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Hazardous Waste Bureau

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

**Subject: Well Completion Report for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5**

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Well Completion Report for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5. The submittal of this report satisfies the 2016 Compliance Order on Consent Appendix B Milestones and Targets, Chromium IM & Characterization, Number 5, Chromium Injection Well (4) Completion Reports for Fiscal Year 2016 on March 31, 2017.

If you have any questions, please contact Stephani Swickley at (505) 606-1628 (sfuller@lanl.gov) or Cheryl Rodriguez at (505) 665-5330 (cheryl.rodriguez@em.doe.gov).

Sincerely,

Bruce Robinson, Program Director
Environmental Remediation Program
Los Alamos National Laboratory

Sincerely,

David S. Rhodes, Director
Office of Quality and Regulatory Compliance
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Los Alamos Field Office

BR/DR/SS:sm

Enclosures: Two hard copies with electronic files – Well Completion Report for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 (EP2017-0006)

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LA-UR-17-22162
March 2017
EP2017-0006

# Well Completion Report for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Associate Directorate for Environmental Management

EP2017-0006

# Well Completion Report for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5

March 2017

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## EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated injection/pumping system installation for groundwater injection wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5, located within Los Alamos National Laboratory (LANL or the Laboratory). The primary purpose of the chromium injection (CrIN) wells is to achieve hydraulic control of off-site hexavalent chromium plume migration within the regional aquifer in Mortandad Canyon at the Laboratory. The wells were drilled and constructed in accordance with the New Mexico Environment Department's (NMED's) January 22, 2016, approval with modifications of the "Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6." This completion report does not include injection well CrIN-6. Installation of injection well CrIN-6 will be conducted under the December 13, 2016, "Drilling Work Plan for Groundwater Injection Well CrIN-6," approved by NMED on January 4, 2017.

All the CrIN boreholes were drilled using dual-rotary air-drilling methods to total depth. Fluid additives used included potable water, foam, and polymer. Foam-assisted drilling was used to total depth. Two of the wells, CrIN-1 and CrIN-2, are conventional vertical completions, while CrIN-3, CrIN-4, and CrIN-5 are angled completions.

The following geologic formations were encountered: Quaternary alluvium, Tshirege Member Unit 2v, Tshirege Member Unit 1v, Tshirege Member Unit 1g, Cerro Toledo Formation, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, the Cerros del Rio volcanics, the Puye Formation, and Miocene pumiceous sediments.

The wells were completed as single-screen wells within the uppermost portion of the regional aquifer. The screened intervals are all within Puye Formation sediments.

The wells were completed in accordance with NMED-approved well designs. They were developed and the regional aquifer groundwater met target water-quality parameters. Aquifer testing indicates the CrIN wells will perform effectively in meeting the planned objectives. Injection/pumping systems and transducers were installed in the wells.

## CONTENTS



### Figures

**Tables**

**Appendixes**

**Acronyms and Abbreviations**

| | |
|---|---|
| amsl | above mean sea level |
| ASTM | American Society for Testing and Materials |
| bgs | below ground surface |
| btoc | below top of casing |
| Consent Order | Compliance Order on Consent |
| CrIN | chromium injection |
| DTW | depth to water |
| EES | Earth and Environmental Sciences (Laboratory group) |
| EM | Environmental Management |
| ESH | Environment, Safety, and Health (Laboratory directorate) |
| FCV | flow control valve |
| gpm | gallons per minute |
| hp | horsepower |
| I.D. | inside diameter |
| JWGS | Jet West Geophysical Services, LLC |
| LANL | Los Alamos National Laboratory |
| NAD | North American Datum |
| NMED | New Mexico Environment Department |
| NR | not recorded |
| NTU | nephelometric turbidity unit |
| O.D. | outside diameter |
| PVC | polyvinyl chloride |
| TD | total depth |

## 1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and dedicated pumping system installation for groundwater injection wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5. The report is prepared in accordance with the guidance in Appendix F, Section II, of the June 2016 Compliance Order on Consent (the Consent Order). The groundwater injection boreholes were drilled and completed between May and September 2016 at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Management (EM) Directorate. The wells were drilled and constructed in accordance with the New Mexico Environment Department's (NMED's) January 22, 2016, approval with modifications of the "Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6" (LANL 2015, 601048; NMED 2016, 601158). This completion report does not include injection well CrIN-6. Installation of injection well CrIN-6 will be conducted under the December 13, 2016, "Drilling Work Plan for Groundwater Injection Well CrIN-6," approved by NMED on January 4, 2017 (LANL 2015, 601048; NMED 2017, 602097).

The objective of the chromium injection (CrIN) wells is to control the migration of chromium-contaminated groundwater. The wells are located in Mortandad Canyon (Figure 1.0-1), just south and east of the centroid along the downgradient perimeter of the hexavalent chromium plume in the regional groundwater beneath the canyon. Injection wells CrIN-1 and CrIN-2 are located in the canyon bottom and are conventional vertical completions. Injection well CrIN-3, also in the canyon bottom, is an angled completion drilled from regional monitoring well R-44's pad at 17 degrees (from vertical) toward the west. Injection wells CrIN-4 and CrIN-5 are located on the mesa top and were drilled from regional monitoring well R-50's pad. CrIN-4 was drilled at 11 degrees (from vertical) toward the east, and CrIN-5 was drilled at 25 degrees (from vertical) toward the southwest.

The boreholes were drilled to varying total depths (TDs). During drilling, cuttings samples were collected at 10-ft intervals from ground surface to TD. The injection wells were installed with screened intervals in the uppermost portion of the regional aquifer within Puye Formation volcaniclastic sediments.

Post-installation activities at each location included well development, aquifer testing, surface completion, geodetic surveying, and injection/pumping system installation. Future activities will include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the EM Records Processing Facility. This report contains brief descriptions of activities and supporting figures, tables, and appendixes associated with the CrIN well drilling project.

## 2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide activities associated with the drilling, installation, and development of injection wells CrIN-1 through CrIN-5:

- "Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6" (LANL 2015, 601048);
- "Storm Water Pollution Prevention Plan, CrIN Well Pads and Construction Support Activities, Los Alamos National Laboratory" (LANL 2016, 602108);
- "[Integrated Work Document for] Implementation of the Drilling Work Plan for Groundwater Extraction Well CrEX-1" (Holt Services Inc. 2016, 602106);

- "IDW [Integrated Work Document] for Drilling and Installation of LANL Vertical Chromium Injection Wells" (Yellow Jacket Drilling 2016, 602107);
- "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); and
- "Waste Characterization Strategy Form for Chromium Wells CrIN-1 [with complete Attachment 4]" (LANL 2014, 600344).

## 3.0 DRILLING ACTIVITIES

This section describes the drilling approach and provides a summary of field activities conducted at the CrIN wells.

### 3.1 Drilling Approach

The drilling method, equipment, and drill-casing were selected to drill the CrIN wells to the required depths. The drilling approach ensured that a sufficiently sized drill casing was used to meet the required 3-in.-minimum annular thickness of the filter pack around an 8.62-in.–outside-diameter (-O.D.) well screens.

Two separate drilling service providers worked on the CrIN well drilling project. One company, Yellow Jacket Drilling, drilled and completed the vertical wells (CrIN-1 and CrIN-2), and another company, Holt Services, Inc., drilled and completed the angle wells (CrIN-3, CrIN-4, and CrIN-5).

Dual-rotary drilling methods using two Foremost DR-24HD drill rigs were employed to drill the CrIN boreholes. The drill rigs were equipped with conventional direct-circulation drilling rods, tricone bits, downhole hammer bits, underreaming hammer bits, deck-mounted air compressors, auxiliary compressors, and general drilling equipment. In all wells, A53 grade B flush-welded mild carbon-steel casing (24-in.-O.D., 20-in.-O.D., 18-in.-O.D., 16-in.-O.D., and 14-in.–inside-diameter [I.D.]) was used for drilling.

The dual-rotary drilling technique used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole included potable water and a mixture of potable water with Baroid Quik Foam foaming agent and Baroid EZ-Mud polymer emulsion. The fluids were used to cool the bit and help lift cuttings from the borehole. Foaming agents were used during the entire drilling effort to assist in lifting cuttings to the surface. The vertical boreholes were drilled using both casing-advance and open-hole methods.

The angled boreholes were drilled using only the dual-rotary and casing advance method (no open hole intervals) and relied on the rigidity of the drill casing to maintain the predetermined angle. The rig's tower was braced with prefabricated structural steel to hold the tower at the proper angle. Each angled borehole was different and required its own unique set of bracing. The drilling pads were also prepared specifically for the angle-drilling operation. Shallow trenches were excavated to position the drill rig so the bottom of the rig's tower could rest on firm ground.

The angled boreholes were surveyed at several points during the drilling process and upon reaching TD to ensure they remained and terminated on target. An inertial microsensor gyro surveying tool that is unaffected by magnetic environments was used for surveying. Figure 3.1-1 presents the TD surveys and original drilling targets for the three angled boreholes, CrIN-3, CrIN-4, and CrIN-5.

## 3.2 Drilling Activities

In late March and early April 2016, two Foremost DR-24HD drill rigs, drilling equipment, and supplies were mobilized to Mortandad Canyon to support the CrIN drilling project. Equipment and tooling were decontaminated before mobilization to the site. The two drilling operations worked concurrently to project completion. Table 3.2-1 presents chronological milestone dates for duration of drilling and well construction of the CrIN wells.

Drilling operations proceeded smoothly and as expected at all locations. Only two minor events occurred that hampered progress. Angled drilling started at the CrIN-4 location and proceeded normally until the Cerros del Rio basalt was encountered. At approximately 200 ft into the basalt, the underreaming hammer bit sheared off two of its three arms. The drilling tools were removed from the borehole and the broken bit parts were fished out. The drilling service provider elected to switch to a different type of underreaming hammer bit, and no further problems were encountered. Well construction was slowed at the vertical CrIN-1 location when the drive shoe on the 14-in. drill casing had not been successfully severed on the initial attempt, resulting in the removal of the stainless-steel well casing from the borehole. It was cut apart, sent off-site for rebevelling, and then reinstalled.

# 4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for the CrIN wells. No groundwater samples were collected during drilling. All sampling activities were conducted in accordance with applicable quality procedures.

## 4.1 Cuttings Sampling

Cuttings samples were collected from the CrIN well boreholes at 10.0-ft intervals from ground surface to the TD. 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 the cuttings before the cuttings were removed from the site. All screening measurements were within the range of background values. The cuttings samples were delivered to the Laboratory’s archiving facility at the conclusion of drilling activities.

Section 5.1 of this report summarizes the stratigraphy encountered at CrIN wells.

# 5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered 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

Rock units for the boreholes are presented below in order of youngest to oldest in stratigraphic occurrence. Lithologic descriptions are based on binocular microscope analysis of drill cuttings collected from the discharge hose. Lithologic descriptions for each geologic unit encountered at each borehole are in included in Appendix A. Figures 5.1-1 through 5.1-5 illustrate the stratigraphy at the CrIN boreholes.

### CrIN-1

The following were encountered during the drilling of CrIN-1: alluvium, Qal (0–100 ft below ground surface [bgs]); Otowi Member of the Bandelier Tuff, Qbo (100–240 ft bgs); Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (240–260 ft bgs); Cerros del Rio volcanics, Tb 4 (260–675 ft bgs); Puye Formation, Tpf (675–960 ft bgs); Miocene pumiceous sediments, Tjfp (960–1000 ft bgs); and Miocene Jemez alluvial sediments, Tcar (1000–1040 ft bgs).

**CrIN-2**

The following were encountered during the drilling of CrIN-2: alluvium, Qal (0–60 ft bgs); Cerro Toledo interval, Qct (60–110 ft bgs); Otowi Member of the Bandelier Tuff, Qbo (110–270 ft bgs); Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (270–300 ft bgs); Cerros del Rio volcanics, Tb 4 (300–740 ft bgs); Puye Formation, Tpf (740–990 ft bgs); and Miocene pumiceous sediments, Tjfp (990–1062 ft bgs).

**CrIN-3**

CrIN-3 is an angled borehole drilled 17 degrees from vertical. Stratigraphic contacts are listed in linear feet along borehole length. Figure 5.1-3 presents the stratigraphy vertically, and approximated vertical depth projections are provided in parentheses.

The following were encountered during the drilling of CrIN-3: alluvium, Qal (0–30 ft); Tshirege Member of the Bandelier Tuff Unit 1g, Qbt 1g (30–70 ft); Cerro Toledo interval, Qct (70–110 ft); Otowi Member of the Bandelier Tuff, Qbo (110–330 ft); Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (330–340 ft); Puye Formation, Tpf (340–350 ft); Cerros del Rio volcanics, Tb 4 (350–755 ft); and Puye Formation, Tpf (755–1021 ft).

**CrIN-4**

CrIN-4 is an angled borehole drilled 11 degrees from vertical. Stratigraphic contacts are listed in linear feet along borehole length. Figure 5.1-4 presents stratigraphy vertically and approximated vertical depth projections are provided in parentheses.

The following were encountered during the drilling of CrIN-4: Tshirege Member of the Bandelier Tuff Unit 2, Qbt 2 (0–30 ft); Tshirege Member of the Bandelier Tuff Unit 1v, Qbt 1v (30–150 ft); Tshirege Member of the Bandelier Tuff Unit 1g, Qbt 1g (150–230 ft); Cerro Toledo interval, Qct (230–250 ft); Otowi Member of the Bandelier Tuff, Qbo (250–500 ft); Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (500–540 ft); Puye Formation, Tpf (540–560 ft); Cerros del Rio volcanics, Tb 4 (560–900 ft); and Puye Formation, Tpf (900–1202 ft).

**CrIN-5**

CrIN-5 is an angled borehole drilled 25 degrees from vertical. Stratigraphic contacts are listed in linear feet along borehole length. Figure 5.1-5 presents stratigraphy vertically and approximated vertical depth projections parenthetically.

The following units were encountered during the drilling of CrIN-5: Tshirege Member of the Bandelier Tuff Unit 2, Qbt 2 (0–40 ft); Tshirege Member of the Bandelier Tuff Unit 1v, Qbt 1v (40–160 ft); Tshirege Member of the Bandelier Tuff Unit 1g, Qbt 1g (160–250 ft); Cerro Toledo interval, Qct (250–280 ft); Otowi Member of the Bandelier Tuff, Qbo (280–560 ft); Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (560–580 ft); Puye Formation, Tpf (580–610 ft); Cerros del Rio volcanics, Tb 4 (610–970 ft); Puye Formation, Tpf (970–1292 ft).

### 5.2 Groundwater

The CrIN-1 borehole was advanced to the TD of 1040 ft bgs. The water level was 879.0 ft bgs on June 21, 2016, before well installation. The depth to water (DTW) in the completed well was 871.4 ft bgs on July 17.

The CrIN-2 borehole was advanced to the TD of 1062 ft bgs. The water level was 899.0 ft bgs on May 10 before well installation. The DTW in the completed well was 899.1 ft bgs on May 27.

The CrIN-3 borehole was advanced to the TD of 1021.1 ft. The water level was 924.0 ft (linear) below the top of drill casing on August 17 before well installation. The DTW in the completed well was 928.8 ft (linear), or approximately 888.2 ft bgs (estimated) on September 7.

The CrIN-4 borehole was advanced to the TD of 1202.5 ft. The water level was 1078.1 ft (linear) below the top of drill casing on May 11 before well installation. The DTW in the completed well was 1078.9 ft (linear), or approximately 1059.1 ft bgs (estimated) on June 15.

The CrIN-5 borehole was advanced to the TD of 1292 ft. The water level was 1156.8 ft (linear) below the top of drill casing on July 1 before well installation. The DTW in the completed well was 1159.1 ft (linear), or approximately 1050.5 ft bgs (estimated) on July 30.

## 6.0 BOREHOLE LOGGING

All of the CrIN boreholes were logged by Jet West Geophysical Services, LLC (JWGS), upon reaching TD (Table 6.0-1). Logging consisted of cased-hole gamma ray and neutron density. The gamma and neutron logs are included in Appendix B (on CD included with this document).

Two video logs were run to assist in drilling and well construction activities. Video logging was conducted on April 23, 2016, at CrIN-4 to determine the orientation of the broken underreaming hammer arms and to help fish them out of the borehole. Video logging was conducted on June 27 at CrIN-1 to determine if the drive shoe was still attached to the 14-in. drill casing. Video logs were also run to document the condition of the completed wells. Video logging was conducted with Laboratory logging equipment and staff.

## 7.0 WELL INSTALLATION

The CrIN wells were installed following drilling completion, geophysical logging, water-level observation, and the cutting off of the drive shoe on the bottom of the drill casing at each location.

### 7.1 Well Design

The CrIN wells were designed in accordance with the objectives outlined in the approved "Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6" (LANL 2015, 601048; NMED 2016, 601158). The drill cuttings, driller's logs, results of the downhole geophysics, and DTW were reviewed. The primary objective in setting the screens was to achieve hydraulic control of off-site plume migration. A secondary objective was to keep the well screens entirely within the Puye Formation to achieve the greatest hydraulic effect for plume control in the interval(s) believed to contain the highest chromium concentrations.

The CrIN wells were designed with nominal 50-ft screened intervals to hydraulically manipulate chromium-contaminated groundwater near the top of the regional aquifer within the Puye Formation. CrIN-5 was designed with a 60-ft screen to yield an effective vertical submergence of 54 ft because of its 25-degree angle. The well designs were submitted to NMED and approved before starting construction

(LANL 2015, 601048; NMED 2016, 601158). The final CrIN well designs and NMED's approvals are included in Appendix C.

## 7.2 Well Construction

The CrIN wells were constructed of 8.0-in.-I.D./8.63-in.-O.D. Type A304 passivated stainless-steel, beveled and welded casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The screened sections utilize 10.0-ft and 20.0-ft lengths of 8.0-in.-I.D. 0.040-in. slot, rod-based, wire-wrapped screens to make up the screen intervals. Two sets of four stainless-steel centralizers were welded to the well casing approximately 5.0 ft above and below the screened interval at all of the wells. One set of four stainless-steel centralizers were welded to the well casing every 60 ft the entire length of the well at the angled wells. All individual casing and screen sections were welded together using compatible stainless-steel welding rods. Twenty-foot-long stainless-steel sumps were placed below the bottom of the well screens. Two-inch steel tremie pipes were used to deliver backfill and annular fill materials downhole during well construction. Stainless-steel well casing, screens, and tremie pipes were decontaminated before installation.

Figures 7.2-1 through 7.2-5 present as-built schematics showing construction details for the completed wells. Tables 7.2-1 through 7.2-5 present the annular fill materials used.

# 8.0 POST-INSTALLATION ACTIVITIES

Following well installation, the wells were developed and aquifer pumping tests were conducted. Dedicated injection/pumping systems have been installed. The wellhead surface completions have been installed as part of the treatment system piping and infrastructure project. A geodetic survey has been performed. Site-restoration activities will be completed following the final disposition of contained drill cuttings and groundwater. Drill cuttings will be managed in accordance with the NMED-approved Decision Tree for the Land Application of Drill Cuttings (April 2016). Drilling, purge, and development waters will be managed in accordance with the NMED-approved Decision Tree for Land Application of Groundwater (November 2016).

## 8.1 Well Development

The wells were developed following the completion of well construction. Initially, the screened intervals were swabbed and bailed to remove formation fines in the filter pack and well sump. Bailing continued until water clarity visibly improved. Following swabbing and bailing, final well development was then performed with a submersible pump.

The swabbing tools employed were 7.5-in.-O.D., 1-in.-thick nylon discs attached to a weighted steel rods. The wireline-conveyed tools were drawn repeatedly across the screened intervals, causing a surging action across the screens and filter packs. Various bailing tools were employed to remove sediment from the well sumps. The tools were repeatedly lowered by wireline, filled, withdrawn from the wells, and emptied into the cuttings pits.

After bailing, 30-horsepower (hp), 6-in. submersible pumps were installed in the wells for the final stage of well development. The screened intervals were pumped from top to bottom and from bottom to top in 2-ft increments.

As part of well development, the CrIN wells were disinfected with a chlorine treatment following aquifer testing and before the installation of a dedicated injection and pumping system to eliminate any biological fouling that could occur in the well screen and submerged filter pack intervals while the wells sat idle before being brought online. Sodium hypochlorite was mixed at the surface with potable water to a concentration of 100 ppm. The total volume of the solution was calculated and mixed to an equivalent of 4 casing volumes in the well(s). The solution was introduced to the screen interval via tremie pipe and either surged (vertical locations) or recirculated with a pump (angled locations) for 2 h and was allowed to remain in the well(s) for a period of approximately 12 h. Within 24 h of application, the well(s) were purged to remove at least 10 casing volumes of water.

#### 8.1.1 Well Development Field Parameters

The field parameters of turbidity, temperature, and pH were monitored with a multi-parameter instrument and a flow-through cell at the CrIN wells during well development. Field water-quality parameters for development and aquifer testing at each well are presented in Tables 8.1-1 through 8.1-5.

### 8.2 Aquifer Testing

Following development, the wells underwent aquifer testing consisting of step drawdown tests and 24-h constant rate tests. Constant rate pumping was followed by a 24-h recovery period. All the aquifer tests used 30-hp pumps. Turbidity, temperature, and pH were measured during the aquifer tests. Table 8.2-1 presents a summary of testing dates and pumping rates. Field water-quality parameters and aquifer testing volumes are presented in Tables 8.1-1 through 8.1-5. The CrIN wells' aquifer test results and analysis are presented in Appendix D.

### 8.3 Injection and Pumping System Installation

Dedicated injection and pumping systems have been installed in the CrIN wells. The systems have a 6-in. Grundfos submersible pump with a 30-hp Franklin Electric motor inside a stainless-steel pump shroud. A flow-control valve is positioned above the pump shroud and is separated from the pump by a check valve. The flow-control valves provide controlled, noncavitating head loss from the column pipe. An inflatable swellable element resides within the flow-control valves. The rate of water injection can be controlled by pneumatically manipulating the element. The element may be fully inflated to shut the flow-control valve and allow pumping from the wells with a single column pipe. The pump and flow-control valve assemblies are fully positioned in the well sumps to prevent the injected water from being delivered directly next to the screen intervals. The column pipe consists of 3.0-in. spline-lock, schedule 80, 304 stainless-steel. Two 1.0-in.-I.D. schedule 80 polyvinyl chloride (PVC) tubes are installed along with, and banded to, the pump column. A dedicated 100 psi In-Situ Level Troll 500 transducer is 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 short section of 0.010-in. slotted screen and a closed bottom.

Pumping system details for the CrIN wells are presented in Figures 8.3-1a through 8.3-5a. Figures 8.3-1b through 8.3-5b present technical notes for the wells and dedicated hardware.

### 8.4 Wellhead Completion

Reinforced concrete subsurface vaults have been installed at the CrIN wellheads. The vaults are slightly elevated aboveground surface and will provide long-term structural integrity for the well and piping infrastructure. Brass monument markers have been embedded in the northwest corner of the vaults. 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 8.4-1 shows details of the current injection well vault completions.

