.0 INTRODUCTION

This appendix describes the hydrogeological analysis of the aquifer tests at well CrEX-1 located in Mortandad Canyon within the existing chromium plume. The primary objective of the analysis was to determine the hydraulic properties of the zones screened by CrEX-1.

Conceptual Hydrogeology

The CrEX-1 screened intervals consist of a 50-ft-long screen from 990 ft to 1040 ft below ground surface (bgs) and a 20-ft-long screen from 1070 ft to 1090 ft bgs. There is a 30-ft blank zone between the two screens.

CrEX-1 was completed in the Puye Formation (Tpf, 809 ft to 1054 ft bgs), mixed Miocene deposits (Tjpf and Tcar, 1054 ft to 1070 bgs), and Miocene pumiceous sediments (Tjfp, 1070 ft to 1155 ft bgs). Because only the upper 50-ft screen was pumped, the aquifer test provides information about the properties of the Puye Formation and mixed Miocene deposits.

On October 3, 2014, following well installation, well development, installation of the packer between the upper and lower screens, and aquifer testing, depth to water was 997.2 ft bgs in the completed well. The upper screen of CrEX-1 straddles the regional water table. This allows for effective assessment of the uppermost portion of the regional aquifer next to the regional water table where the highest contaminant concentrations are expected. As a result, the effective screen length is about 43 ft (from the water table to the bottom of the upper screen, which is at 1040 ft bgs).

The pumping of CrEX-1 produced a maximum drawdown of about 6.2 m (~20 ft) within the pumped upper screen. However, the well specific capacity did not decline with the increase of the pumping rate (and the respective increase of the pumping drawdown; see below). This suggests that borehole skin effects caused a portion of the drawdown. Skin effect is an increase in the pressure drop at the pumping well when compared with aquifer pressure adjacent to the well. The increased pressure drop is thought to be caused by extra flow resistance near the wellbore because of imperfect hydraulic connection between the well and the aquifer. As a result, the drawdown in the aquifer adjacent to the well is expected to be much lower than the one observed within the pumped borehole. Nevertheless, the pumping caused a decline in the regional water table, and it is likely that vadose zone groundwater flow impacted the drawdowns observed in CrEx-1. Therefore, unconfined (phreatic) groundwater flow is occurring near the pumped well. However, the observed drawdowns are still small compared with the aquifer thickness (>100 ft), so it is acceptable to use analyses that interpret the flow as confined. In addition, analyses accounting for unconfined groundwater flow were also performed using Moench methodology (1997, 600136).

Aquifer Testing

CrEX-1 was tested from October 1 through 4, 2014. Testing consisted of a five-step pumping test on October 1 and a 24-h constant-rate pumping test that started on October 3.

The pumping rates during the five-step test and the 24-h pumping test are shown in Figure D-1.0-1. The figure also shows the water-level fluctuations measured in CrEX-1. The pumping rates were relatively steady. The water level declined and rebounded very fast when pumping was turned on and off. The initial over-shooting of the water levels during recovery after the pump was turned off potentially suggests groundwater recharge from the vadose zone. The water level also returned relatively fast to prepumping conditions after the pump was turned off. This suggests that the aquifer is relatively well producing, and borehole skin effects may be impacting the observed drawdowns within the pumping well.

D-2.0 AQUIFER-TEST INTERPRETATION

Drawdown and recovery data can be analyzed using a variety of methods. The Theis equation (1934-1935, 098241) describes drawdown around a well as follows (Equation D-2.0-1):

$$s = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-x}}{x}dx = \frac{Q}{4\pi T}W(u) = \frac{Q}{4\pi T}W\left(\frac{r^2}{4at}\right) = \frac{Q}{4\pi T}W\left(\frac{r^2 S}{4Tt}\right)$$ **Equation D-2.0-1**

where *s* is drawdown (in m), *Q* is discharge rate (in m^3/d), *T* is transmissivity (in m^2/d), *a* is hydraulic diffusivity (characterizing the speed of propagation of hydraulic pressures in the subsurface) (in m^2/d), *S* is storage coefficient (dimensionless [-]), *t* is pumping time (in d), and *r* is the distance from the pumping well (in m).