### 8.5 Geodetic Survey

A licensed professional land surveyor conducted a geodetic survey of all of the CrIN wells on January 26, 2017. The survey data conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates will be expressed relative to New Mexico State Plane Coordinate System Central Zone 83 (North American Datum [NAD] 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929.

Survey points include ground-surface elevation near the concrete vaults, the top of the brass monument marker in the top of the concrete vaults, and the top of the well casings. Survey data for the CrIN wells are presented in Table 8.5-1.

### 8.6 Waste Management and Site Restoration

Waste generated from the CrIN drilling project includes drilling fluids, drill cuttings, and contact waste. A summary of the waste characterization samples collected during drilling, construction, and development of the CrIN wells is presented in Tables 8.6-1 through 8.6-5. All waste streams produced during drilling and development activities were sampled in accordance with the “Waste Characterization Strategy Form for Chromium Well CrEX-1 [with complete Attachment 4]” (LANL 2014, 600344). Development water was land-applied under a temporary permission to discharge (NMED 2014, 600128).

Fluids produced during drilling and containerized in the pits will be evaporated on-site. Evaporation activities began in June 2016.

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 determination program per the waste characterization strategy form (LANL 2014, 600344) and ENV-RCRA-QP-010, “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 shipped to an off-site treatment, storage, and disposal facility.

Cuttings produced during drilling were sampled, and analytical results will be reviewed with the goal of land application. Once the fluids are evaporated or removed from the pit, a composite volatile organic analyte sample of the cuttings will be collected and evaluated against land-application criteria (ENV-RCRA-QP-011, “Land Application of Drill Cuttings”). If cuttings meet land-application criteria, materials will be spread across the pad area, and the site will be reseeded as required for site reclamation. Water generated from development and aquifer testing activities was treated and land applied under DP-1793 Work Plan 3.

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 Logistics Heavy Equipment/ Roads and Grounds 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 and well construction at the CrIN wells were performed as specified in approved "Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6" (LANL 2015, 601048; NMED 2016, 601158). No deviations from the plan occurred.

## 10.0 ACKNOWLEDGMENTS

Yellow Jacket Drilling drilled and installed injection wells CrIN-1 and CrIN-2.

Holt Services, Inc., drilled and installed injection wells CrIN-3, CrIN-4, and CrIN-5.

## 11.0 REFERENCES AND MAP DATA SOURCES

### 11.1 References

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

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

Holt Services Inc., March 13, 2016. "IWD [Integrated Work Document] for 2016 Drilling and Installation of LANL Wells CrIN-4, CrIN-5, and CrIN-3," Los Alamos, New Mexico. (Holt Services Inc., 2016, 602106)

LANL (Los Alamos National Laboratory), February 28, 2014. "Waste Characterization Strategy Form for Chromium Well CrEx-1 [with complete Attachment 4]," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2014, 600344)

LANL (Los Alamos National Laboratory), December 2015. "Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6," Los Alamos National Laboratory document LA-UR-15-29392, Los Alamos, New Mexico. (LANL 2015, 601048)

LANL (Los Alamos National Laboratory), February 4, 2016. "Storm Water Pollution Prevention Plan, CrIN Well Pads and Construction Support Activities, Los Alamos National Laboratory," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2016, 602108)

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)

NMED (New Mexico Environment Department), January 22, 2016. "Approval with Modifications, Drilling Work Plan for Chromium Plume Control Interim Measure and Plume-Center Characterization Injection Wells CrIN-1 through CrIN-6," New Mexico Environment Department letter to D. Hintze (DOE-EM-LA) and M. Brandt (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2016, 601158)

NMED (New Mexico Environment Department), January 4, 2017. "Approval [for the] Drilling Work Plan for Groundwater Injection Wells CrIN-6," New Mexico Environment Department letter to D. Hintze (DOE-EM-LA) and M. Brandt (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2017, 602097)

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)

Yellow Jacket Drilling, March 2, 2016. "IWD [Integrated Work Document] for Drilling and Installation of LANL Vertical Chromium Injection Wells," Los Alamos, New Mexico. (Yellow Jacket Drilling 2016, 602107)

### 11.2 Map Data Sources

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

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

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

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

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

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

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

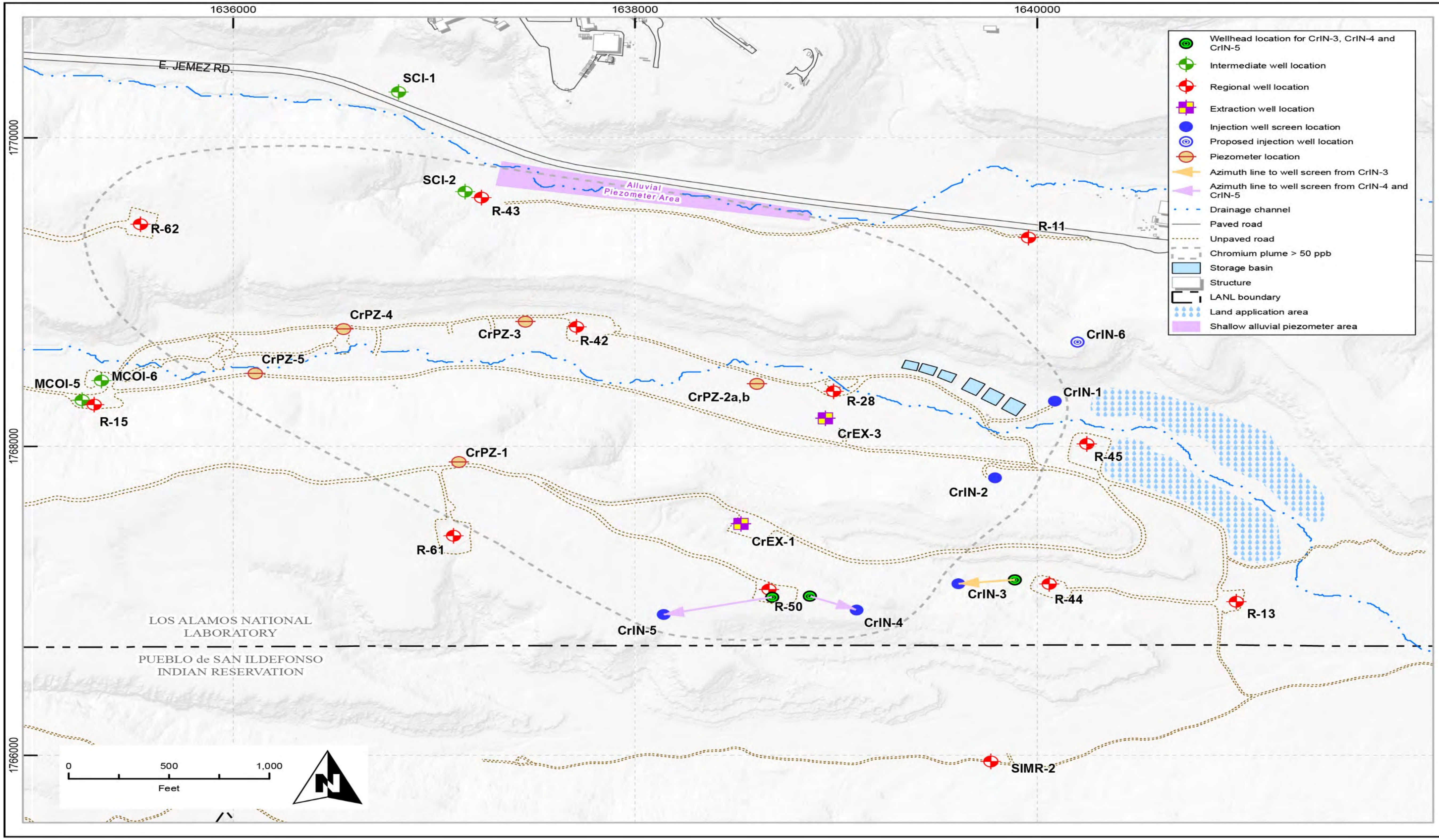



**Figure 1.0-1** Location of injection wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5

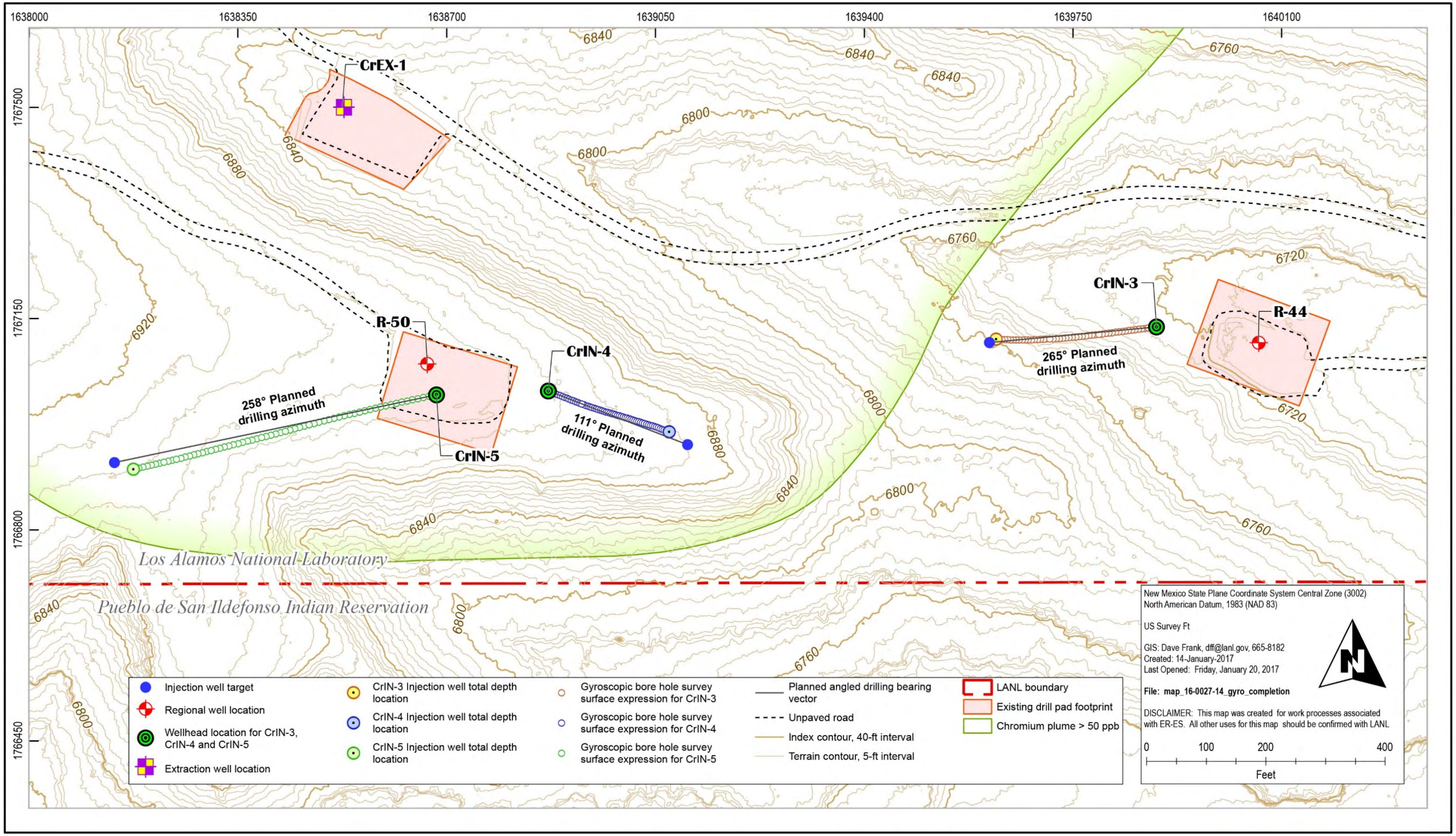



**Figure 3.1-1 TD surveys and original drilling targets for CrIN-3, CrIN-4, and CrIN-5**

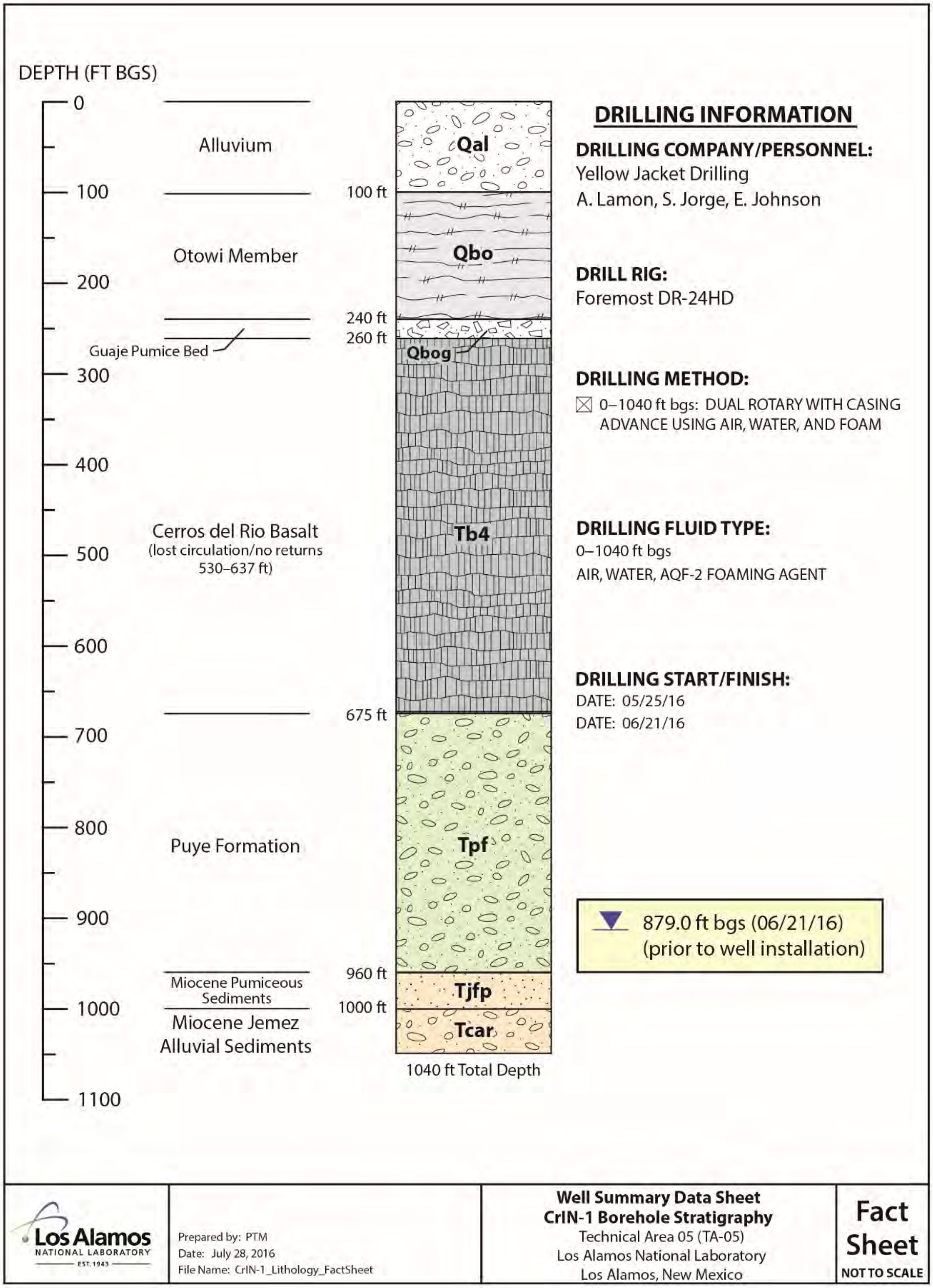



**Figure 5.1-1 Injection well CrIN-1 borehole stratigraphy**

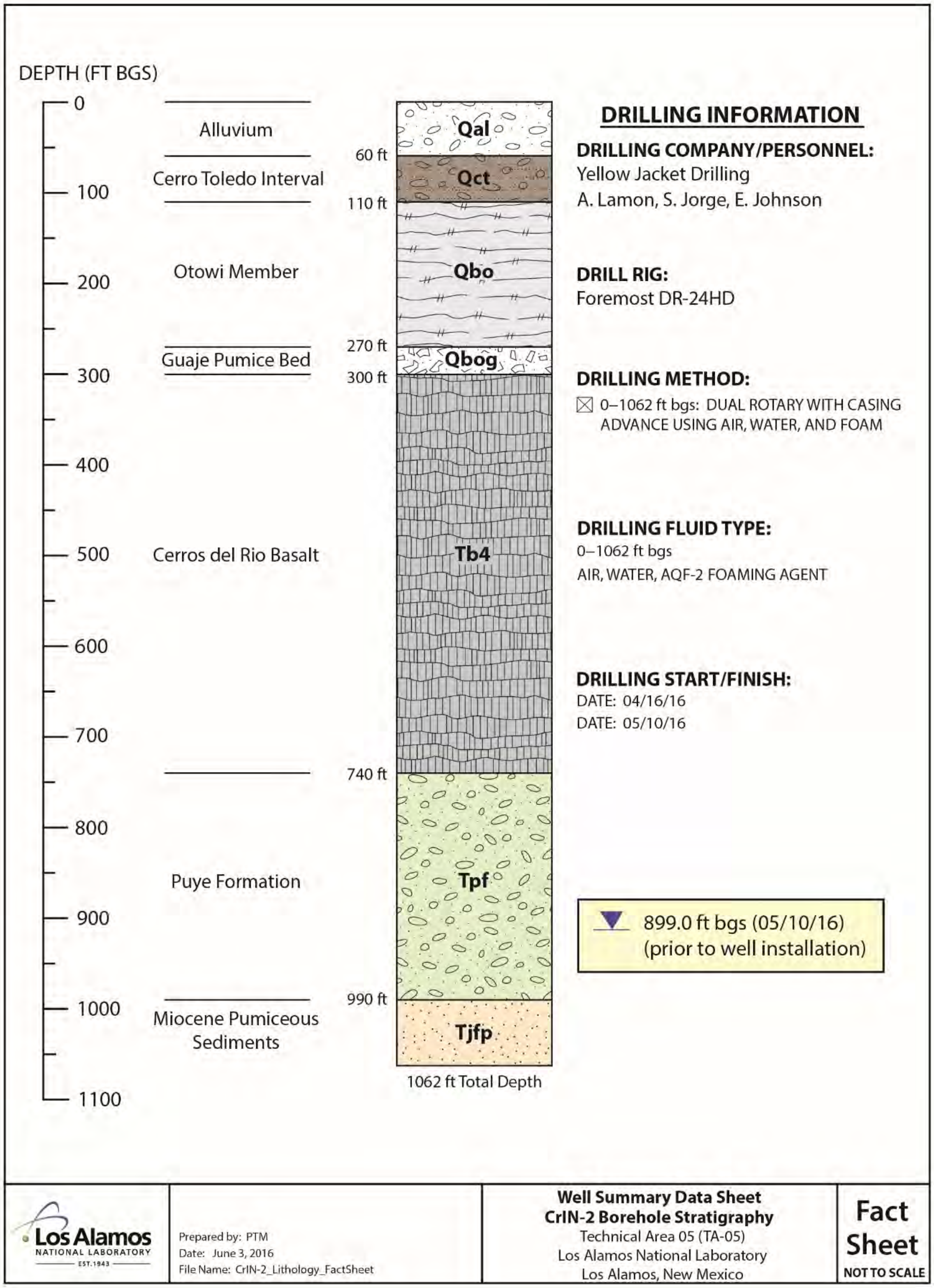



**Figure 5.1-2 Injection well CrIN-2 borehole stratigraphy**

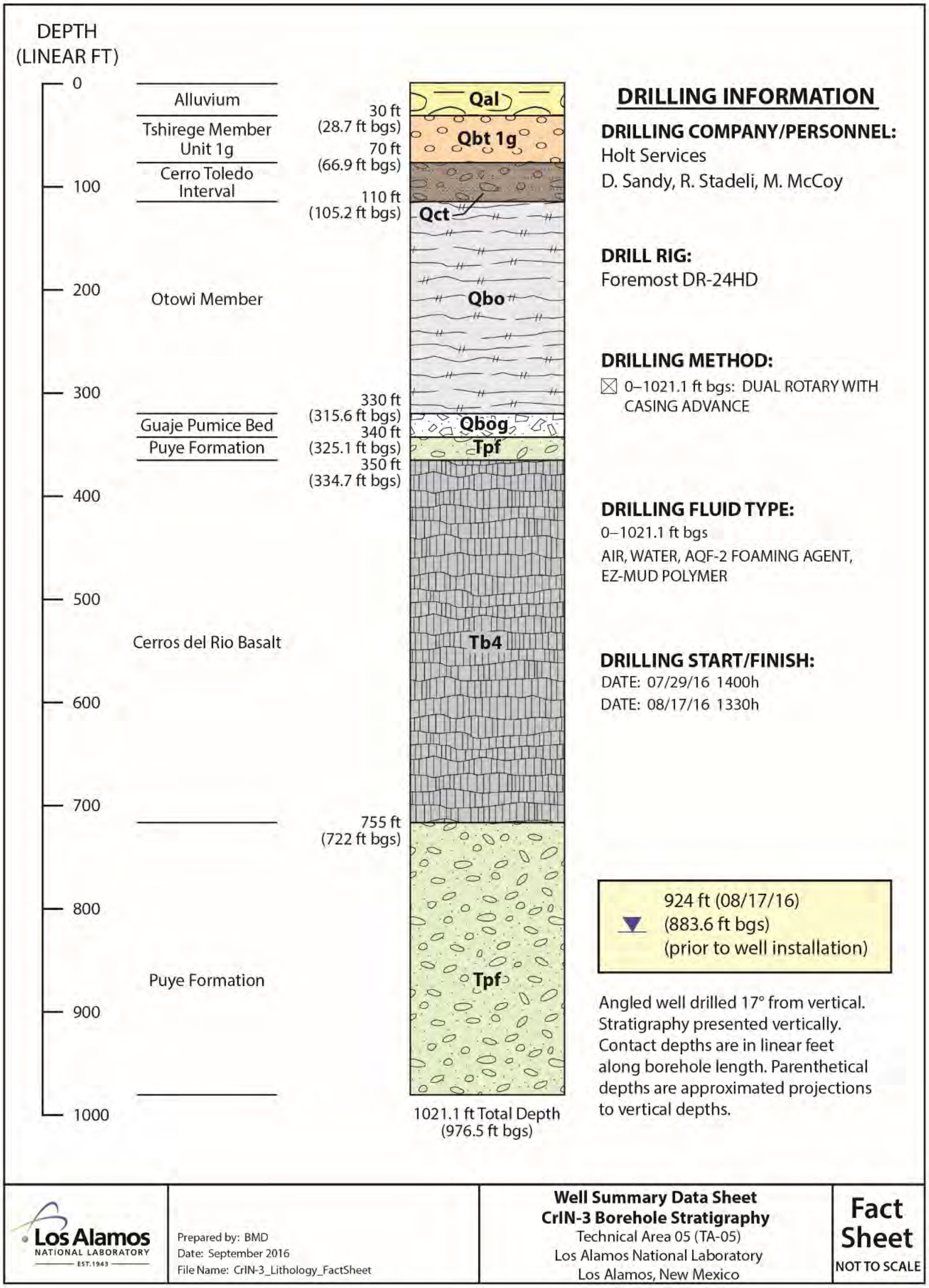



**Figure 5.1-3 Injection well CrIN-3 borehole stratigraphy**

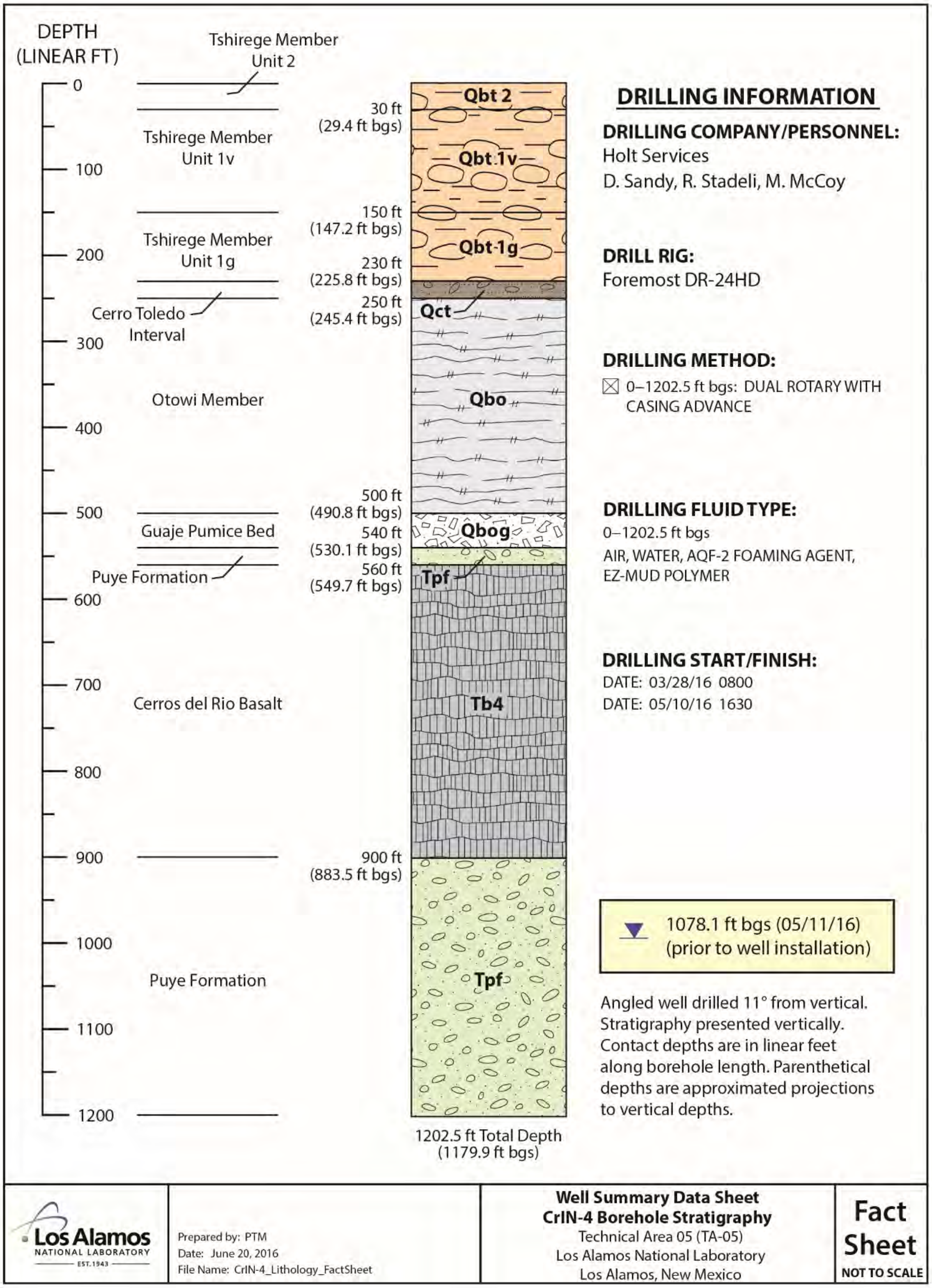



**Figure 5.1-4 Injection well CrIN-4 borehole stratigraphy**

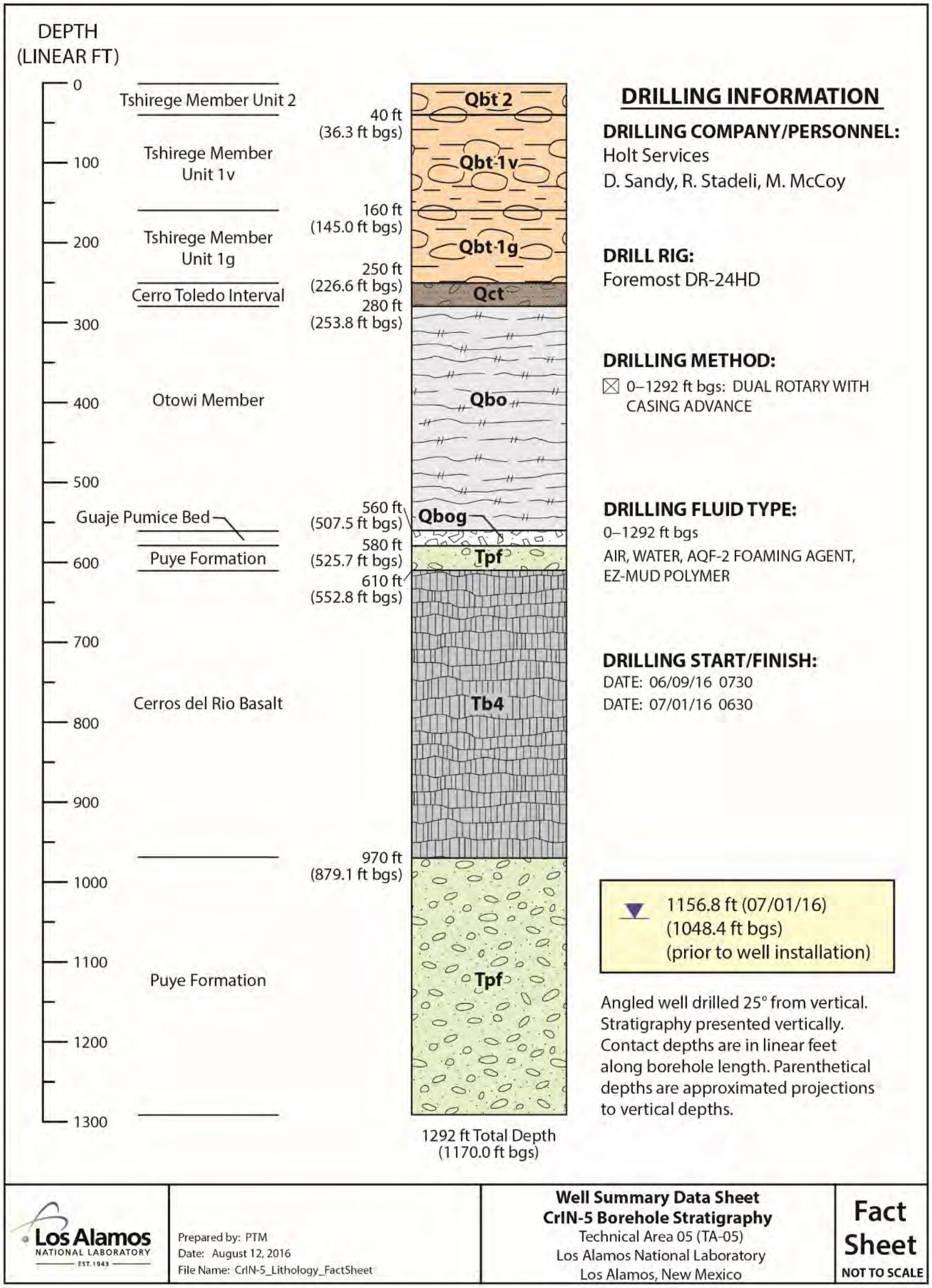



**Figure 5.1-5 Injection well CrIN-5 borehole stratigraphy**

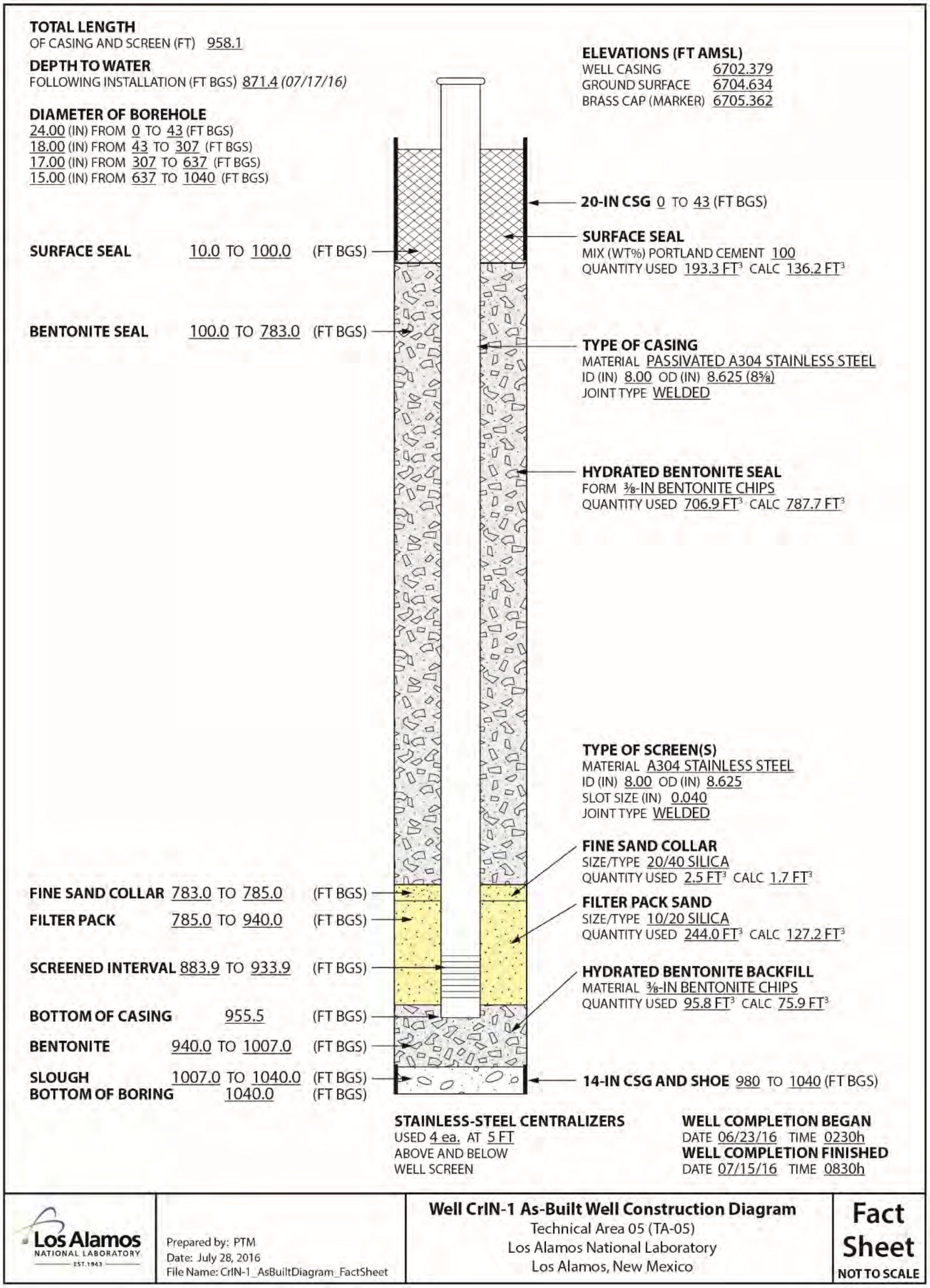



**Figure 7.2-1 Injection well CrIN-1 as-built well construction diagram**

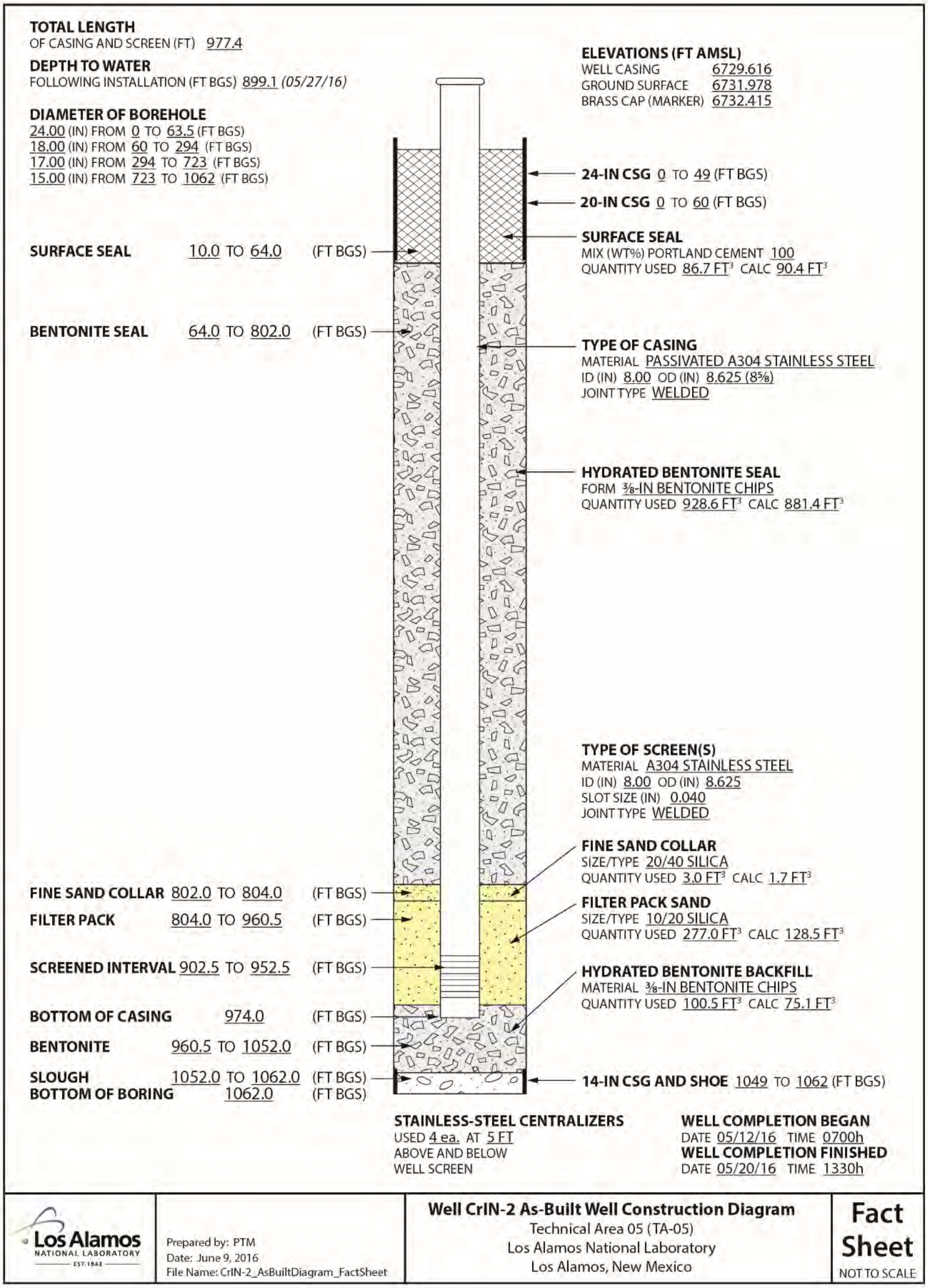



**Figure 7.2-2 Injection well CrIN-2 as-built well construction diagram**

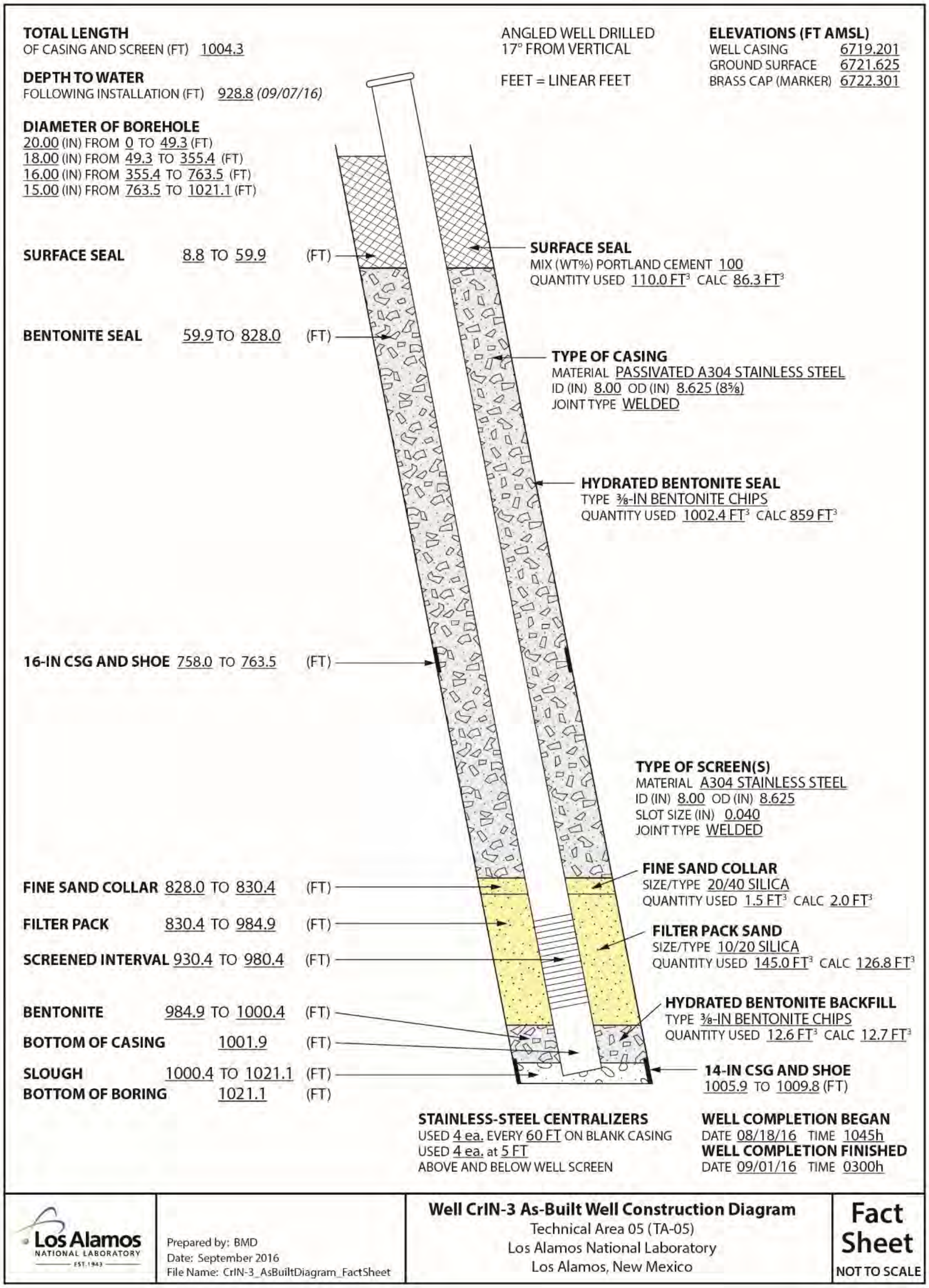



**Figure 7.2-3 Injection well CrIN-3 as-built well construction diagram**

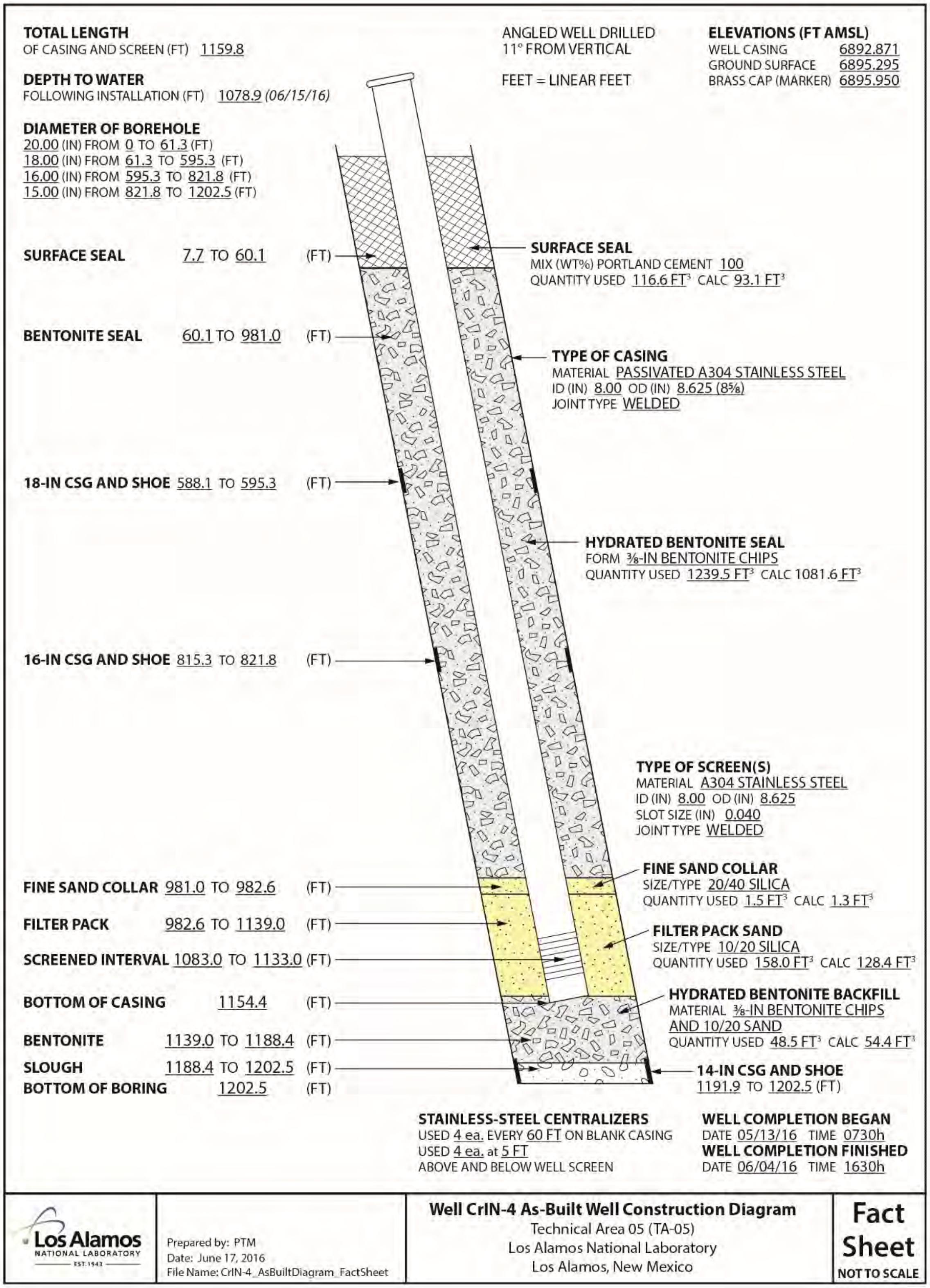



**Figure 7.2-4 Injection well CrIN-4 as-built well construction diagram**

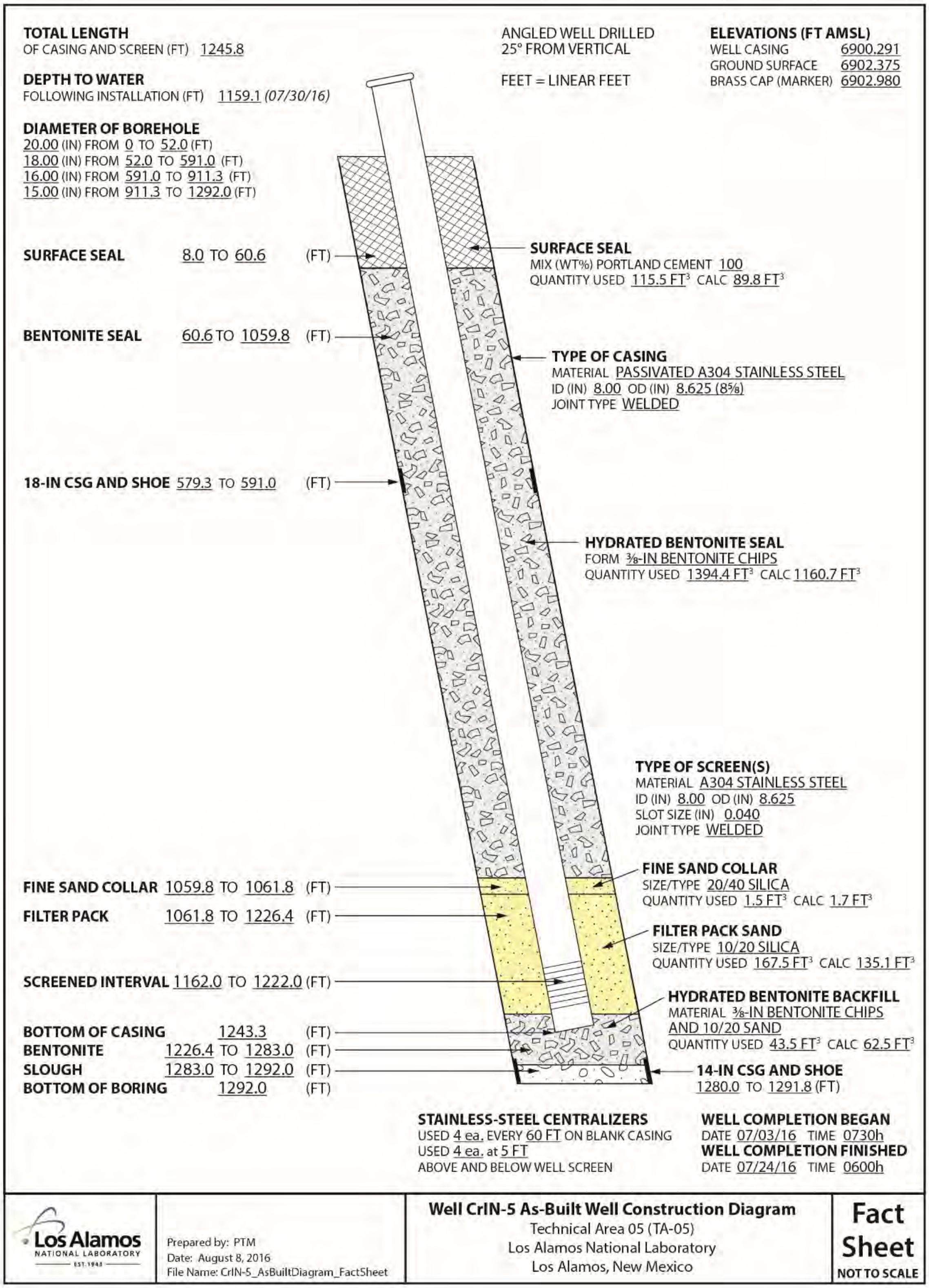



**Figure 7.2-5 Injection well CrIN-5 as-built well construction diagram**

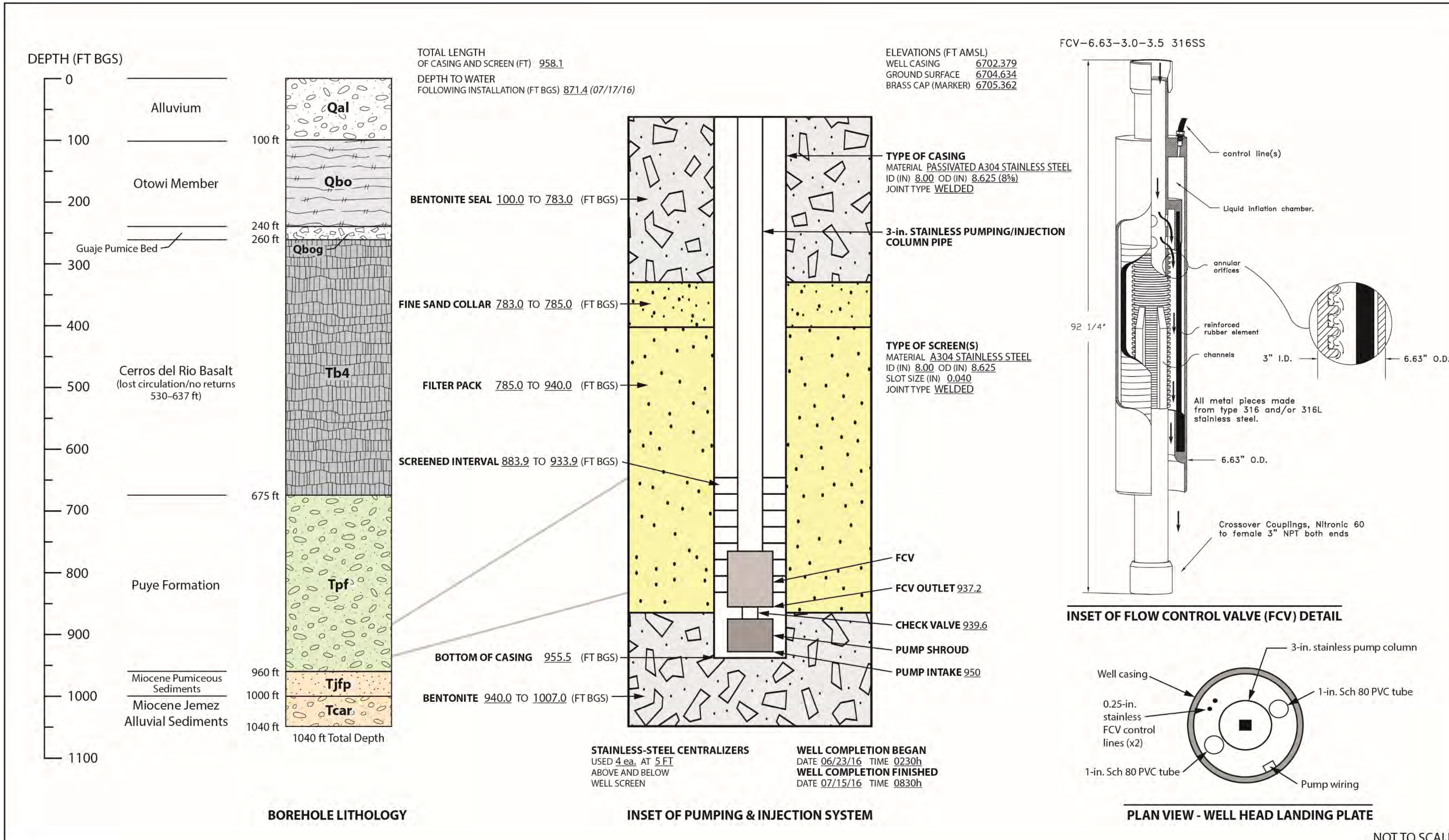



**Figure 8.3-1a Injection well CrIN-1 as-built diagram with borehole lithology and technical well completion details**

## CrIN-1 TECHNICAL NOTES:

### SURVEY INFORMATION *

Brass Marker

| | |
|---|---|
| Northing: | 1768296.963 |
| Easting: | 1640089.494 |
| Elevation: | 6705.362 |

Well Casing (top of well seal)

| | |
|---|---|
| Northing: | 1768293.719 |
| Easting: | 1640089.572 |
| Elevation: | 6702.379 |

Well Seal Thickness
0.09 ft.

### BOREHOLE GEOPHYSICAL LOGS

Logger: Jet West Geophysical Services
Logs: Natural Gamma Ray, Neutron Density
Date: 06/20/2016

### DRILLING INFORMATION

Drilling Company
Yellow Jacket Drilling, Inc.

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual rotary fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF foam

### MILESTONE DATES

Drilling

| | |
|---|---|
| Start: | 05/25/2016 |
| Finished: | 06/21/2016 |

Well Completion

| | |
|---|---|
| Start: | 06/23/2016 |
| Finished: | 07/13/2016 |

Well Development

| | |
|---|---|
| Start: | 07/14/2016 |
| Finished: | 07/18/2016 |

### WELL DEVELOPMENT

Development Methods
Swabbing, bailing, and pumping

Parameter Measurements (Final)

| | |
|---|---|
| pH: | 7.74 |
| Temperature: | 19.61°C |
| Turbidity: | 0.9 NTU |

### AQUIFER TESTING

Step Tests