The Cooper-Jacob method (1946, 098236) provides a simplification of the Theis equation. The Cooper-Jacob equation describes drawdown around a pumping well as follows (Equation D-2.0-2):

$$s = \frac{2.303Q}{4\pi T}log_{10}\frac{2.25at}{r^2} = \frac{2.303Q}{4\pi T}log_{10}\frac{2.25Tt}{r^2 S}$$ **Equation D-2.0-2**

The Cooper-Jacob equation is valid whenever the *u* value in the Theis equation above is less than 0.05. For small radius values (e.g., corresponding to borehole radii), *u* is less than 0.05 at very early pumping times and, therefore, is less than 0.05 for most or all measured drawdown values. Thus, for the pumped well, the Cooper-Jacob equation usually can be considered a valid approximation of the Theis equation. According to the Cooper-Jacob method, the time-drawdown data are plotted on a semilog plot, 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 Equation D-2.0-2:

$$T = \frac{2.303Q}{4\pi\Delta s}$$ **Equation D-2.0-3**

where Δs is the slope of the straight line on the semilog plot (typically estimated as a change over one log cycle of the graph) (in m). The Cooper-Jacob method also allows for estimation of the hydraulic diffusivity *a* (and respectively of the storage coefficient *S*). However, these estimates are typically highly unreliable when drawdowns are observed at the pumping well. The hydraulic diffusivity and the storage coefficient can be estimated reliably only when based on drawdowns observed at an observation well near the pumping well.

The recovery data are analyzed using the Theis recovery method, which is a semilog analysis method similar to the Cooper-Jacob method described above. In this method, the only difference is that the residual drawdown is plotted on a semilog plot 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 straight line as in the Cooper-Jacob method above. The recovery data are particularly useful compared with drawdown data. Because the pump is not running, data responses associated with temporal discharge rate fluctuations are eliminated. The result is that the recovery data set is generally "smoother" and easier to analyze.

More complicated analytical solutions are available to account for drawdown impacts caused by vadose zone flow, partial well penetration, aquifer leakage, etc. Some of these analytical solutions are available in simulation codes such as WELLS (http://wells.lanl.gov) and AQTESOLV (http://www.aqtesolv.com). For example, the codes allow for analyses using the Moench method (1997, 600136); this method is applied to analyze the drawdown data as well.

D-3.0 DATA ANALYSIS

This section presents the data obtained during the aquifer tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for the five-step test and 24-h constant-rate pumping test.

Five-Step Variable-Rate Aquifer Test

The specific capacity data obtained from the CrEX-1 five-step pumping test are summarized in Table D-3.0-1. The table also includes specific capacity data obtained during the 24-h constant-rate pumping test. Note that these values are approximate because the pumping drawdowns did not reach equilibration at the end of the pumping period during all the tests. During the step tests, the specific capacity varied between about 100 m^2/d and 120 m^2/d (~5.5 gallons per minute [gpm]/ft and 6.6 gpm/ft). The step-test data demonstrate that the specific capacity of the well does not seem to depend on the pumping rate, which suggests the well is well developed.

24-Hour Constant-Rate Aquifer Test

Figure D-3.0-1 shows a semilog plot of the drawdown data recorded during the 24-h constant-rate pumping test conducted at an average pumping rate of 517.6 m^3/d (~94.9 gpm). The test data show a well-defined drawdown curve with short-term, temporary equilibration of the water-level decline midway through the test (Figure D-3.0-1); there might also be a second, very short equilibration period close to the end of the test. The temporary equilibration may be caused by (1) vadose zone recharge (delayed yield effects), (2) three-dimensional groundwater flow effects (because of vertical expansion of the cone of depression), (3) recharge boundary effects, or (4) fluctuations in municipal water-supply pumping. It is important to note that the drawdowns did not equilibrate at the end of the 24-h constant-rate pumping test. However, based on the general understanding of the hydrogeologic conditions at the site, equilibration is expected at later pumping times.