| | |
|---|---|
| Pumping Rates: | 30, 50, 70 gpm |
| Performed on: | 07/18/2016 |

24-h Constant-Rate Pumping Test

| | |
|---|---|
| Water Produced: | 106,440 gal. |
| Pumping Rate: | 70 gpm |
| Performed on: | 07/19/2016–07/20/2016 |

### DEDICATED HARDWARE

Pump
Make: Grundfos
Type: 85S300-26

Motor
Make: Franklin Electric
Model: 2366168120

Flow Control Valve
Make: Baski, 6-5/8-in.
S/N: 28732

Pump Column
3-inch, sch. 80, 304 stainless steel, spline lock couplings

Gauge Tubes
2 X 1.0-in. flush threaded sch. 80 PVC

Transducer
Make: In-Situ Level TROLL
Model: LT 500
Range: 100 psig/231 ft
S/N: TBD

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 As-built technical notes for injection well CrIN-1**

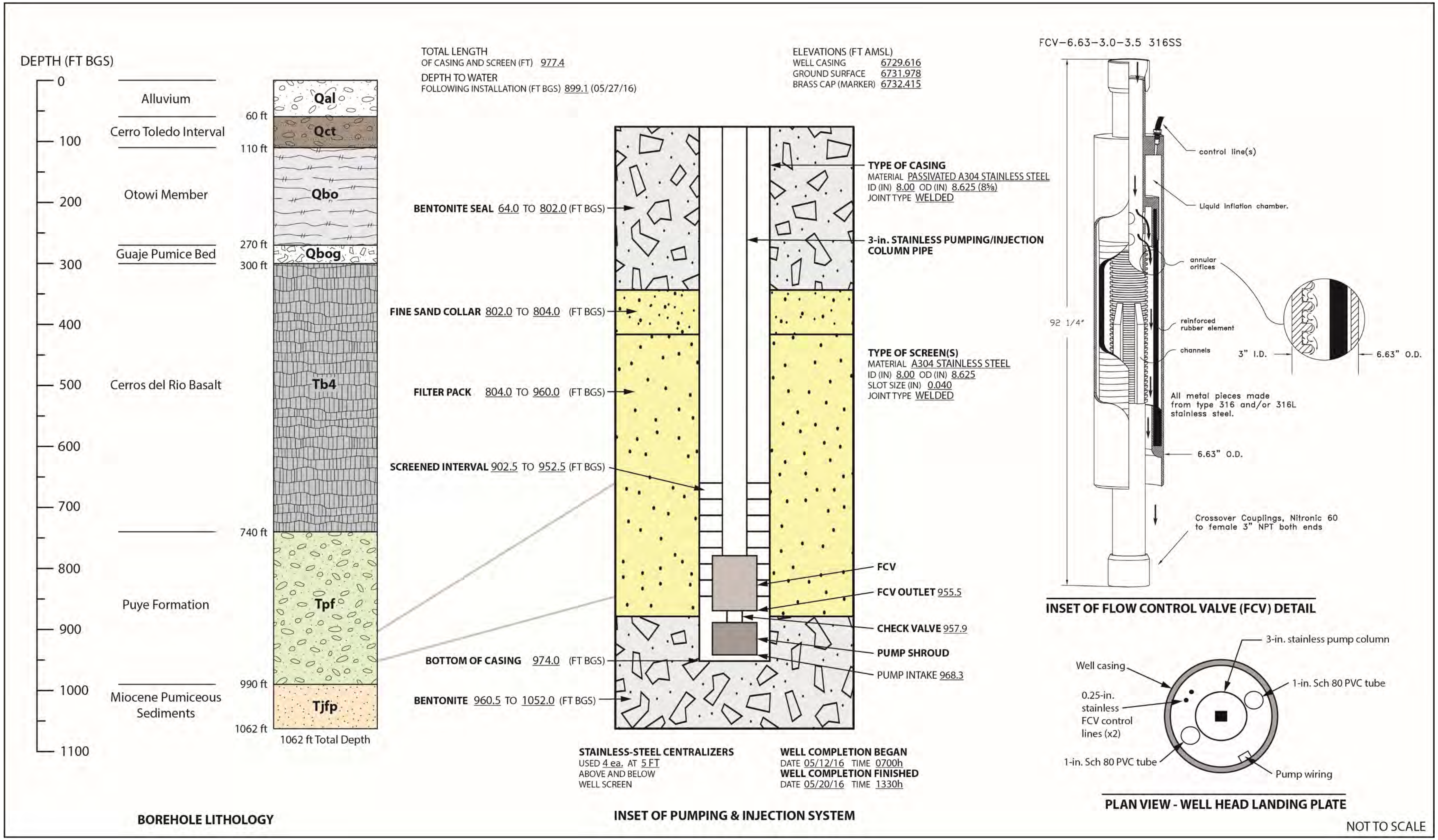



**Figure 8.3-2a Injection well CrIN-2 as-built diagram with borehole lithology and technical well completion details**

## CrIN-2 TECHNICAL NOTES:

### SURVEY INFORMATION *
Brass Marker
Northing: 1767800.805
Easting: 1639791.482
Elevation: 6732.415

Well Casing (top of well seal)
Northing: 1767797.468
Easting: 1639791.835
Elevation: 6729.616

Well Seal Thickness
0.09 ft.

### BOREHOLE GEOPHYSICAL LOGS
Logger: Jet West Geophysical Services
Logs: Natural Gamma Ray, Neutron Density
Date: 05/09/2016

### DRILLING INFORMATION
Drilling Company
Yellow Jacket Drilling, Inc.

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual rotary fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF foam

### MILESTONE DATES
Drilling
Start: 04/16/2016
Finished: 05/10/2016

Well Completion
Start: 05/12/2016
Finished: 05/20/2016

Well Development
Start: 05/25/2016
Finished: 05/30/2016

### WELL DEVELOPMENT
Development Methods
Swabbing, bailing, and pumping

Parameter Measurements (Final)
pH: 7.75
Temperature: 20.52°C
Turbidity: 0.8 NTU

### AQUIFER TESTING
Step Tests
Pumping Rates: 30, 50, 70 gpm
Performed on: 05/31/2016
24-h Constant-Rate Pumping Test
Water Produced: 83,080 gal.
Pumping Rate: 58 gpm
Performed on: 06/01/2016–06/02/2016

### DEDICATED HARDWARE
Pump
Make: Grundfos
Type: 85S300-26

Motor
Make: Franklin Electric
Model: 2366168120

Flow Control Valve
Make: Baski, 6-5/8-in.
S/N: 28733

Pump Column
3-inch, sch. 80, 304 stainless steel, spline lock couplings

Gauge Tubes
2 X 1.0-in. flush threaded sch. 80 PVC

Transducer
Make: In-Situ Level TROLL
Model: LT 500
Range: 100 psig/231 ft
S/N: TBD

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 8.3-2b As-built technical notes for injection well CrIN-2**

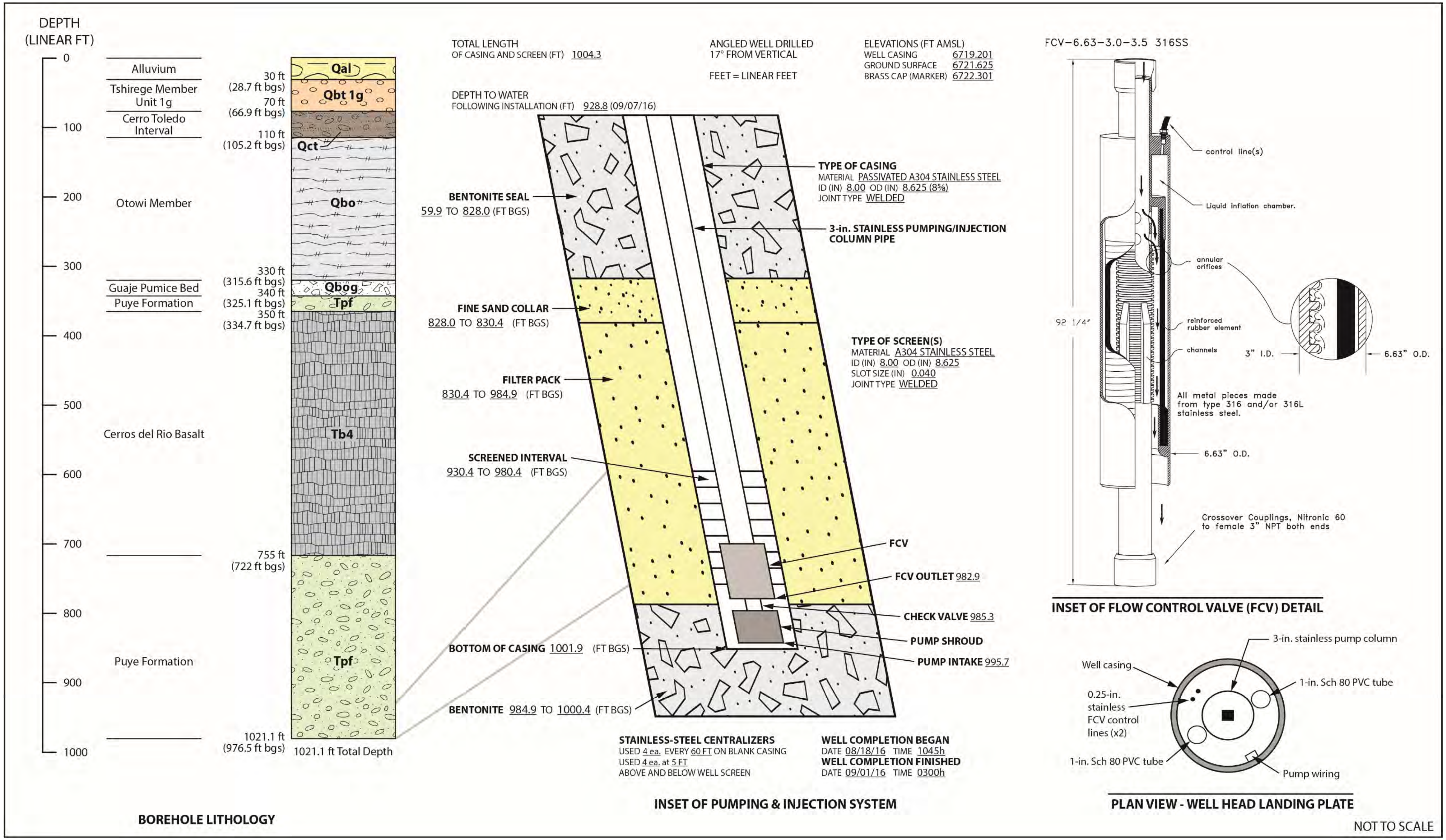



**Figure 8.3-3a Injection well CrIN-3 as-built diagram with borehole lithology and technical well completion details**

## CrIN-3 TECHNICAL NOTES:

### SURVEY INFORMATION *

Brass Marker
Northing: 1767139.006
Easting: 1639887.412
Elevation: 6722.301

Well Casing (top of well seal)
Northing: 1767135.850
Easting: 1639888.440
Elevation: 6719.201

Well Seal Thickness
0.08 ft.

### BOREHOLE GEOPHYSICAL LOGS

Logger: Jet West Geophysical Services
Logs: Natural Gamma Ray, Neutron Density
Date: 08/15/2016

### DRILLING INFORMATION

Drilling Company
Holt Services, Inc.