Based on analysis of the drawdown curve in Figure D-3.0-1, two periods can be characterized with straight lines matching the drawdown data (there is potentially a third period at the end of the pumping test, but clearly the slope of the third period matches the slope of the second period). The first straight-line match defines the transmissivity of the aquifer in close vicinity to the well. The estimated aquifer transmissivity close to CrEX-1 is 510 m^2/d (41,000 gpd/ft). The second straight-line slope defines lower transmissivity. The transmissivity is lower because, at later pumping times, the cone of depression has reached a portion of the aquifer with lower transmissivity. This potentially suggests aquifer heterogeneity. The second (late-time) straight-line slope characterizes the effective aquifer properties impacting the groundwater flow towards CrEX-1. The estimated effective aquifer transmissivity in the vicinity of CrEX-1 is about 360 m^2/d (30,000 gpd/ft).

Figure D-3.0-2 presents analysis of the drawdown data performed using the Moench method (1997, 600136), assuming unconfined groundwater flow; the analysis was performed using the code AQTESOLV. The analysis produced better overall representation of the drawdown data and better characterization of the late-time data. As a result, the estimated transmissivity value is consistent with the late-time estimate given above, assuming confined conditions. The estimated effective aquifer transmissivity is 340 m^2/d, assuming unconfined conditions.

Figure D-3.0-3 shows CrEX-1 drawdown recovery after the 24-h constant-rate pumping test. The drawdown recovery was plotted on a semilog plot versus the ratio *t/t'*, where *t* is the time since pumping began, and *t'* is the time since pumping stopped. The recovery at late times (in Figure D-3.0-3, time increases from left to right) shows two well-defined straight-line periods separated by a period of temporal drawdown equilibration. As stated above, the temporary equilibration may be caused by (1) vadose zone recharge (delayed yield effect), (2) three-dimensional groundwater flow effects (because of vertical expansion of the cone of depression), (3) boundary effects, or (4) fluctuations in municipal water-supply pumping. However, in Figure D-3.0-3, both straight lines have very similar slopes and defined transmissivity values of 480 m^2/d and 490 m^2/d, respectively (39,000 gpd/ft and 40,000 gpd/ft, respectively). These transmissivity estimates are between the transmissivity estimates based on the drawdown data and are expected to represent the effective aquifer properties impacting the groundwater flow towards the well during drawdown recovery of CrEX-1. In conclusion, it can be assumed that the value of 490 m^2/d (40,000 gpd/ft) is the current best estimate of the aquifer transmissivity in the area near CrEX-1. This transmissivity value is very similar to the estimate obtained by a recent R-28 aquifer test analysis conducted in 2014 (LANL 2014, 255110).

The saturated thickness corresponding to the transmissivity value is not known to estimate hydraulic conductivity. The saturated thickness is impacted by the pumping because the pumping causes a decline in the regional water table. Assuming the saturated thickness is the length of the initial saturated screened interval (~43 ft; before the pumping started) minus half the observed drawdown (~10 ft), the estimated average hydraulic conductivity is about 49 m/d or 161 ft/d. This estimate is uncertain, but the value of hydraulic conductivity is consistent with the estimate obtained for R-28 (~120 ft/d).

The CrEX-1 transmissivity and hydraulic conductivity estimates suggest that the well is tapping a highly permeable zone in the regional aquifer. This helps achieve the CrEX-1 objective of hydraulic capture of contaminated groundwater.

D-4.0 REFERENCES

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

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

Cooper, H.H., Jr., and C.E. Jacob, August 1946. "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History," *American Geophysical Union Transactions,* Vol. 27, No. 4, pp. 526-534. (Cooper and Jacob 1946, 098236)

LANL (Los Alamos National Laboratory), March 2014. "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2," Los Alamos National Laboratory document LA-UR-14-21642, Los Alamos, New Mexico. (LANL 2014, 255110)

Moench, A.F., June 1997. "Flow to a Well of Finite Diameter in a Homogenous, Anisotropic Water Table Aquifer," *Water Resources Research,* Vol. 33, No. 6, pp. 1397–1407. (Moench 1997, 600136)

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

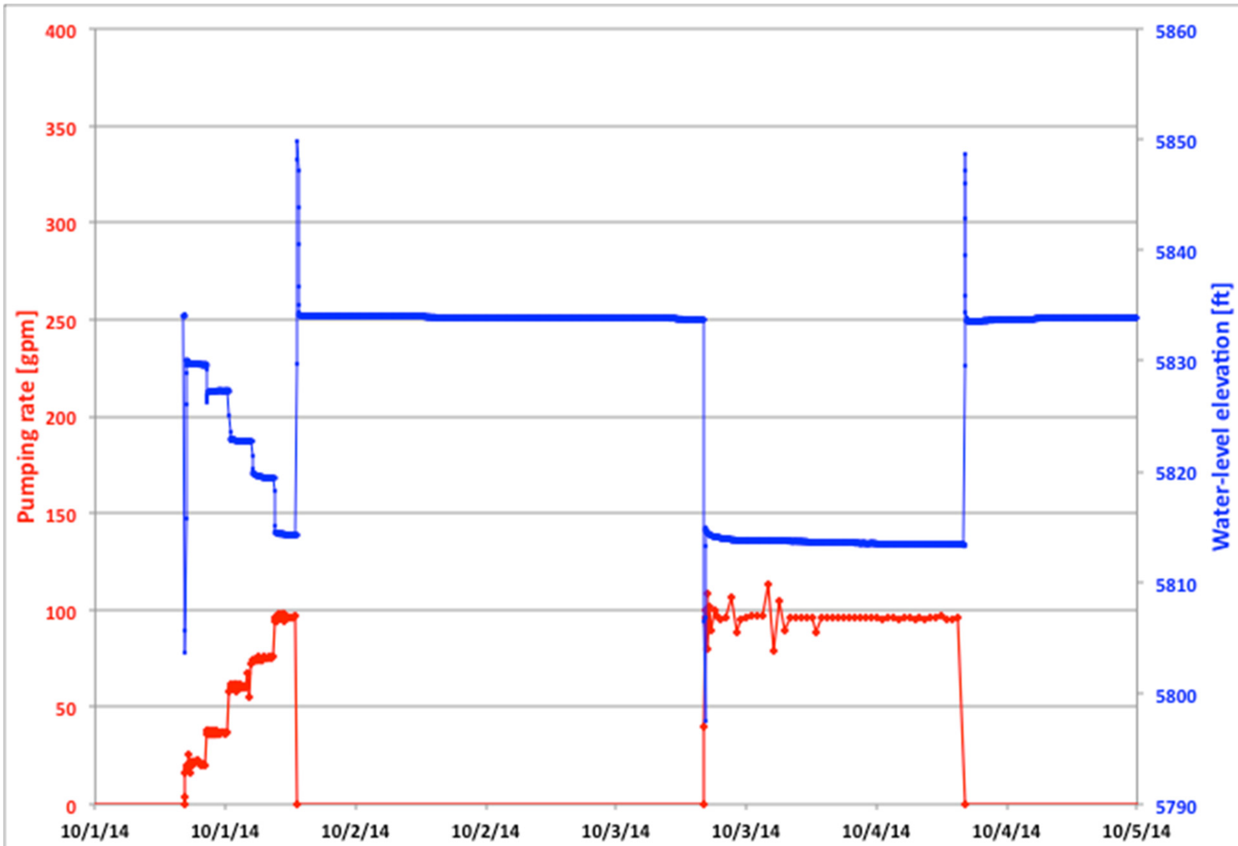
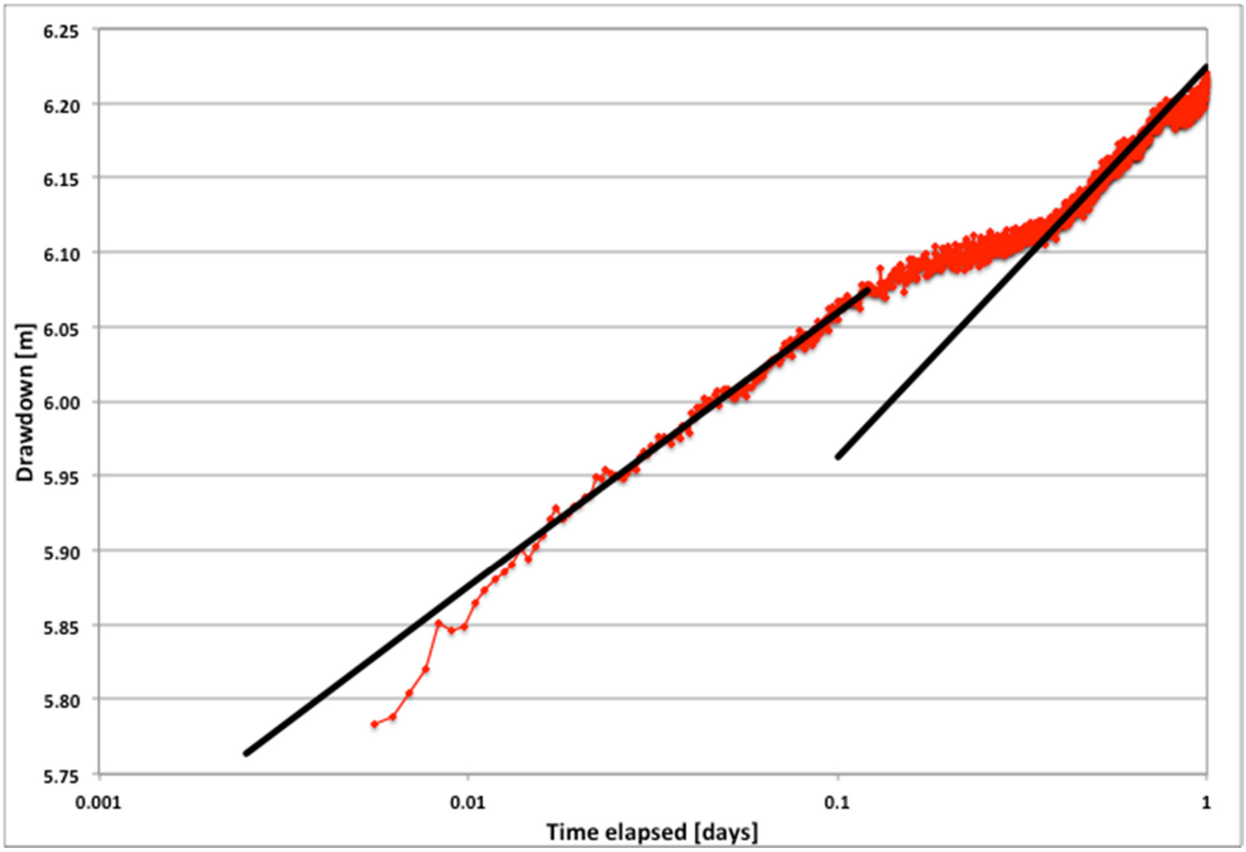