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual rotary fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF foam, EZ Mud

### MILESTONE DATES

Drilling
Start: 07/29/2016
Finished: 08/17/2016

Well Completion
Start: 08/18/2016
Finished: 09/01/2016

Well Development
Start: 09/03/2016
Finished: 09/07/2016

### WELL DEVELOPMENT

Development Methods
Swabbing, bailing, and pumping

Parameter Measurements (Final)
pH: 7.73
Temperature: 19.97°C
Turbidity: 1.3 NTU

### AQUIFER TESTING

Step Tests
Pumping Rates: 50, 60, 80 gpm
Performed on: 09/08/2016
24-h Constant-Rate Pumping Test
Water Produced: 117,579 gal.
Pumping Rate: 81 gpm
Performed on: 09/08/2016–09/09/2016

### DEDICATED HARDWARE

Pump
Make: Grundfos
Type: 85S300-26

Motor
Make: Franklin Electric
Model: 2366168120

Flow Control Valve
Make: Baski, 6-5/8-in.
S/N: 28865

Pump Column
3-inch, sch. 80, 304 stainless steel, spline lock couplings

Gauge Tubes
2 X 1.0-in. flush threaded sch. 80 PVC

Transducer
Make: In-Situ Level TROLL
Model: LT 500
Range: 100 psig/231 ft
S/N: TBD

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 8.3-3b As-built technical notes for injection well CrIN-3**

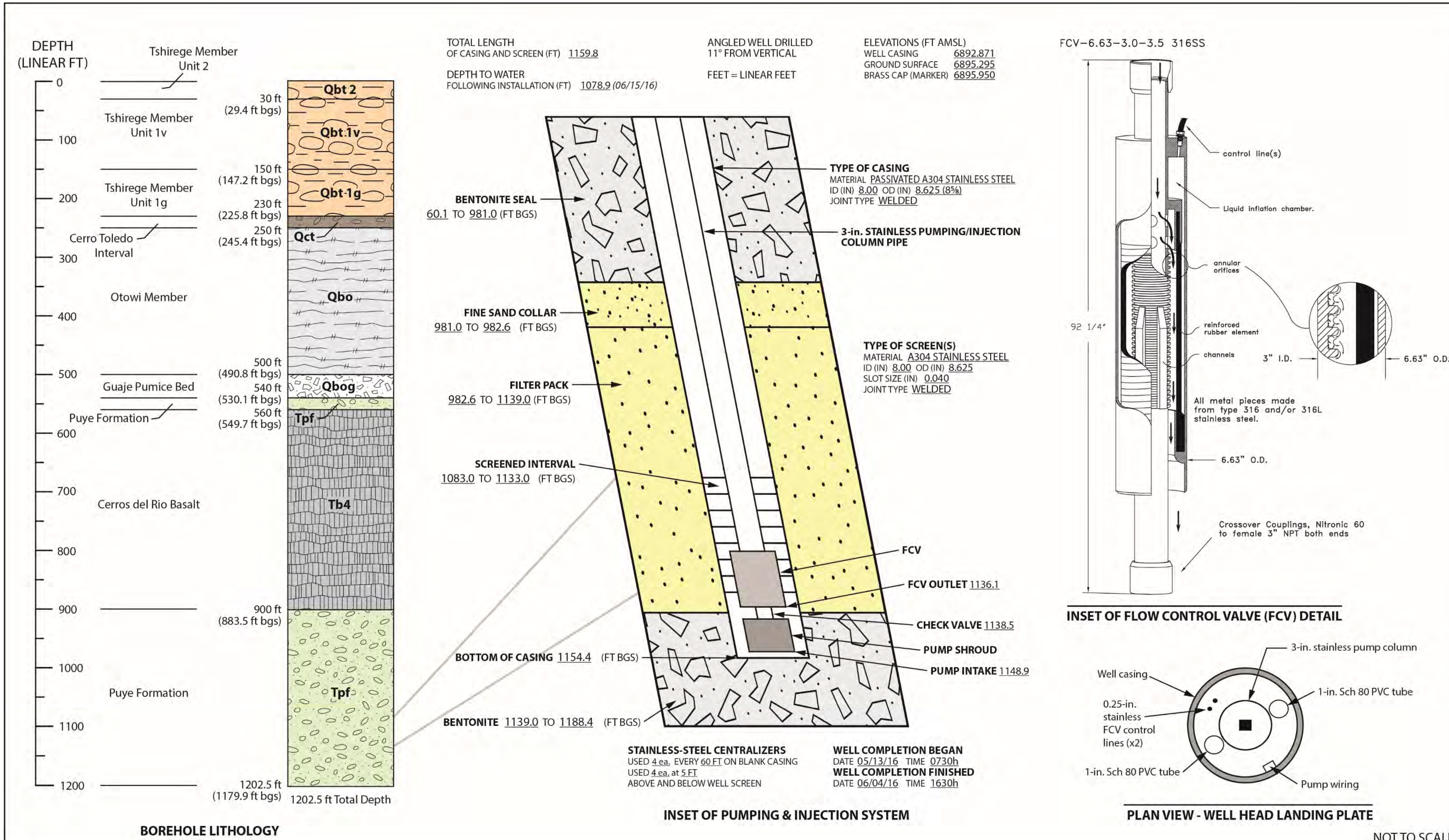



**Figure 8.3-4a Injection well CrIN-4 as-built diagram with borehole lithology and technical well completion details**

## CrIN-4 TECHNICAL NOTES:

### SURVEY INFORMATION *

Brass Marker
Northing: 1767032.919
Easting: 1638863.128
Elevation: 6895.950

Well Casing (top of well seal)
Northing: 1767029.532
Easting: 1638871.688
Elevation: 6892.871

Well Seal Thickness
0.08 ft.

### BOREHOLE GEOPHYSICAL LOGS

Logger: Jet West Geophysical Services
Logs: Natural Gamma Ray, Neutron Density
Date: 05/11/2016

### DRILLING INFORMATION

Drilling Company
Holt Services, Inc.

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual rotary fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF foam, EZ Mud

### MILESTONE DATES

Drilling
Start: 03/28/2016
Finished: 05/10/2016

Well Completion
Start: 05/13/2016
Finished: 06/04/2016

Well Development
Start: 06/13/2016
Finished: 06/20/2016

### WELL DEVELOPMENT

Development Methods
Swabbing, bailing, and pumping

Parameter Measurements (Final)
pH: 7.69
Temperature: 20.70°C
Turbidity: 2.5 NTU

### AQUIFER TESTING

Step Tests
Pumping Rates: 38, 60, 75 gpm
Performed on: 06/21/2016
24-h Constant-Rate Pumping Test
Water Produced: 88,847 gal.
Pumping Rate: 62 gpm
Performed on: 06/21/2016–06/22/2016

### DEDICATED HARDWARE

Pump
Make: Grundfos
Type: 85S300-26

Motor
Make: Franklin Electric
Model: 2366168120

Flow Control Valve
Make: Baski, 6-5/8-in.
S/N: 28808

Pump Column
3-inch, sch. 80, 304 stainless steel, spline lock couplings

Gauge Tubes
2 X 1.0-in. flush threaded sch. 80 PVC

Transducer
Make: In-Situ Level TROLL
Model: LT 500
Range: 100 psig/231 ft
S/N: 464659

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 8.3-4b As-built technical notes for injection well CrIN-4**

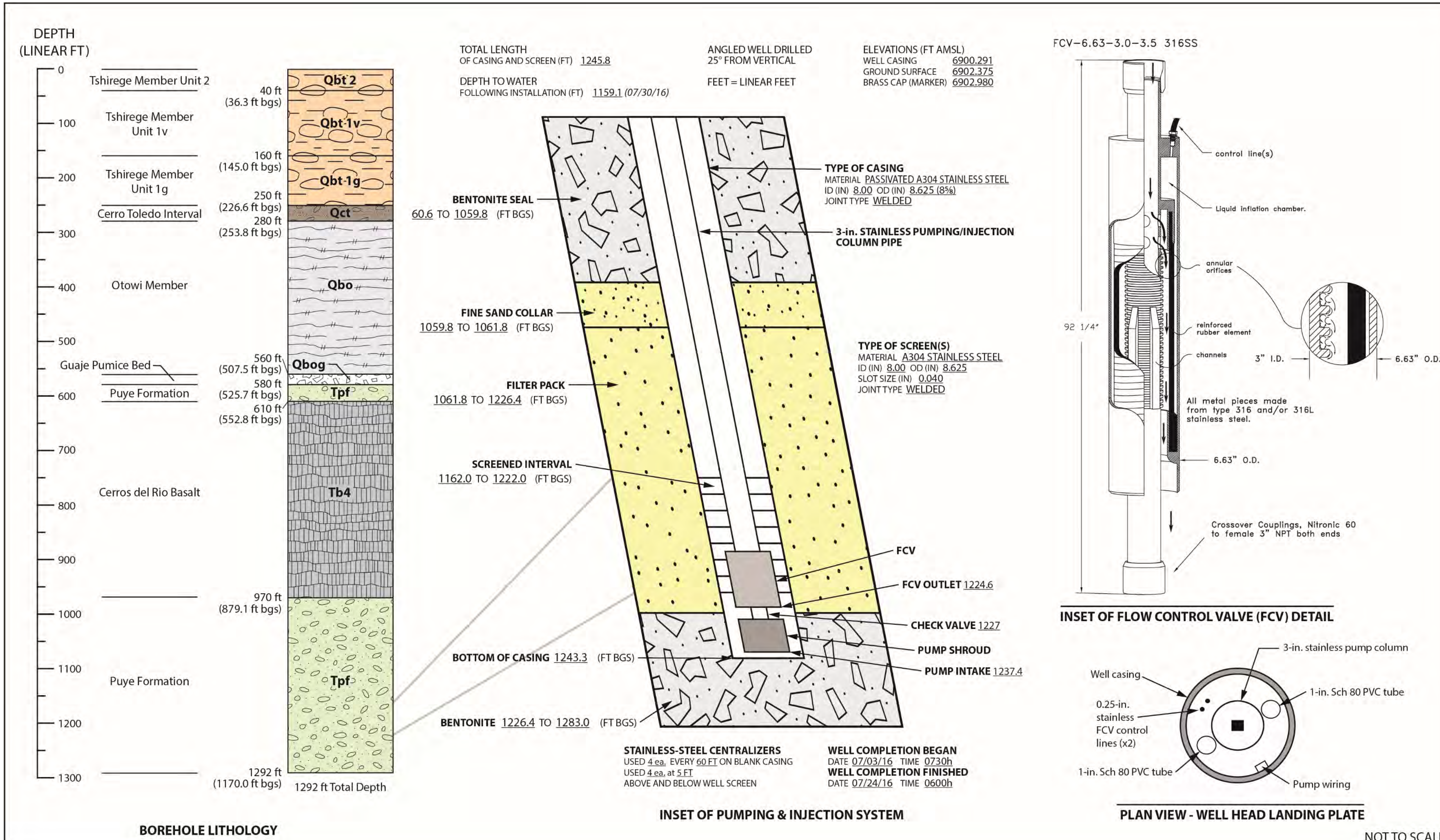



**Figure 8.3-5a Injection well CrIN-5 as-built diagram with borehole lithology and technical well completion details**

## CrIN-5 TECHNICAL NOTES:

### SURVEY INFORMATION *

Brass Marker
Northing: 1767025.241
Easting: 1638678.338
Elevation: 6902.980

Well Casing (top of well seal)
Northing: 1767023.434
Easting: 1638680.808
Elevation: 6900.291

Well Seal Thickness
0.08 ft.

### BOREHOLE GEOPHYSICAL LOGS

Logger: Jet West Geophysical Services
Logs: Natural Gamma Ray, Neutron Density
Date: 07/01/2016

### DRILLING INFORMATION

Drilling Company
Holt Services, Inc.

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual rotary fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF foam, EZ Mud

### MILESTONE DATES

Drilling
Start: 06/09/2016
Finished: 07/01/2016

Well Completion
Start: 07/03/2016
Finished: 07/24/2016

Well Development
Start: 07/26/2016
Finished: 08/02/2016

### WELL DEVELOPMENT

Development Methods
Swabbing, bailing, and pumping

Parameter Measurements (Final)
pH: 6.87
Temperature: 21.33°C
Turbidity: 0.0 NTU

### AQUIFER TESTING

Step Tests
Pumping Rates: 32, 50, 68 gpm
Performed on: 08/03/2016
24-h Constant-Rate Pumping Test
Water Produced: 88,435 gal.
Pumping Rate: 61 gpm
Performed on: 08/03/2016–08/04/2016

### DEDICATED HARDWARE

Pump
Make: Grundfos
Type: 85S300-26

Motor
Make: Franklin Electric
Model: 2366168120

Flow Control Valve
Make: Baski, 6-5/8-in.
S/N: 28807

Pump Column
3-inch, sch. 80, 304 stainless steel, spline lock couplings

Gauge Tubes
2 X 1.0-in. flush threaded sch. 80 PVC

Transducer
Make: In-Situ Level TROLL
Model: LT 500
Range: 100 psig/231 ft
S/N: 464415

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 8.3-5b As-built technical notes for injection well CrIN-5**

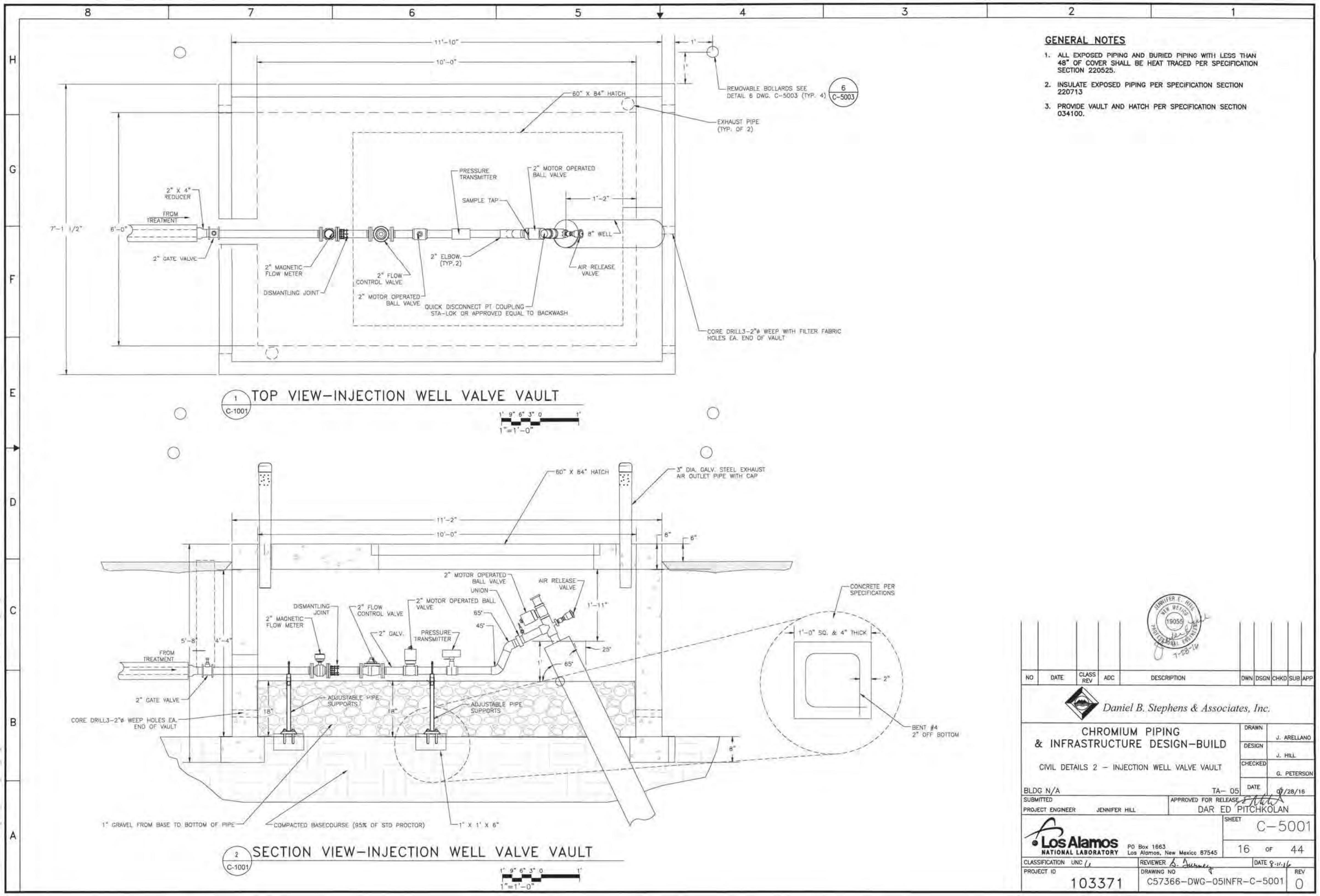



Figure 8.4-1 Surface completion of injection well vaults

**Table 3.2-1**
**Chronological Drilling Milestone Dates**

| Well | Drilling Start | Drilling Finish | Well Construction Start | Well Construction Finish |
|---|---|---|---|---|
| CrIN-4 | 3/28/2016 | 5/10/2016 | 5/13/2016 | 6/04/2016 |
| CrIN-2 | 4/16/2016 | 5/10/2016 | 5/12/2016 | 5/20/2016 |
| CrIN-1 | 5/25/2016 | 6/21/2016 | 6/23/2016 | 7/15/2016 |
| CrIN-5 | 6/09/2016 | 7/01/2016 | 7/03/2016 | 7/24/2016 |
| CrIN-3 | 7/29/2016 | 8/17/2016 | 8/18/2016 | 9/01/2016 |

**Table 6.0-1**
**Logging Runs**

| Date(s) | Location | Type of Log | Depth (ft bgs) | Description |
|---|---|---|---|---|
| 4/23/2016 | CrIN-4 | Video | 0–729 | View broken underreamer. |
| 5/09/2016 | CrIN-2 | Gamma ray and neutron | 0–1051 | JWGS cased hole stacked gamma ray and neutron density to TD. |
| 5/11/2016 | CrIN-4 | Gamma ray and neutron | 0-1193 | JWGS cased hole stacked gamma ray and neutron density to TD. |
| 6/20/2016 | CrIN-1 | Gamma ray and neutron | 0–1011 | JWGS cased hole stacked gamma ray and neutron density to TD. |
| 6/27/2016 | CrIN-1 | Video | 0–985 | View condition of casing cut. |
| 7/01/2016 | CrIN-5 | Gamma ray and neutron | 0–1281 | JWGS cased hole stacked gamma ray and neutron density to TD. |
| 8/09/2016 | CrIN-4 | Video | 0–1154 | As-built video to document completion condition. |
| 8/09/2016 | CrIN-2 | Video | 0–974 | As-built video to document completion condition. |
| 8/10/2016 | CrIN-1 | Video | 0–955 | As-built video to document completion condition. |
| 8/15/2016 | CrIN-3 | Gamma ray and neutron | 0–1003 | JWGS cased hole stacked gamma ray and neutron density to TD. |
| 9/23/2016 | CrIN-5 | Video | 0–1243 | As-built video to document completion condition. |
| 10/13/2016 | CrIN-3 | Video | 0–1001 | As-built video to document completion condition. |

**Table 7.2-1**
**CrIN-1 Injection Well Annular Fill Materials**

| Material | Volume |
|---|---|
| Upper surface seal: cement slurry | 193.3 $ft^3$ |
| Upper bentonite seal: bentonite chips | 706.9 $ft^3$ |
| Fine sand collar: 20/40 silica sand | 2.5 $ft^3$ |
| Filter pack: 10/20 silica sand | 244.0 $ft^3$ |
| Backfill: bentonite chips | 95.8 $ft^3$ |

**Table 7.2-2**
**CrIN-2 Injection Well Annular Fill Materials**

| Material | Volume |
|---|---|
| Upper surface seal: cement slurry | 86.7 $ft^3$ |
| Upper bentonite seal: bentonite chips | 928.6 $ft^3$ |
| Fine sand collar: 20/40 silica sand | 3.0 $ft^3$ |
| Filter pack: 10/20 silica sand | 277.0 $ft^3$ |
| Backfill: bentonite chips | 100.5 $ft^3$ |

**Table 7.2-3**
**CrIN-3 Injection Well Annular Fill Materials**

| Material | Volume |
|---|---|
| Upper surface seal: cement slurry | 110.0 $ft^3$ |
| Upper bentonite seal: bentonite chips | 1002.4 $ft^3$ |
| Fine sand collar: 20/40 silica sand | 1.5 $ft^3$ |
| Filter pack: 10/20 silica sand | 145.0 $ft^3$ |
| Backfill: bentonite chips | 12.6 $ft^3$ |

**Table 7.2-4**
**CrIN-4 Injection Well Annular Fill Materials**

| Material | Volume |
|---|---|
| Upper surface seal: cement slurry | 116.6 $ft^3$ |
| Upper bentonite seal: bentonite chips | 1239.5 $ft^3$ |
| Fine sand collar: 20/40 silica sand | 1.5 $ft^3$ |
| Filter pack: 10/20 silica sand | 158.0 $ft^3$ |
| Backfill: bentonite chips | 48.5 $ft^3$ |

**Table 7.2-5**
**CrIN-5 Injection Well Annular Fill Materials**

| Material | Volume |
|---|---|
| Upper surface seal: cement slurry | 115.5 $ft^3$ |
| Upper bentonite seal: bentonite chips | 1394.4 $ft^3$ |
| Fine sand collar: 20/40 silica sand | 1.5 $ft^3$ |
| Filter pack: 10/20 silica sand | 167.5 $ft^3$ |
| Backfill: bentonite chips and 10/20 silica sand | 43.5 $ft^3$ |

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

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 7/17/2016 | 9:15 | 0 | 876.51 | 0.00 | 0 | n/a[c] | n/a | n/a |
| | 9:45 | 27 | 881.59 | 5.08 | n/a | n/a | n/a | n/a |
| | 10:01 | 27 | 882.15 | 5.64 | 150 | 4.18 | 97.7 | 19.14 |
| | 10:30 | 27 | 882.25 | 5.74 | 810 | 7.39 | 33 | 20.32 |
| | 10:45 | 27 | 882.39 | 5.88 | 1210 | 7.3 | 27.2 | 20.07 |
| | 11:00 | 27 | 882.33 | 5.82 | 1600 | 7.38 | 21.7 | 19.68 |
| | 11:15 | 40 | 883.50 | 6.99 | 1980 | 7.39 | 17.2 | 19.38 |
| | 11:30 | 40 | 884.88 | 8.37 | 2680 | 7.44 | 20.7 | 19.52 |
| | 11:45 | 40 | 885.04 | 8.53 | 3330 | 7.51 | 27.4 | 21.97 |
| | 12:00 | 40 | 885.21 | 8.70 | 4010 | 7.56 | 24.2 | 22.05 |
| | 12:15 | 40 | 885.21 | 8.70 | 4650 | 7.59 | 15.1 | 23.08 |
| | 12:30 | 40 | 885.19 | 8.68 | 5330 | 7.55 | 9.05 | 25.53 |
| | 12:45 | 40 | 885.18 | 8.67 | 6060 | 7.57 | 9.32 | 27.73 |
| | 13:00 | 40 | 885.12 | 8.61 | 6730 | 7.58 | 8.85 | 27.95 |
| | 13:15 | 40 | 885.16 | 8.65 | 7410 | 7.59 | 8.01 | 28.34 |
| | 14:00 | 40 | 886.32 | 9.81 | 7410 | n/a | n/a | n/a |
| | 14:15 | 40 | 886.29 | 9.78 | 8410 | n/a | 9.32 | 25.47 |
| | 14:30 | 40 | 886.30 | 9.79 | 9050 | 5.18 | 7.81 | 19.48 |
| | 14:45 | 40 | 886.31 | 9.80 | 9710 | 7.37 | 7.32 | 21.51 |
| | 15:00 | 40 | 886.28 | 9.77 | 10370 | 7.57 | 5.39 | 20.24 |
| | 15:15 | 40 | 886.20 | 9.69 | 11070 | 7.59 | 4.87 | 22.4 |
| | 15:30 | 40 | 886.21 | 9.70 | 11730 | 7.66 | 5.83 | 22.15 |
| | 15:45 | 40 | 886.23 | 9.72 | 12440 | 7.66 | 3.74 | 22.52 |
| | 16:00 | 40 | 886.23 | 9.72 | 13140 | 7.65 | 4.89 | 22.97 |
| | 16:15 | 40 | 886.24 | 9.73 | 13760 | 7.63 | 3.81 | 23.87 |
| | 16:30 | 40 | 886.23 | 9.72 | 14440 | 7.65 | 2.79 | 23.41 |
| | 16:45 | 40 | 886.25 | 9.74 | 15160 | 7.63 | 2.13 | 22.63 |
| | 17:00 | 40 | 886.24 | 9.73 | 15810 | 7.63 | 2.9 | 22.28 |
| | 17:45 | 60 | 887.64 | 11.13 | n/a | n/a | n/a | n/a |
| | 17:55 | 60 | 887.32 | 10.81 | 17060 | 7.60 | 5.91 | 23.87 |
| | 18:15 | 60 | 887.33 | 10.82 | 18240 | 7.66 | 5.55 | 24.17 |
| | 18:30 | 60 | 887.99 | 11.48 | 19180 | 7.67 | 3.15 | 24.82 |

**Table 8.1-1 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 7/17/2016 | 18:45 | 60 | 887.99 | 11.48 | 20180 | 7.66 | 3.97 | 24.73 |
| | 19:00 | 75 | 890.44 | 13.93 | 21320 | 7.66 | 1.77 | 32.61 |
| | 19:15 | 75 | 890.72 | 14.21 | 22360 | 7.66 | 5.72 | 23.69 |
| | 19:30 | 75 | 890.80 | 14.29 | 23485 | n/a | 3.97 | 22.57 |
| | 19:35 | 75 | n/a | n/a | 23950 | n/a | n/a | n/a |
| 7/18/2016 | 7:45 | 0 | 876.67 | 0.00 | 23950 | n/a | n/a | n/a |
| | 8:10 | 70 | 888.64 | 11.97 | 24760 | n/a | n/a | n/a |
| | 8:15 | 70 | 889.24 | 12.57 | 25000 | 6.52 | 4.4 | 20.67 |
| | 8:30 | 70 | 889.84 | 13.17 | 26100 | 6.97 | 3.38 | 20.58 |
| | 8:45 | 70 | 889.98 | 13.31 | 27190 | 7.24 | 1.34 | 21.35 |
| | 9:15 | n/a | 890.06 | 13.39 | 29320 | 7.45 | 3.04 | 20.37 |
| | 9:30 | n/a | 886.85 | 10.18 | 30230 | 7.5 | 2.33 | 21.59 |
| | 9:45 | n/a | n/a | n/a | 31870 | 7.54 | 2.29 | 21.73 |
| **24-h Aquifer Test** | | | | | | | | |
| 7/19/2016 | 9:00 | 70 | 879.63 | 7.95 | 41610 | n/a | n/a | n/a |
| | 9:15 | 70 | 884.23 | 12.55 | 42740 | 7.64 | 1.98 | 19.20 |
| | 9:30 | 70 | 884.68 | 13.00 | 43800 | 7.77 | 1.44 | 19.56 |
| | 9:45 | 70 | 884.79 | 13.11 | 44920 | 7.75 | 1.70 | 20.04 |
| | 10:00 | 70 | 884.84 | 13.16 | 46010 | 7.74 | 1.54 | 20.46 |
| | 10:15 | 70 | 884.84 | 13.16 | 47130 | 7.75 | 1.29 | 20.70 |
| | 10:30 | 70 | 884.86 | 13.18 | 48240 | 7.75 | 1.84 | 20.79 |
| | 10:45 | 70 | 884.85 | 13.17 | 49350 | 7.74 | 1.15 | 21.19 |
| | 11:00 | 70 | 884.84 | 13.16 | 50460 | 7.73 | 1.75 | 20.20 |
| | 11:15 | 70 | 884.83 | 13.15 | 51570 | 7.73 | 1.25 | 20.38 |
| | 11:30 | 70 | 884.82 | 13.14 | 52660 | 7.74 | 1.56 | 21.75 |
| | 11:45 | 70 | 884.82 | 13.14 | 53780 | 7.73 | 1.45 | 22.28 |
| | 12:00 | 70 | 884.80 | 13.12 | 54880 | 7.73 | 1.55 | 22.88 |
| | 12:15 | 70 | 884.79 | 13.11 | 56000 | 7.73 | 1.23 | 23.33 |
| | 12:30 | 70 | 884.76 | 13.08 | 57110 | 7.73 | 1.84 | 23.62 |
| | 12:45 | 70 | 884.74 | 13.06 | 58220 | 7.74 | 1.45 | 24.06 |
| | 13:00 | 70 | 884.72 | 13.04 | 59330 | 7.73 | 1.93 | 23.16 |
| | 13:15 | 70 | 884.70 | 13.02 | 60460 | 7.74 | 1.26 | 23.87 |
| | 13:30 | 70 | 884.67 | 12.99 | 61550 | 7.74 | 1.36 | 24.56 |
| | 13:45 | 70 | 884.67 | 12.99 | 62670 | 7.75 | 1.45 | 24.29 |

**Table 8.1-1 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 7/19/2016 | 14:00 | 70 | 884.63 | 12.95 | 63770 | 7.73 | 0.72 | 21.21 |
| | 14:18 | 70 | 884.61 | 12.93 | 65170 | 7.81 | 1.32 | 21.46 |
| | 14:30 | 70 | 884.60 | 12.92 | 66010 | 7.50 | 1.90 | 19.37 |
| | 14:45 | 70 | 884.56 | 12.88 | 67140 | 7.77 | 0.42 | 20.00 |
| | 15:00 | 70 | 884.54 | 12.86 | 68240 | 7.76 | 0.64 | 19.85 |
| | 15:15 | 70 | 884.53 | 12.85 | 69340 | 7.76 | 1.86 | 19.90 |
| | 15:30 | 70 | 884.51 | 12.83 | 70460 | 7.76 | 0.76 | 20.68 |
| | 15:45 | 70 | 884.48 | 12.80 | 71560 | 7.76 | 1.28 | 20.75 |
| | 16:00 | 70 | 884.47 | 12.79 | 72640 | 7.76 | 0.97 | 21.85 |
| | 16:15 | 70 | 884.43 | 12.75 | 73740 | 7.77 | 1.38 | 23.25 |
| | 16:30 | 70 | 884.41 | 12.73 | 74860 | 7.76 | 0.75 | 23.32 |
| 7/19/2016 | 16:45 | 70 | 884.40 | 12.72 | 75970 | 7.77 | 1.04 | 23.32 |
| | 17:00 | 70 | 884.38 | 12.70 | 77070 | 7.78 | 1.08 | 23.84 |
| | 17:15 | 70 | 884.35 | 12.67 | 78200 | 7.78 | 0.74 | 24.49 |
| | 17:30 | 70 | 884.35 | 12.67 | 79320 | 7.80 | 0.70 | 21.21 |
| | 17:45 | 70 | 884.32 | 12.64 | 80420 | 7.78 | 0.73 | 21.37 |
| | 18:00 | 70 | 884.30 | 12.62 | 81520 | 7.80 | 0.81 | 21.43 |
| | 18:15 | 70 | 884.28 | 12.60 | 82660 | 7.77 | 1.05 | 21.04 |
| | 18:30 | 70 | 884.26 | 12.58 | 83850 | 7.76 | 0.59 | 20.68 |
| | 18:45 | 70 | 884.24 | 12.56 | 84850 | 7.74 | 0.63 | 20.20 |
| | 19:00 | 70 | 884.23 | 12.55 | 85970 | 7.74 | 0.76 | 21.09 |
| | 19:15 | 70 | 884.22 | 12.54 | 87090 | 7.76 | 0.87 | 21.77 |
| | 19:35 | 70 | 884.21 | 12.53 | 88450 | 7.72 | 0.64 | 21.53 |
| | 19:45 | 70 | 884.20 | 12.52 | 87470 | 7.70 | 0.85 | 20.92 |
| | 20:00 | 70 | 884.21 | 12.53 | 90400 | 7.66 | 1.74 | 19.21 |
| | 20:15 | 70 | 884.19 | 12.51 | 91470 | 7.69 | 0.82 | 19.75 |
| | 20:30 | 70 | 884.18 | 12.50 | 92600 | 7.69 | 1.07 | 19.63 |
| | 20:45 | 70 | 884.17 | 12.49 | 93740 | 7.68 | 0.60 | 19.63 |
| | 21:00 | 70 | 884.14 | 12.46 | 94880 | 7.68 | 0.57 | 19.61 |
| | 21:15 | 70 | 884.12 | 12.44 | 95890 | 7.69 | 0.67 | 19.71 |
| | 21:30 | 70 | 884.13 | 12.45 | 97070 | 7.69 | 0.56 | 19.70 |
| | 21:45 | 70 | 884.10 | 12.42 | 98080 | 7.69 | 0.92 | 19.66 |
| | 22:00 | 70 | 884.09 | 12.41 | 101220 | 7.70 | 0.58 | 19.66 |

**Table 8.1-1 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 7/19/2016 | 22:15 | 70 | 884.09 | 12.41 | 100410 | 7.69 | 0.61 | 19.40 |
| | 22:30 | 70 | 884.08 | 12.40 | 101540 | 7.68 | 0.65 | 19.30 |
| | 22:45 | 70 | 884.06 | 12.38 | 102520 | 7.70 | 0.48 | 19.22 |
| | 23:00 | 70 | 884.05 | 12.37 | 103590 | 7.70 | 0.57 | 19.27 |
| | 23:15 | 70 | 884.04 | 12.36 | 104740 | 7.71 | 0.58 | 19.23 |
| | 23:30 | 70 | 884.04 | 12.36 | 105810 | 7.70 | 0.55 | 19.17 |
| | 23:45 | 70 | 884.04 | 12.36 | 106920 | 7.65 | 0.49 | 18.13 |
| 7/20/2016 | 0:00 | 70 | 884.03 | 12.35 | 108020 | 7.69 | 1.23 | 17.91 |
| | 0:15 | 70 | 884.01 | 12.33 | 109160 | 7.69 | 0.61 | 17.92 |
| | 0:30 | 70 | 884.00 | 12.32 | 110490 | 7.69 | 1.37 | 18.32 |
| | 0:45 | 70 | 883.99 | 12.31 | 111280 | 7.68 | 0.32 | 18.33 |
| | 1:00 | 70 | 884.00 | 12.32 | 112400 | 7.69 | 0.36 | 18.36 |
| | 1:15 | 70 | 883.96 | 12.28 | 113570 | 7.66 | 0.61 | 18.48 |
| | 1:30 | 70 | 883.93 | 12.25 | 114610 | 7.68 | 0.91 | 18.37 |
| | 1:45 | 70 | 883.91 | 12.23 | 115760 | 7.67 | 0.49 | 18.44 |
| | 2:00 | 70 | 883.90 | 12.22 | 116860 | 7.72 | 0.65 | 18.28 |
| | 2:15 | 70 | 883.90 | 12.22 | 117950 | 7.71 | 0.53 | 18.14 |
| | 2:30 | 70 | 883.87 | 12.19 | 119010 | 7.70 | 0.60 | 17.86 |
| | 2:45 | 70 | 883.86 | 12.18 | 120200 | 7.71 | 0.51 | 17.34 |
| | 3:00 | 70 | 883.84 | 12.16 | 121350 | 7.73 | 0.54 | 17.12 |
| | 3:15 | 70 | 883.84 | 12.16 | 122400 | 7.70 | 0.25 | 17.18 |
| | 3:30 | 70 | 883.80 | 12.12 | 123460 | 7.70 | 0.41 | 17.11 |
| | 3:45 | 70 | 883.80 | 12.12 | 124600 | 7.74 | 0.39 | 16.98 |
| | 4:00 | 70 | 883.79 | 12.11 | 125870 | 7.73 | 0.50 | 16.90 |
| | 4:15 | 70 | 883.76 | 12.08 | 126760 | 7.73 | 0.39 | 16.84 |
| | 4:30 | 70 | 883.75 | 12.07 | 127880 | 7.79 | 0.38 | 16.66 |
| | 4:45 | 70 | 883.72 | 12.04 | 128970 | 7.76 | 0.33 | 16.65 |
| | 5:00 | 70 | 883.72 | 12.04 | 130140 | 7.75 | 0.43 | 16.64 |
| | 5:15 | 70 | 883.71 | 12.03 | 131130 | 7.75 | 0.46 | 16.70 |
| | 5:30 | 70 | 883.71 | 12.03 | 132230 | 7.79 | 0.53 | 16.69 |
| | 5:45 | 70 | 883.69 | 12.01 | 133320 | 7.72 | 0.41 | 16.47 |
| | 6:00 | 70 | 883.66 | 11.98 | 134390 | 7.71 | 0.23 | 16.34 |
| | 6:15 | 70 | 883.69 | 12.01 | 135520 | 7.70 | 0.39 | 16.32 |

**Table 8.1-1 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 7/20/2016 | 6:30 | 70 | 883.66 | 11.98 | 136630 | 7.69 | 0.48 | 16.56 |
| | 6:45 | 70 | 883.64 | 11.96 | 137730 | 7.73 | 0.38 | 16.72 |
| | 7:00 | 70 | 883.65 | 11.97 | 138890 | 7.72 | 0.47 | 17.02 |
| | 7:15 | 70 | 883.63 | 11.95 | 139920 | 7.72 | 0.28 | 17.58 |
| | 7:30 | 70 | 883.63 | 11.95 | 140990 | 7.74 | 0.47 | 18.20 |
| | 7:45 | 70 | 883.61 | 11.93 | 142150 | 7.76 | 0.40 | 18.71 |
| | 8:00 | 70 | 883.60 | 11.92 | 143190 | 7.75 | 0.55 | 18.83 |
| | 8:15 | 70 | 883.61 | 11.93 | 144300 | 7.74 | 0.21 | 18.98 |
| | 8:30 | 70 | 883.59 | 11.91 | 145390 | 7.75 | 0.86 | 19.20 |
| | 8:45 | 70 | 883.57 | 11.89 | 146530 | 7.74 | 0.37 | 19.42 |
| | 9:00 | 70 | 883.57 | 11.89 | 147610 | 7.74 | 0.90 | 19.61 |
| | 9:06 | n/a | 875.31 | 3.63 | 148050 | n/a | n/a | n/a |

[a] gpm = Gallon per minute

[b] NTU = Nephelometric turbidity unit.

[c] n/a = Not applicable.

**Table 8.1-2**
**Field Water-Quality Parameters and Well Performance for Development of Well CrIN-2**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 5/28/2016 | 12:40 | 0 | 903.91 | 0.00 | 0 | n/a[c] | n/a | n/a |
| | 12:45 | 80 | 912.26 | 8.35 | 60 | 8.09 | NR[d] | 20.25 |
| | 12:50 | 80 | 921.63 | 17.72 | 980 | 8.17 | 223.00 | 20.11 |
| | 13:00 | 80 | 912.95 | 9.04 | 1560 | 8.19 | 206.26 | 20.14 |
| | 13:05 | 40 | 909.51 | 5.60 | 1900 | 8.17 | 130.00 | 20.16 |
| | 13:15 | 40 | 909.30 | 5.39 | 2340 | 8.15 | 62.30 | 20.47 |
| | 13:25 | 40 | 909.29 | 5.38 | 2780 | 8.15 | 47.20 | 20.11 |
| | 13:35 | 40 | 909.31 | 5.40 | 3260 | 8.16 | 37.40 | 20.36 |
| | 13:47 | 40 | 909.40 | 5.49 | 3740 | 8.12 | 28.60 | 21.09 |
| | 13:57 | 40 | 909.35 | 5.44 | 4290 | 8.11 | 24.90 | 21.63 |
| | 14:12 | 35 | 908.22 | 4.31 | 4920 | 8.08 | 19.20 | 20.65 |
| | 14:27 | 35 | 909.93 | 6.02 | 5440 | 8.08 | 16.30 | 20.32 |
| | 14:42 | 35 | 907.63 | 3.72 | 5940 | 8.06 | 17.10 | 20.23 |
| | 14:57 | 35 | 907.64 | 3.73 | 6430 | 8.05 | 13.90 | 20.33 |
| | 16:05 | 27 | 905.10 | 1.19 | 6740 | 8.02 | 18.21 | 20.40 |
| | 16:15 | 27 | 905.55 | 1.64 | 7000 | 8.01 | 14.50 | 20.46 |
| | 16:30 | 27 | 905.58 | 1.67 | 7380 | 8.03 | 17.20 | 20.58 |
| | 16:45 | 27 | 905.58 | 1.67 | 7850 | 8.01 | 13.50 | 20.77 |
| | 17:05 | 27 | 906.40 | 2.49 | 8380 | 8.00 | 10.05 | 20.91 |
| | 17:15 | 27 | 906.42 | 2.51 | 8700 | 8.00 | 12.00 | 20.58 |
| | 17:30 | 27 | 906.52 | 2.61 | 9050 | 7.99 | 8.46 | 20.74 |
| | 17:45 | 27 | 906.32 | 2.41 | 9480 | 7.99 | 6.75 | 20.51 |
| | 18:00 | 27 | 906.38 | 2.47 | 9870 | 7.93 | 8.68 | 20.41 |
| | 18:15 | 27 | 906.35 | 2.44 | 10300 | 7.96 | 5.81 | 20.51 |
| | 18:30 | 27 | 906.34 | 2.43 | 10670 | 7.91 | 5.14 | 20.44 |
| | 18:45 | 27 | 906.24 | 2.33 | 11070 | 7.94 | 6.68 | 20.38 |
| | 19:00 | 27 | 906.21 | 2.30 | 11410 | 7.95 | 4.38 | 20.35 |
| 5/29/2016 | 8:50 | 0 | 902.56 | 0.00 | 11520 | n/a | n/a | n/a |
| | 9:15 | 27 | 906.19 | 3.63 | 11940 | 7.91 | 13.90 | 20.61 |
| | 9:30 | 27 | 906.30 | 3.74 | 12370 | 7.92 | 11.60 | 20.81 |
| | 9:50 | 27 | 906.21 | 3.65 | 12770 | 7.93 | 9.37 | 20.83 |
| | 10:10 | 27 | 906.09 | 3.53 | 13300 | 7.93 | 6.54 | 20.78 |
| | 11:30 | 27 | 906.12 | 3.56 | 14080 | 7.88 | 8.33 | 24.67 |

**Table 8.1-2 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 5/29/2016 | 12:40 | 27 | 906.37 | 3.81 | 15450 | 7.89 | 7.96 | 21.61 |
| | 13:00 | 27 | 906.36 | 3.80 | 16430 | 7.87 | 3.29 | 21.52 |
| | 13:26 | 27 | 906.34 | 3.78 | 17140 | 7.87 | 2.65 | 21.34 |
| | 13:46 | 27 | 906.31 | 3.75 | 17700 | 7.85 | 2.88 | 21.77 |
| | 14:06 | 27 | 906.37 | 3.81 | 18250 | 7.83 | 1.82 | 23.37 |
| | 14:26 | 27 | 906.51 | 3.95 | 18910 | 7.84 | 1.71 | 26.12 |
| | 14:50 | 27 | 906.38 | 3.82 | 19700 | 7.83 | 3.75 | 26.65 |
| | 15:10 | 27 | 906.32 | 3.76 | 20310 | 7.84 | 1.08 | 29.83 |
| | 15:30 | 27 | 906.35 | 3.79 | 20910 | 7.83 | 1.76 | 31.62 |
| | 16:20 | 50 | n/a | n/a | 21150 | n/a | n/a | n/a |
| | 16:35 | 50 | 909.85 | 7.29 | 21920 | n/a | n/a | n/a |
| | 16:37 | 50 | 909.84 | 7.28 | 22040 | n/a | n/a | n/a |
| | 16:40 | 50 | 909.85 | 7.29 | 22220 | n/a | n/a | n/a |
| | 17:00 | 50 | 903.30 | 0.74 | 22850 | n/a | n/a | n/a |
| | 17:25 | 50 | 909.85 | 7.29 | 23070 | n/a | n/a | n/a |
| | 17:40 | 60 | 903.21 | 0.65 | 23100 | n/a | n/a | n/a |
| | 17:50 | 60 | 910.84 | 8.28 | 23800 | n/a | n/a | n/a |
| | 17:56 | 60 | 910.93 | 8.37 | 24190 | n/a | n/a | n/a |
| | 18:00 | 60 | 910.94 | 8.38 | 24410 | n/a | n/a | n/a |
| | 18:10 | 0 | 903.10 | 0.54 | 24410 | n/a | n/a | n/a |
| | 18:15 | 60 | n/a | n/a | 24490 | n/a | n/a | n/a |
| | 18:25 | 60 | 910.94 | 8.38 | 25200 | 7.80 | 4.02 | 26.37 |
| | 18:30 | 0 | n/a | n/a | 25510 | n/a | n/a | n/a |
| | 18:46 | 60 | n/a | n/a | 25540 | n/a | n/a | n/a |
| | 18:50 | 60 | 910.53 | 7.97 | 25830 | 7.90 | 1.95 | 20.33 |
| | 19:00 | 60 | n/a | n/a | 26480 | 7.83 | 2.23 | 20.34 |
| 5/30/2016 | 8:50 | 0 | 902.57 | 0.00 | 26580 | n/a | n/a | n/a |
| | 9:00 | 60 | 909.71 | 7.14 | 26820 | 7.80 | 40.90 | 18.43 |
| | 9:15 | 60 | 910.08 | 7.51 | 27800 | 7.82 | 6.16 | 20.15 |
| | 9:35 | 60 | 910.12 | 7.55 | 29120 | 7.84 | 2.07 | 20.22 |
| | 9:50 | 60 | 910.03 | 7.46 | 30710 | 7.83 | 2.12 | 20.21 |
| | 10:05 | 60 | 910.15 | 7.58 | 31100 | 7.84 | 1.94 | 20.23 |
| | 10:20 | 60 | 910.15 | 7.58 | 32090 | 7.85 | 1.41 | 20.27 |