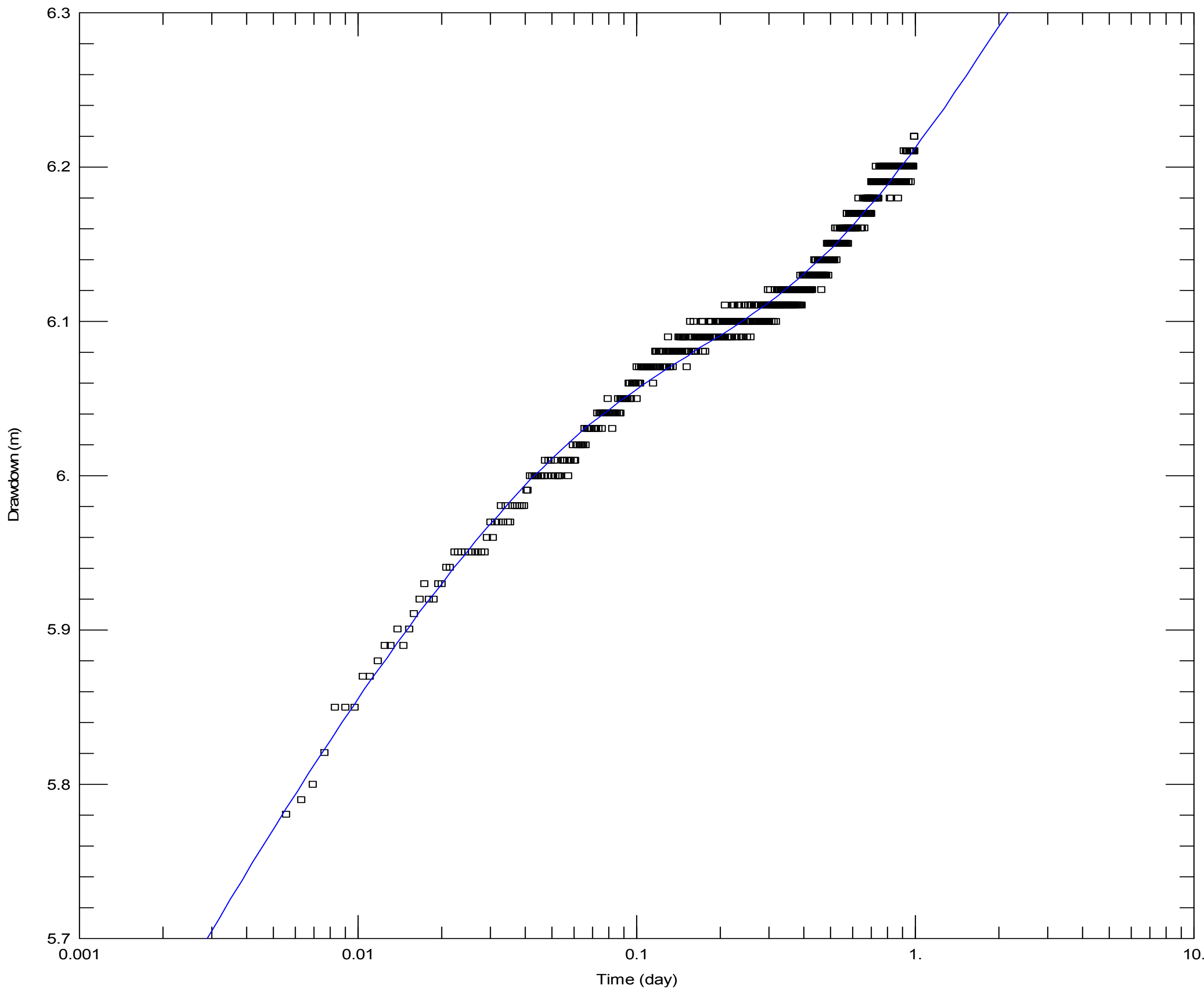