**Table 8.1-2 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 5/30/2016 | 10:30 | 60 | 910.15 | 7.58 | 32760 | 7.83 | 0.45 | 20.26 |
| | 11:35 | 60 | 910.48 | 7.91 | 34160 | 7.83 | 1.86 | 20.40 |
| | 11:50 | 66 | 910.44 | 7.87 | 35210 | 7.82 | 0.71 | 20.44 |
| | 12:05 | 66 | 910.49 | 7.92 | 36200 | 7.82 | 0.66 | 20.47 |
| | 12:20 | 66 | 910.44 | 7.87 | 37220 | 7.82 | 0.62 | 20.51 |
| | 12:35 | 66 | 910.44 | 7.87 | 38240 | 7.81 | 0.49 | 20.47 |
| | 12:50 | 70 | 910.41 | 7.84 | 39350 | 7.80 | 0.64 | 20.52 |
| | 13:05 | 70 | 911.33 | 8.76 | 40480 | 7.80 | 0.13 | 20.46 |
| | 13:20 | 70 | 911.38 | 8.81 | 41620 | 7.80 | 0.13 | 20.49 |
| | 13:35 | 71 | 911.39 | 8.82 | 42750 | 7.79 | 0.60 | 20.50 |
| | 14:00 | 40 | 907.80 | 5.23 | 44100 | 7.80 | 0.22 | 20.49 |
| | 14:15 | 40 | 907.79 | 5.22 | 44840 | 7.80 | 0.05 | 20.50 |
| | 14:35 | 40 | 907.74 | 5.17 | 45680 | 7.80 | 0.02 | 20.48 |
| **Step Test** | | | | | | | | |
| 5/31/2016 | 11:50 | 0 | 902.82 | 0.00 | 46050 | n/a | n/a | n/a |
| | 12:00 | 30 | 902.82 | 0.00 | 46050 | n/a | n/a | n/a |
| | 12:15 | 30 | 907.88 | 5.06 | 46530 | 7.79 | 0.46 | 20.30 |
| | 12:30 | 30 | 907.82 | 5.00 | 47030 | 7.75 | 0.38 | 20.44 |
| | 12:45 | 30 | 907.89 | 5.07 | 47510 | 7.76 | 1.01 | 20.43 |
| | 12:55 | 30 | 907.89 | 5.07 | 47790 | 7.75 | 0.62 | 20.36 |
| | 13:00 | 0 | n/a | n/a | 48070 | n/a | n/a | n/a |
| | 14:00 | 50 | 903.85 | 1.03 | 48070 | n/a | n/a | n/a |
| | 14:15 | 50 | 910.15 | 7.33 | 48900 | 7.79 | 0.19 | 20.27 |
| | 14:30 | 50 | 910.15 | 7.33 | 49750 | 7.79 | 0.61 | 20.30 |
| | 14:45 | 50 | 910.14 | 7.32 | 50610 | 7.77 | 0.68 | 20.28 |
| | 15:00 | 0 | n/a | n/a | 51440 | n/a | n/a | n/a |
| | 16:00 | 70 | n/a | n/a | 51440 | n/a | n/a | n/a |
| | 16:37 | 70 | 912.16 | 9.34 | 51440 | 7.79 | 2.39 | 20.29 |
| | 16:52 | 70 | 912.41 | 9.59 | 52680 | 7.77 | 1.02 | 20.34 |
| | 17:07 | 70 | 912.46 | 9.64 | 53790 | 7.76 | 1.41 | 20.36 |
| | 17:22 | 70 | 921.44 | 18.62 | 54840 | 7.76 | 0.97 | 20.35 |
| | 17:30 | 70 | 921.45 | 18.63 | 55430 | 7.76 | 1.43 | 20.39 |
| **24-h Aquifer Test** | | | | | | | | |
| 6/1/2016 | 9:58 | 0 | 903.93 | 0.00 | 55970 | n/a | n/a | n/a |
| | 10:00 | 50 | 903.93 | 0.00 | 55970 | n/a | n/a | n/a |

**Table 8.1-2 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 6/1/2016 | 10:15 | 50 | 910.36 | 6.43 | 56840 | 7.78 | 1.49 | 20.74 |
| | 10:30 | 50 | 910.41 | 6.48 | 57720 | 7.78 | 1.51 | 20.66 |
| | 10:45 | 58 | 910.39 | 6.46 | 58600 | 7.77 | 0.05 | 20.76 |
| | 11:00 | 58 | 910.39 | 6.46 | 59500 | 7.77 | 1.25 | 21.40 |
| | 11:15 | 58 | 910.38 | 6.45 | 60390 | 7.77 | 0.28 | 21.30 |
| | 11:30 | 58 | 910.39 | 6.46 | 61270 | 7.79 | 0.13 | 21.29 |
| | 11:45 | 58 | 910.42 | 6.49 | 62160 | 7.78 | 0.10 | 21.13 |
| | 12:00 | 58 | 910.39 | 6.46 | 63050 | 7.77 | 0.12 | 21.03 |
| | 12:15 | 58 | 910.43 | 6.50 | 63940 | 7.78 | 0.80 | 20.88 |
| | 12:30 | 58 | 910.41 | 6.48 | 64830 | 7.77 | 0.40 | 20.52 |
| | 12:45 | 58 | 910.42 | 6.49 | 65720 | 7.77 | 0.10 | 21.02 |
| | 13:00 | 58 | 910.41 | 6.48 | 66670 | 7.77 | 0.29 | 21.15 |
| | 13:15 | 58 | 910.40 | 6.47 | 67500 | 7.77 | 0.04 | 21.35 |
| | 13:30 | 58 | 910.41 | 6.48 | 68390 | 7.77 | 0.02 | 21.53 |
| | 13:45 | 58 | 910.40 | 6.47 | 69280 | 7.77 | 0.04 | 21.51 |
| | 14:00 | 58 | 910.37 | 6.44 | 70180 | 7.76 | 0.66 | 21.67 |
| | 14:15 | 58 | 910.36 | 6.43 | 71070 | 7.76 | 0.14 | 20.91 |
| 6/1/2016 | 14:30 | 58 | 910.37 | 6.44 | 71960 | 7.77 | 0.25 | 20.95 |
| | 14:45 | 58 | 910.34 | 6.41 | 72860 | 7.76 | 0.88 | 20.95 |
| | 15:00 | 58 | 910.33 | 6.40 | 73740 | 7.76 | 0.24 | 20.99 |
| | 15:15 | 58 | 910.33 | 6.40 | 74640 | 7.77 | 0.72 | 21.21 |
| | 15:30 | 58 | 910.34 | 6.41 | 75530 | 7.76 | 0.61 | 20.88 |
| | 15:45 | 58 | 910.31 | 6.38 | 76420 | 7.76 | 0.50 | 20.58 |
| | 16:00 | 58 | 910.33 | 6.40 | 77320 | 7.76 | 1.28 | 20.44 |
| | 16:15 | 58 | 910.31 | 6.38 | 78180 | 7.76 | 3.65 | 20.42 |
| | 16:30 | 58 | 910.32 | 6.39 | 79080 | 7.76 | 3.36 | 20.45 |
| | 16:45 | 58 | 910.31 | 6.38 | 79950 | 7.76 | 2.67 | 20.45 |
| | 17:00 | 58 | 910.31 | 6.38 | 80830 | 7.76 | 3.21 | 20.44 |
| | 17:15 | 58 | 910.30 | 6.37 | 81710 | 7.76 | 1.04 | 20.58 |
| | 17:30 | 58 | 910.31 | 6.38 | 82590 | 7.76 | 0.95 | 20.72 |
| | 17:45 | 58 | 910.32 | 6.39 | 83480 | 7.76 | 3.19 | 20.48 |
| | 18:00 | 58 | 910.32 | 6.39 | 84340 | 7.76 | 2.18 | 20.25 |
| | 18:15 | 58 | 910.34 | 6.41 | 85210 | 7.76 | 0.56 | 19.72 |
| | 18:30 | 58 | 910.33 | 6.40 | 86080 | 7.76 | 0.16 | 19.80 |

**Table 8.1-2 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 6/1/2016 | 18:45 | 58 | 910.35 | 6.42 | 86940 | 7.77 | 1.38 | 19.83 |
| | 19:00 | 58 | 910.33 | 6.40 | 87810 | 7.82 | 1.30 | 19.87 |
| | 19:15 | 58 | 910.32 | 6.39 | 88720 | 7.83 | 1.49 | 19.72 |
| | 19:30 | 58 | 910.32 | 6.39 | 89560 | 7.81 | 1.31 | 19.68 |
| | 19:45 | 58 | 910.32 | 6.39 | 90460 | 7.79 | 1.43 | 19.66 |
| | 20:00 | 58 | 910.33 | 6.40 | 91280 | 7.79 | 2.86 | 19.59 |
| | 20:15 | 58 | 910.33 | 6.40 | 92140 | 7.78 | 2.20 | 19.53 |
| | 20:30 | 58 | 910.33 | 6.40 | 93010 | 7.78 | 1.20 | 19.53 |
| | 20:45 | 58 | 910.33 | 6.40 | 93850 | 7.78 | 1.55 | 19.52 |
| | 21:00 | 58 | 910.33 | 6.40 | 94730 | 7.78 | 2.00 | 19.52 |
| | 21:15 | 58 | 910.33 | 6.40 | 95600 | 7.78 | 2.20 | 19.52 |
| | 21:30 | 58 | 910.33 | 6.40 | 96450 | 7.78 | 2.21 | 19.48 |
| | 21:45 | 58 | 910.34 | 6.41 | 97330 | 7.78 | 1.67 | 19.48 |
| | 22:00 | 58 | 910.33 | 6.40 | 98100 | 7.78 | 1.33 | 19.48 |
| | 22:15 | 58 | 910.33 | 6.40 | 98810 | 7.78 | 1.20 | 19.44 |
| | 22:30 | 58 | 910.33 | 6.40 | 99220 | 7.78 | 1.53 | 19.43 |
| | 22:45 | 58 | 910.33 | 6.40 | 100680 | 7.79 | 0.51 | 19.35 |
| | 23:00 | 58 | 910.33 | 6.40 | 101540 | 7.79 | 1.20 | 19.43 |
| | 23:15 | 58 | 910.33 | 6.40 | 102330 | 7.79 | 1.22 | 19.48 |
| | 23:30 | 58 | 910.33 | 6.40 | 103170 | 7.79 | 0.62 | 19.34 |
| | 23:45 | 58 | 910.35 | 6.42 | 104030 | 7.79 | 0.64 | 19.41 |
| 6/2/2016 | 0:00 | 58 | 910.32 | 6.39 | 104860 | 7.79 | 0.95 | 19.42 |
| | 0:15 | 58 | 910.33 | 6.40 | 106020 | 7.79 | 1.82 | 19.40 |
| | 0:30 | 58 | 910.31 | 6.38 | 107370 | 7.76 | 1.54 | 20.21 |
| | 0:45 | 58 | 910.31 | 6.38 | 108160 | 7.79 | 0.92 | 20.20 |
| | 1:00 | 58 | 910.33 | 6.40 | 109060 | 7.74 | 1.17 | 20.19 |
| | 1:15 | 58 | 910.33 | 6.40 | 109880 | 7.74 | 1.55 | 20.20 |
| | 1:30 | 58 | 910.33 | 6.40 | 109380 | 7.75 | 1.50 | 20.21 |
| | 1:45 | 58 | 910.35 | 6.42 | 110380 | 7.75 | 1.42 | 20.20 |
| | 2:00 | 58 | 910.34 | 6.41 | 111530 | 7.74 | 1.39 | 20.21 |
| | 2:15 | 58 | 910.34 | 6.41 | 112480 | 7.74 | 1.39 | 20.20 |
| | 2:30 | 58 | 910.31 | 6.38 | 113210 | 7.74 | 1.32 | 20.21 |
| | 2:45 | 58 | 910.32 | 6.39 | 114240 | 7.74 | 1.14 | 20.21 |
| | 3:00 | 58 | 910.32 | 6.39 | 114890 | 7.74 | 0.77 | 20.21 |

**Table 8.1-2 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft bgs) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[b]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 6/2/2016 | 3:15 | 58 | 910.36 | 6.43 | 115740 | 7.74 | 1.20 | 20.21 |
| | 3:30 | 58 | 910.35 | 6.42 | 116530 | 7.74 | 1.27 | 20.21 |
| | 3:45 | 58 | 910.33 | 6.40 | 117400 | 7.74 | 1.15 | 20.24 |
| | 4:00 | 58 | 910.37 | 6.44 | 118150 | 7.74 | 1.26 | 20.22 |
| | 4:15 | 58 | 910.38 | 6.45 | 119060 | 7.74 | 1.10 | 20.23 |
| | 4:30 | 58 | 910.35 | 6.42 | 119940 | 7.74 | 0.90 | 20.20 |
| | 4:45 | 58 | 910.39 | 6.46 | 120720 | 7.74 | 1.12 | 20.21 |
| | 5:00 | 58 | 910.40 | 6.47 | 121530 | 7.74 | 1.10 | 20.20 |
| | 5:15 | 58 | 910.40 | 6.47 | 122360 | 7.76 | 1.15 | 20.19 |
| | 5:30 | 58 | 910.40 | 6.47 | 123200 | 7.76 | 1.20 | 20.17 |
| | 5:45 | 58 | 910.40 | 6.47 | 124040 | 7.76 | 1.10 | 20.18 |
| | 6:00 | 58 | 910.41 | 6.48 | 124850 | 7.79 | 0.87 | 20.18 |
| | 6:15 | 58 | 910.41 | 6.48 | 125680 | 7.76 | 1.01 | 20.10 |
| | 6:30 | 58 | 910.37 | 6.44 | 126530 | 7.79 | 1.63 | 20.01 |
| | 6:45 | 58 | 910.37 | 6.44 | 127410 | 7.77 | 1.47 | 19.94 |
| | 7:00 | 58 | 910.37 | 6.44 | 128200 | 7.77 | 1.29 | 20.05 |
| | 7:15 | 58 | 910.34 | 6.41 | 129060 | 7.76 | 1.06 | 20.18 |
| | 7:30 | 58 | 910.31 | 6.38 | 129920 | 7.76 | 1.05 | 19.75 |
| | 7:45 | 58 | 910.31 | 6.38 | 130830 | 7.76 | 1.09 | 19.86 |
| | 8:00 | 58 | 910.32 | 6.39 | 131630 | 7.77 | 1.30 | 20.23 |
| | 8:15 | 58 | 910.32 | 6.39 | 132490 | 7.76 | 1.47 | 20.51 |
| | 8:30 | 58 | 910.31 | 6.38 | 133350 | 7.76 | 1.03 | 20.74 |
| | 8:45 | 58 | 910.31 | 6.38 | 134210 | 7.76 | 0.86 | 21.02 |
| | 9:00 | 58 | 910.33 | 6.40 | 135130 | 7.75 | 1.06 | 21.19 |
| | 9:15 | 58 | 910.32 | 6.39 | 135940 | 7.76 | 0.14 | 21.81 |
| | 9:30 | 58 | 910.31 | 6.38 | 136810 | 7.75 | 0.12 | 22.14 |
| | 9:45 | 58 | 910.32 | 6.39 | 137670 | 7.75 | 0.80 | 20.52 |
| | 10:09 | 0 | n/a | n/a | 139050 | n/a | n/a | n/a |

[a] gpm = Gallon per minute

[b] NTU = Nephelometric turbidity unit.

[c] n/a = Not applicable.

[d] NR = Not recorded.

**Table 8.1-3**
**Field Water-Quality Parameters and Well Performance for Development of Well CrIN-3**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development[d]** | | | | | | | | |
| Well development data for CrIN-3 were lost. | | | | | | | | |
| **Step Test** | | | | | | | | |
| 9/8/2016 | 7:45 | 0 | 932.4 | 3.6 | 0 | NR[e] | NR | NR |
| | 7:48 | 52.0 | 930.3 | 1.5 | 340 | 6.33 | 11.0 | 18.39 |
| | 7:56 | 55.0 | 930.1 | 1.3 | 570 | NR | NR | NR |
| | 8:02 | 50.0 | 929.9 | 1.1 | 805 | NR | NR | NR |
| | 8:08 | 44.0 | 929.7 | 0.9 | 1045 | 7.47 | 9.7 | 20.90 |
| | 8:15 | 47.0 | 929.8 | 1.0 | 1285 | 7.54 | 25.4 | 21.00 |
| | 8:20 | 46.0 | 929.7 | 0.9 | 1530 | NR | NR | NR |
| | 8:25 | 47.0 | 929.7 | 0.9 | 1770 | 7.64 | 16.2 | 21.61 |
| | 8:30 | 48.0 | 929.7 | 0.9 | 1860 | NR | NR | NR |
| | 8:40 | 49.0 | 929.7 | 0.9 | NR | 7.67 | 23.1 | 21.50 |
| | 8:45 | 48.0 | 929.9 | 1.1 | NR | NR | NR | NR |
| | 8:55 | 52.0 | 930.3 | 1.5 | 2915 | NR | NR | NR |
| | 8:56 | NR | 930.4 | 1.6 | 3220 | 7.67 | 25.5 | 21.55 |
| | 8:58 | 61.0 | 930.5 | 1.7 | 3530 | NR | NR | NR |
| | 9:00 | 61.0 | 930.5 | 1.7 | 3850 | NR | NR | NR |
| | 9:05 | 61.0 | 930.5 | 1.7 | 4145 | NR | NR | NR |
| | 9:10 | 61.0 | 930.5 | 1.7 | 4450 | 7.65 | 33.4 | 20.53 |
| | 9:15 | 62.0 | 930.5 | 1.7 | 4755 | NR | NR | NR |
| | 9:20 | 64.0 | 930.5 | 1.7 | 5055 | NR | NR | NR |
| | 9:25 | 59.0 | 930.5 | 1.7 | 5360 | 7.65 | 7.3 | 20.48 |
| | 9:30 | 61.0 | 930.5 | 1.7 | NR | NR | NR | NR |
| | 9:35 | 61.0 | 930.5 | 1.7 | NR | NR | NR | NR |
| | 9:40 | 60.0 | 930.5 | 1.7 | NR | 7.66 | 8.0 | 20.46 |
| | 9:45 | 61.0 | 930.9 | 2.1 | NR | NR | NR | NR |
| | 9:50 | 75.0 | 931.4 | 2.6 | NR | NR | NR | NR |
| | 9:55 | 81.0 | 931.5 | 2.7 | 6125 | 7.64 | 6.9 | 20.00 |
| | 10:00 | 81.0 | 931.5 | 2.7 | 6530 | NR | NR | NR |
| | 10:05 | 80.0 | 931.6 | 2.8 | 6930 | NR | NR | NR |
| | 10:10 | 80.0 | 931.6 | 2.8 | 7330 | 7.64 | 5.9 | 20.04 |
| | 10:15 | 80.0 | 931.5 | 2.7 | 7730 | NR | NR | NR |
| | 10:20 | 80.0 | 931.6 | 2.8 | 8130 | NR | NR | NR |
| | 10:25 | 82.0 | 931.5 | 2.7 | 8540 | NR | NR | NR |

**Table 8.1-3 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Step Test** | | | | | | | | |
| 9/8/2016 | 10:30 | 80.6 | 931.5 | 2.7 | 8943 | 7.64 | 5.5 | 20.02 |
| | 10:35 | 80.6 | 931.6 | 2.8 | 9346 | NR | NR | NR |
| | 10:40 | 80.8 | 931.6 | 2.8 | 9750 | 7.64 | 5.3 | 20.01 |
| **24-h Aquifer Test** | | | | | | | | |
| 9/8/2016 | 15:00 | NR | 932.1 | 3.3 | 9773 | NR | NR | NR |
| | 15:15 | 81.0 | 931.4 | 2.6 | 10787 | NR | NR | NR |
| | 15:23 | 80.0 | 931.4 | 2.6 | 11431 | 7.55 | 1.7 | 20.16 |
| | 15:25 | 81.5 | 931.4 | 2.6 | 11594 | NR | NR | NR |
| | 15:35 | 81.0 | 931.5 | 2.7 | 12399 | 7.51 | 3.6 | 20.12 |
| | 15:45 | 81.0 | 931.5 | 2.7 | 13208 | NR | NR | NR |
| | 15:50 | 80.6 | 931.5 | 2.7 | 13611 | 7.50 | 2.8 | 20.09 |
| | 15:55 | 80.8 | 931.5 | 2.7 | 14015 | NR | NR | NR |
| | 16:00 | 81.0 | 931.5 | 2.7 | 14420 | 7.51 | 2.8 | 20.10 |
| | 16:15 | 81.0 | 931.5 | 2.7 | 15635 | 7.47 | 2.9 | 20.10 |
| | 16:30 | 81.0 | 931.5 | 2.7 | 16850 | 7.48 | 3.3 | 20.05 |
| | 16:40 | 81.5 | 931.5 | 2.7 | 17665 | NR | NR | NR |
| | 16:50 | 80.5 | 931.5 | 2.7 | 18470 | 7.54 | 5.3 | 20.04 |
| | 17:00 | 81.0 | 931.5 | 2.7 | 19280 | 7.57 | 4.7 | 20.03 |
| | 17:20 | 81.0 | 931.5 | 2.7 | 20900 | 7.59 | 3.2 | 20.02 |
| | 17:30 | 80.9 | 931.5 | 2.7 | 21709 | 7.60 | 3.0 | 20.01 |
| | 17:45 | 81.0 | 931.5 | 2.7 | 22924 | 7.62 | 2.3 | 20.01 |
| | 18:00 | 81.1 | 931.5 | 2.7 | 24140 | 7.62 | 2.7 | 20.00 |
| | 18:15 | 81.2 | 931.5 | 2.7 | 25355 | 7.62 | 3.5 | 19.97 |
| | 18:30 | 81.1 | 931.5 | 2.7 | 26573 | 7.63 | 2.8 | 19.94 |
| | 18:45 | 81.1 | 931.5 | 2.7 | 27789 | 7.63 | 1.9 | 19.92 |
| | 19:00 | 81.1 | 931.5 | 2.7 | 29006 | 7.64 | 1.9 | 19.91 |
| | 19:30 | 81.2 | 931.5 | 2.7 | 31442 | 7.65 | 2.0 | 19.89 |
| | 20:00 | 81.3 | 931.5 | 2.7 | 33880 | 7.66 | 1.7 | 19.88 |
| | 20:30 | 81.2 | 931.5 | 2.7 | 36317 | 7.67 | 1.9 | 19.89 |
| | 21:00 | 81.4 | 931.5 | 2.7 | 38760 | 7.67 | 1.7 | 19.88 |
| | 21:30 | 81.3 | 931.6 | 2.8 | 41200 | 7.67 | 1.8 | 19.88 |
| | 22:00 | 81.3 | 931.6 | 2.8 | 43640 | 7.68 | 2.1 | 19.87 |
| | 22:30 | 81.5 | 931.6 | 2.8 | 46086 | 7.68 | 2.2 | 19.87 |
| 9/8/2016 | 23:00 | 81.5 | 931.6 | 2.8 | 48530 | 7.69 | 1.8 | 19.87 |
| | 23:30 | 81.4 | 931.6 | 2.8 | 50972 | 7.68 | 1.7 | 19.86 |
| | 0:00 | 81.6 | 931.6 | 2.8 | 53421 | 7.69 | 1.7 | 19.83 |

**Table 8.1-3 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 9/9/2016 | 0:30 | 81.4 | 931.6 | 2.8 | 55864 | 7.69 | 1.8 | 19.81 |
| | 1:00 | 81.6 | 931.6 | 2.8 | 58312 | 7.70 | 1.6 | 19.81 |
| | 1:30 | 81.7 | 931.6 | 2.8 | 60762 | 7.70 | 1.4 | 19.80 |
| | 2:00 | 81.6 | 931.6 | 2.8 | 63211 | 7.70 | 1.4 | 19.79 |
| | 2:30 | 81.6 | 931.6 | 2.8 | 65658 | 7.71 | 1.5 | 19.79 |
| | 3:00 | 81.5 | 931.6 | 2.8 | 68103 | 7.71 | 1.5 | 19.79 |
| | 3:30 | 81.6 | 931.6 | 2.8 | 70550 | 7.71 | 1.2 | 19.79 |
| | 4:00 | 81.7 | 931.6 | 2.8 | 73000 | 7.71 | 1.2 | 19.78 |
| | 4:30 | 81.4 | 931.6 | 2.8 | 75443 | 7.71 | 1.2 | 19.77 |
| | 5:00 | 81.7 | 931.6 | 2.8 | 77895 | 7.72 | 1.2 | 19.78 |
| | 5:30 | 81.5 | 931.6 | 2.8 | 80340 | 7.71 | 1.3 | 19.77 |
| | 6:00 | 81.7 | 931.6 | 2.8 | 82791 | 7.72 | 1.2 | 19.77 |
| | 6:30 | 81.7 | 931.6 | 2.8 | 85241 | 7.72 | 1.2 | 19.77 |
| | 7:00 | 82.0 | 931.6 | 2.8 | 87700 | 7.72 | 1.2 | 19.77 |
| | 7:30 | 81.6 | 931.6 | 2.8 | 90149 | 7.72 | 1.2 | 19.80 |
| | 8:00 | 81.9 | 931.7 | 2.9 | 92607 | 7.73 | 1.1 | 19.84 |
| | 8:30 | 81.9 | 931.7 | 2.9 | 95063 | 7.73 | 1.2 | 19.85 |
| | 9:00 | 81.5 | 931.7 | 2.9 | 97509 | 7.73 | 1.2 | 19.87 |
| | 9:30 | 81.5 | 931.7 | 2.9 | 99955 | 7.73 | 1.1 | 19.87 |
| | 10:00 | 81.7 | 931.7 | 2.9 | 102407 | 7.73 | 1.2 | 19.88 |
| | 10:30 | 81.4 | 931.7 | 2.9 | 104850 | 7.73 | 1.2 | 19.89 |
| | 11:00 | 81.8 | 931.7 | 2.9 | 107305 | 7.73 | 1.2 | 19.91 |
| | 11:30 | 81.2 | 931.7 | 2.9 | 109742 | 7.74 | 1.4 | 19.95 |
| | 12:00 | 81.8 | 931.7 | 2.9 | 112195 | 7.73 | 1.2 | 19.99 |
| | 12:30 | 81.3 | 931.6 | 2.8 | 114635 | 7.73 | 1.1 | 20.02 |
| | 13:00 | 81.7 | 931.6 | 2.8 | 117085 | 7.73 | 1.2 | 19.98 |
| | 13:30 | 81.5 | 931.6 | 2.8 | 119530 | 7.73 | 1.2 | 19.97 |
| | 14:00 | 81.5 | 931.6 | 2.8 | 121976 | 7.73 | 1.2 | 19.98 |
| | 14:30 | 81.6 | 931.6 | 2.8 | 124424 | 7.73 | 1.3 | 19.97 |
| | 15:00 | 81.4 | 931.6 | 2.8 | 126867 | 7.73 | 1.3 | 19.97 |

[a] gpm = Gallon per minute.
[b] ft btoc = Feet below top of casing.
[c] NTU = Nephelometric turbidity unit.
[d] This is the only data point available for well development.
[e] NR = Not recorded.