Figure D-1.0-1 Change in pumping rates (in red, left y-axis) and water-level elevations (in blue, right y-axis) during the five-step test and the 24-h pumping test over time



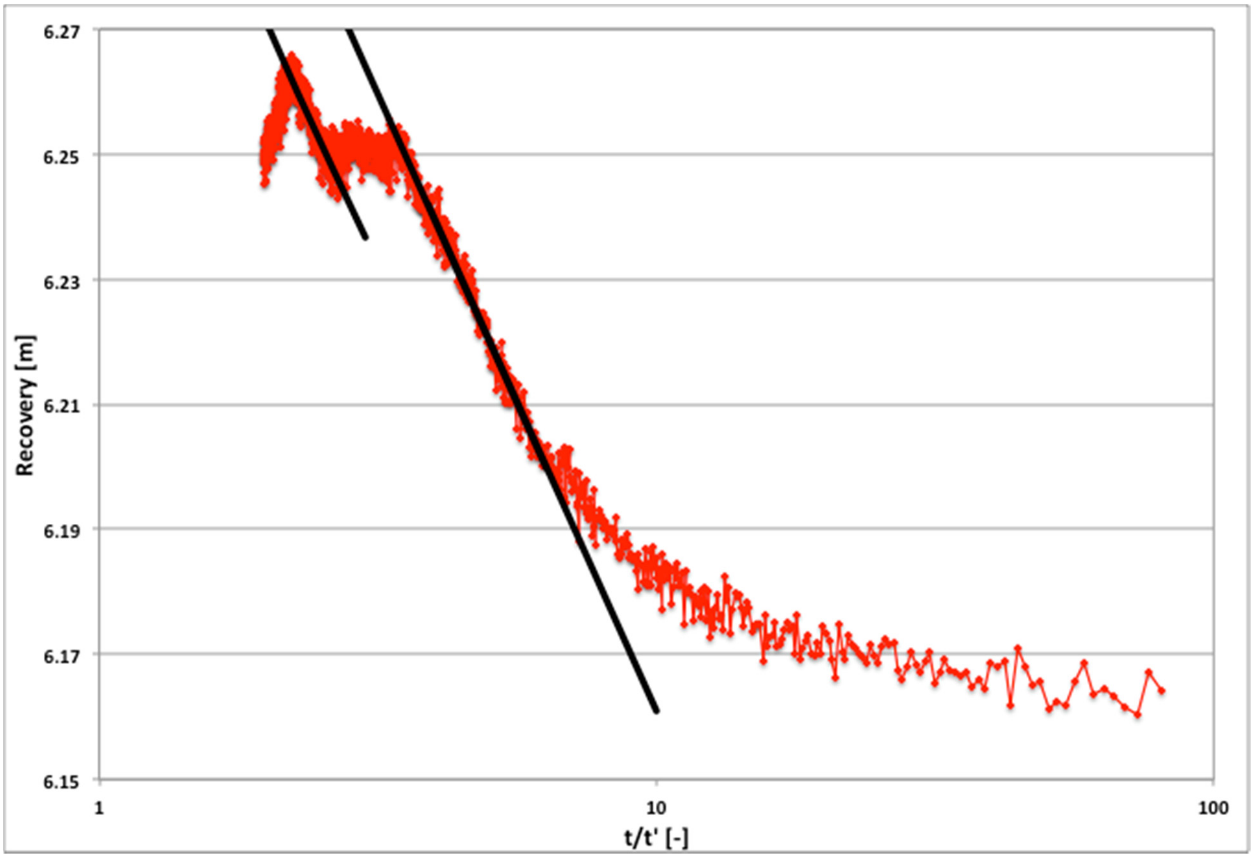
Note: The analysis of the drawdown data was performed using the Cooper-Jacob method, assuming confined groundwater flow.

Figure D-3.0-1 CrEX-1 drawdown versus time during the 24-h constant-rate pumping test



Note: The analysis of the drawdown data was performed using the Moench method (1997, 600136), assuming unconfined groundwater flow; the analysis was performed using the code AQTESOLV.

Figure D-3.0-2 CrEX-1 drawdown versus time during the 24-h constant-rate pumping test



Notes: The drawdown recovery was plotted on a semilog plot versus the ratio *t/t'*, where *t* is the time since pumping began, and *t'* is the time since pumping stopped. Effectively, the time increases from left to right.

Figure D-3.0-3 CrEX-1 drawdown recovery after the 24-h constant-rate pumping test

Table D-3.0-1
Summary of Specific Capacity Data Obtained from CrEX-1 Aquifer Tests

Test	Average Pumping Rate (gpm)	Average Drawdown (ft)	Average Specific Capacity (gpm/ft)	Average Pumping Rate (m^3/d)	Average Drawdown (m)	Average Specific Capacity (m^2/d)
Step test #1	20.5	3.7	5.48	111.6	1.14	98.1
Step test #2	35.7	5.6	6.39	194.5	1.70	114.3
Step test #3	60.3	10.3	5.85	328.8	3.15	104.5
Step test #4	74.8	11.3	6.63	407.5	3.44	118.5
Step test #5	96.2	16.2	5.95	524.2	4.92	106.5
24-h test	94.9	20.1	4.73	517.6	6.12	84.5