**Table 8.1-4**
**Field Water-Quality Parameters and Well Performance for Development of Well CrIN-4**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 6/19/2016 | 15:36 | NR[d] | NR | NR | NR | 8.70 | 10.6 | 20.10 |
| | 15:38 | NR | NR | NR | NR | 8.61 | 3.2 | 20.16 |
| | 17:11 | NR | NR | NR | NR | 12.19 | 4.9 | 21.63 |
| | 17:12 | NR | NR | NR | NR | 12.10 | 1.3 | 21.20 |
| | 18:37 | NR | NR | NR | NR | 12.07 | 4.8 | 20.80 |
| 6/20/2016 | 12:15 | 75.00 | 1090.0 | 0.00 | 0 | 14.14 | 3.5 | 20.71 |
| | 12:33 | 75.00 | 1080.2 | -9.83 | 1020 | 14.46 | 24.3 | 21.32 |
| | 12:48 | 75.00 | 1090.3 | 0.23 | 2153 | 14.20 | 4.6 | 20.31 |
| | 13:03 | 75.00 | 1090.3 | 0.30 | 3280 | 14.33 | 0.6 | 22.67 |
| | 13:18 | 75.00 | 1090.4 | 0.37 | 4413 | 14.24 | 1.2 | 20.71 |
| | 13:33 | 75.00 | 1090.5 | 0.42 | 5542 | 14.27 | 2.4 | 20.49 |
| | 13:48 | 75.00 | 1090.5 | 0.48 | 6682 | 14.40 | 2.8 | 20.95 |
| **Step Test** | | | | | | | | |
| 6/21/2016 | 10:15 | 38.50 | 1080.7 | 1.2 | 12369 | 7.93 | 5.5 | 19.07 |
| | 10:30 | 37.50 | 1080.7 | 1.2 | 12932 | NR | NR | NR |
| | 10:45 | 37.46 | 1080.6 | 1.1 | 13494 | 7.94 | 8.8 | 19.93 |
| | 11:00 | 37.40 | 1081.2 | 1.7 | 14055 | 7.92 | 6.8 | 19.68 |
| | 11:15 | 60.50 | 1082.9 | 3.4 | 14922 | 7.91 | NR | 19.66 |
| | 11:30 | 59.60 | 1083.0 | 3.5 | 15816 | NR | NR | NR |
| | 11:45 | 59.80 | 1083.0 | 3.5 | 16713 | NR | NR | NR |
| | 12:00 | 59.26 | 1085.0 | 5.5 | 17602 | NR | NR | NR |
| | 12:15 | 74.00 | 1085.7 | 6.2 | 18718 | NR | NR | NR |
| | 12:30 | 74.73 | 1085.8 | 6.3 | 19839 | 7.90 | 2.5 | 19.75 |
| | 12:45 | 74.80 | 1085.8 | 6.3 | 20961 | 7.89 | 3.1 | 19.55 |
| | 13:00 | 74.93 | 1083.7 | 4.2 | 22085 | 7.89 | 2.7 | 19.08 |
| **24-h Aquifer Test** | | | | | | | | |
| 6/21/2016 | 15:15 | 62.50 | 1083.1 | 3.6 | 22870 | 6.93 | 4.2 | 21.62 |
| | 15:30 | 62.00 | 1083.2 | 3.7 | 23800 | 7.22 | 5.0 | 21.58 |
| | 15:45 | 62.00 | 1083.2 | 3.7 | 24731 | 7.23 | 0.9 | 21.20 |
| | 16:00 | 62.00 | 1083.2 | 3.7 | 25661 | 7.21 | 3.1 | 21.04 |
| | 16:15 | 62.20 | 1083.2 | 3.7 | 26594 | 7.20 | 1.4 | 20.81 |
| | 16:30 | 61.86 | 1083.2 | 3.7 | 27522 | 7.25 | 2.8 | 20.77 |
| | 16:45 | 61.86 | 1083.3 | 3.8 | 28450 | 7.26 | 16.6 | 20.76 |
| | 17:00 | 62.00 | 1083.3 | 3.8 | 29380 | 7.28 | 0.0 | 20.99 |

**Table 8.1-4 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 6/21/2016 | 17:15 | 61.60 | 1083.3 | 3.8 | 30304 | 7.27 | 2.0 | 20.81 |
| | 17:30 | 61.80 | 1083.3 | 3.8 | 31232 | 7.30 | 0.0 | 20.78 |
| | 17:45 | 61.86 | 1083.3 | 3.8 | 32160 | 7.30 | 3.9 | 20.69 |
| | 18:00 | 61.53 | 1083.3 | 3.8 | 33083 | 7.29 | 2.7 | 20.69 |
| | 18:15 | 61.86 | 1083.3 | 3.8 | 34011 | 7.28 | 9.1 | 20.55 |
| | 18:30 | 61.73 | 1083.3 | 3.8 | 34937 | 7.30 | 0.6 | 20.55 |
| | 18:45 | 61.73 | 1083.3 | 3.8 | 35863 | 7.32 | 6.7 | 20.53 |
| | 19:00 | 61.86 | 1083.3 | 3.8 | 36791 | 7.35 | 1.9 | 20.55 |
| | 19:15 | 61.80 | 1083.3 | 3.8 | 37718 | 7.20 | 4.1 | 20.57 |
| | 19:30 | 61.73 | 1083.4 | 3.9 | 38644 | 7.26 | 0.5 | 20.55 |
| | 19:45 | 61.93 | 1083.4 | 3.9 | 39573 | 7.35 | 1.8 | 20.59 |
| | 20:00 | 61.73 | 1083.4 | 3.9 | 40499 | 7.39 | 6.1 | 20.48 |
| | 20:15 | 61.82 | 1083.4 | 3.9 | 41427 | 7.38 | 2.4 | 20.39 |
| | 20:30 | 62.20 | 1083.4 | 3.9 | 42360 | 7.41 | 3.0 | 20.43 |
| | 20:45 | 62.26 | 1083.4 | 3.9 | 43294 | 7.39 | 0.5 | 20.44 |
| | 21:00 | 61.93 | 1083.5 | 4.0 | 44223 | 7.36 | 202.9 | 20.41 |
| | 21:15 | 68.93 | 1083.4 | 3.9 | 45257 | 7.35 | 0.0 | 20.41 |
| | 21:30 | 55.60 | 1083.5 | 4.0 | 46091 | 7.42 | 0.4 | 20.37 |
| | 21:45 | 62.13 | 1083.5 | 4.0 | 47023 | 7.38 | 0.6 | 20.33 |
| | 22:00 | 62.33 | 1083.5 | 4.0 | 47958 | 7.40 | 16.5 | 20.32 |
| | 22:15 | 61.73 | 1083.5 | 4.0 | 48884 | 7.39 | 0.1 | 20.28 |
| | 22:30 | 61.93 | 1083.5 | 4.0 | 49813 | 7.42 | 0.6 | 20.29 |
| | 22:45 | 62.46 | 1083.5 | 4.0 | 50750 | 7.41 | 0.0 | 20.32 |
| | 23:00 | 61.40 | 1083.4 | 3.9 | 51671 | 7.39 | 3.0 | 20.25 |
| | 23:15 | 61.73 | 1083.5 | 4.0 | 52597 | 7.10 | 0.0 | 20.28 |
| | 23:30 | 61.66 | 1083.4 | 3.9 | 53522 | 7.18 | 0.0 | 20.26 |
| | 23:45 | 67.86 | 1083.5 | 4.0 | 54540 | 7.19 | 0.0 | 20.22 |
| 6/22/2016 | 0:00 | 55.73 | 1083.5 | 4.0 | 55376 | 7.23 | 0.0 | 20.19 |
| | 0:15 | 61.73 | 1083.4 | 3.9 | 56302 | 7.34 | 0.0 | 20.17 |
| | 0:30 | 61.33 | 1083.4 | 3.9 | 57222 | 7.43 | 2.1 | 20.18 |
| | 0:45 | 68.73 | 1083.4 | 3.9 | 58253 | 7.46 | 0.0 | 20.19 |
| | 1:00 | 55.06 | 1083.4 | 3.9 | 59079 | 7.41 | 154.2 | 20.15 |
| | 1:15 | 61.80 | 1083.4 | 3.9 | 60006 | 7.47 | 18.5 | 20.15 |
| | 1:30 | 61.80 | 1083.4 | 3.9 | 60933 | 7.52 | 24.9 | 20.11 |
| | 1:45 | 61.80 | 1083.4 | 3.9 | 61860 | 7.52 | 51.5 | 20.12 |

**Table 8.1-4 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 6/22/2016 | 2:00 | 61.60 | 1083.4 | 3.9 | 62784 | 7.46 | 20.5 | 20.13 |
| | 2:15 | 61.60 | 1083.4 | 3.9 | 63708 | 7.21 | 13.1 | 20.14 |
| | 2:30 | 61.80 | 1083.4 | 3.9 | 64635 | 7.43 | 19.9 | 20.12 |
| | 2:45 | 61.80 | 1083.4 | 3.9 | 65562 | 7.48 | 20.1 | 20.09 |
| | 3:00 | 61.60 | 1083.4 | 3.9 | 66486 | 7.47 | 417.5 | 20.10 |
| | 3:15 | 61.66 | 1083.4 | 3.9 | 67411 | 7.30 | 6.8 | 20.07 |
| | 3:30 | 61.73 | 1083.4 | 3.9 | 68337 | 7.37 | 9.3 | 20.02 |
| | 3:45 | 61.80 | 1083.4 | 3.9 | 69264 | 7.34 | 2.8 | 20.06 |
| | 4:00 | 61.73 | 1083.4 | 3.9 | 70190 | 7.28 | 5.0 | 20.03 |
| | 4:15 | 61.73 | 1083.4 | 3.9 | 71116 | 7.36 | 7.9 | 20.03 |
| | 4:30 | 61.80 | 1083.4 | 3.9 | 72043 | 7.50 | 1217.6 | 20.04 |
| | 4:45 | 61.66 | 1083.4 | 3.9 | 72968 | 7.53 | 14.0 | 20.03 |
| | 5:00 | 61.60 | 1083.4 | 3.9 | 73892 | 7.53 | 1.0 | 20.03 |
| | 5:15 | 61.66 | 1083.4 | 3.9 | 74817 | 7.53 | 1094.8 | 20.02 |
| | 5:30 | 61.73 | 1083.4 | 3.9 | 75743 | 7.54 | 1220.0 | 19.97 |
| | 5:45 | 61.86 | 1083.4 | 3.9 | 76671 | 7.56 | 0.6 | 19.96 |
| | 6:00 | 61.66 | 1083.4 | 3.9 | 77596 | 7.59 | 2.7 | 19.90 |
| | 6:15 | 61.60 | 1083.4 | 3.9 | 78520 | 7.52 | 4.8 | 19.96 |
| | 6:30 | 61.60 | 1083.4 | 3.9 | 79444 | 7.28 | 1.3 | 20.02 |
| | 6:45 | 61.80 | 1083.4 | 3.9 | 80371 | 7.48 | 17.7 | 20.04 |
| | 7:00 | 61.60 | 1083.4 | 3.9 | 81295 | 7.54 | 3.2 | 20.06 |
| | 7:15 | 65.66 | 1083.4 | 3.9 | 82271 | 7.34 | 4.4 | 20.03 |
| | 7:30 | 64.93 | 1083.4 | 3.9 | 83245 | 7.39 | 2.1 | 20.05 |
| | 7:45 | 62.20 | 1083.4 | 3.9 | 84178 | 7.40 | 0.0 | 20.10 |
| | 8:00 | 54.93 | 1083.4 | 3.9 | 85002 | 7.46 | 1.8 | 20.14 |
| | 8:15 | 61.66 | 1083.4 | 3.9 | 85927 | 7.52 | 2.9 | 20.18 |
| | 8:30 | 61.60 | 1083.4 | 3.9 | 86851 | 7.57 | 2.0 | 20.25 |
| | 8:45 | 61.86 | 1083.4 | 3.9 | 87779 | 7.45 | 1.4 | 20.28 |
| | 9:00 | 61.80 | 1083.4 | 3.9 | 88706 | 7.51 | 3.1 | 20.35 |
| | 9:15 | 61.80 | 1083.4 | 3.9 | 89633 | 7.64 | 1.3 | 20.44 |
| | 9:30 | 61.93 | 1083.4 | 3.9 | 90562 | 7.66 | 1.7 | 20.55 |
| | 9:45 | 61.73 | 1083.4 | 3.9 | 91538 | 7.59 | 11.3 | 20.43 |
| | 10:00 | 61.60 | 1083.4 | 3.9 | 92512 | 7.64 | 0.0 | 20.60 |
| | 10:15 | 62.33 | 1083.4 | 3.9 | 93338 | 7.61 | 1.8 | 20.90 |
| | 10:30 | 61.86 | 1083.4 | 3.9 | 94266 | 7.61 | 2.8 | 21.08 |

**Table 8.1-4 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 6/22/2016 | 10:45 | 61.73 | 1083.4 | 3.9 | 95192 | 7.58 | 1.2 | 21.04 |
| | 11:00 | 61.80 | 1083.4 | 3.9 | 96119 | 7.62 | 4.3 | 20.96 |
| | 11:15 | 61.73 | 1083.4 | 3.9 | 97045 | 7.51 | 0.8 | 21.46 |
| | 11:30 | 62.00 | 1083.4 | 3.9 | 97975 | 7.54 | 1.9 | 21.28 |
| | 11:45 | 62.06 | 1083.4 | 3.9 | 98906 | 7.56 | 3.1 | 21.23 |
| | 12:00 | 62.13 | 1083.4 | 3.9 | 99838 | 7.46 | 0.2 | 21.24 |
| | 12:15 | 61.46 | 1083.4 | 3.9 | 100760 | 7.58 | 2.5 | 21.31 |
| | 12:30 | 62.06 | 1083.4 | 3.9 | 101691 | 7.60 | 1.6 | 21.39 |
| | 12:45 | 61.66 | 1083.3 | 3.8 | 102616 | 7.62 | 2.8 | 21.30 |
| | 13:00 | 61.66 | 1083.3 | 3.8 | 103541 | 7.57 | 3.1 | 20.92 |
| | 13:15 | 62.13 | 1083.3 | 3.8 | 104473 | 7.67 | 3.1 | 20.92 |
| | 13:30 | 62.00 | 1083.3 | 3.8 | 105403 | 7.69 | 0.9 | 20.71 |
| | 13:45 | 62.13 | 1083.3 | 3.8 | 106335 | 7.69 | 2.5 | 20.70 |

[a] gpm = Gallon per minute.

[b] ft btoc = Feet below top of casing.

[c] NTU = Nephelometric turbidity unit.

[d] NR = Not recorded.

**Table 8.1-5**
**Field Water-Quality Parameters and Well Performance for Development of Well CrIN-5**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **Well Development** | | | | | | | | |
| 8/2/2016 | 18:14 | NR[d] | NR | NR | NR | 6.37 | 17.1 | 20.56 |
| | 18:22 | NR | NR | NR | NR | 6.93 | 8.0 | 20.42 |
| | 18:37 | NR | NR | NR | NR | 7.14 | 3.6 | 19.64 |
| | 18:52 | NR | NR | NR | NR | 7.22 | 1.7 | 19.57 |
| | 18:58 | NR | NR | NR | NR | 7.26 | 2.6 | 19.54 |
| | 19:00 | NR | NR | NR | NR | 7.27 | 0.5 | 19.55 |
| | 19:04 | NR | NR | NR | NR | 7.30 | 0.5 | 19.61 |
| | 19:07 | NR | NR | NR | NR | 7.25 | 0.2 | 19.66 |
| | 19:15 | NR | NR | NR | NR | 7.37 | 0.1 | 19.69 |
| **Step Test** | | | | | | | | |
| 8/3/2016 | 11:00 | NR | 1157.9 | 0.9 | 0 | NR | NR | NR |
| | 11:04 | NR | 1159.1 | 0.3 | 373 | NR | NR | NR |
| | 11:12 | 32.00 | 1159.2 | 0.4 | 713 | NR | NR | NR |
| | 11:15 | 32.00 | 1159.2 | 0.4 | 843 | NR | NR | NR |
| | 11:30 | 32.00 | 1159.2 | 0.4 | 1313 | NR | NR | NR |
| | 11:45 | 32.00 | 1159.3 | 0.4 | 1782 | NR | NR | NR |
| | 12:00 | 32.00 | 1159.3 | 0.4 | 2268 | NR | NR | NR |
| | 12:09 | 50.00 | 1162.9 | 4.1 | 2693 | NR | NR | NR |
| | 12:15 | 50.00 | 1163.1 | 4.2 | 2993 | NR | NR | NR |
| | 12:30 | 50.00 | 1163.1 | 4.3 | 3791 | NR | NR | NR |
| | 12:45 | 50.00 | 1163.2 | 4.4 | 4515 | NR | NR | NR |
| | 13:00 | 50.00 | 1162.6 | 3.8 | 5284 | NR | NR | NR |
| | 13:08 | 68.00 | 1153.7 | 5.2 | 5793 | NR | NR | NR |
| | 13:15 | 68.00 | 1156.0 | 2.8 | 6402 | NR | NR | NR |
| | 13:30 | 68.00 | 1156.1 | 2.8 | 7344 | NR | NR | NR |
| | 13:45 | 69.00 | 1156.0 | 2.8 | 8318 | NR | NR | NR |
| | 14:00 | 68.00 | 1156.0 | 2.8 | 9343 | NR | NR | NR |
| **24-h Aquifer Test** | | | | | | | | |
| 8/3/2016 | 16:00 | NR | 1161.4 | 2.6 | 9343 | NR | NR | NR |
| | 16:03 | NR | 1161.5 | 2.6 | 9371 | NR | NR | NR |
| | 16:06 | 60.00 | 1161.4 | 2.6 | 9573 | NR | NR | NR |
| | 16:15 | 61.00 | 1161.5 | 2.6 | 10059 | 7.19 | 12.5 | 20.84 |
| | 16:30 | 61.00 | 1161.5 | 2.6 | 10964 | 7.21 | 0.0 | 21.00 |
| | 16:45 | 61.00 | 1161.5 | 2.7 | 11876 | 7.27 | 0.0 | 20.88 |
| | 17:00 | 61.00 | 1161.5 | 2.7 | 12793 | 7.32 | 0.0 | 20.74 |
| | 17:15 | 61.00 | 1161.5 | 2.7 | 13709 | 7.33 | 0.0 | 20.62 |

**Table 8.1-5 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 8/3/2016 | 17:30 | 61.00 | 1161.5 | 2.7 | 14624 | 7.36 | 0.0 | 20.57 |
| | 17:45 | 61.00 | 1161.5 | 2.7 | 15540 | 7.38 | 0.0 | 20.58 |
| | 18:00 | 61.00 | 1161.5 | 2.7 | 16455 | 7.39 | 0.0 | 20.56 |
| | 18:15 | 61.00 | 1161.6 | 2.7 | 17372 | 7.39 | 0.0 | 20.56 |
| | 18:30 | 61.00 | 1161.6 | 2.8 | 18289 | 7.40 | 0.0 | 20.43 |
| | 18:45 | 61.00 | 1161.6 | 2.8 | 19205 | 7.40 | 0.0 | 20.46 |
| | 19:00 | 61.00 | 1161.6 | 2.7 | 20122 | 7.38 | 0.0 | 20.27 |
| | 19:15 | 61.00 | 1161.6 | 2.7 | 21039 | 7.40 | 0.0 | 19.65 |
| | 19:30 | 61.00 | 1161.6 | 2.7 | 21954 | 7.43 | 1.7 | 19.88 |
| | 19:45 | 61.00 | 1161.6 | 2.7 | 22874 | 7.46 | 0.8 | 19.90 |
| | 20:00 | 61.00 | 1161.6 | 2.7 | 23793 | 7.47 | 0.4 | 20.00 |
| | 20:15 | 61.00 | 1161.6 | 2.7 | 24712 | 7.46 | 0.0 | 20.01 |
| | 20:30 | 61.00 | 1161.6 | 2.8 | 25623 | 7.46 | 0.0 | 20.05 |
| | 20:45 | 61.00 | 1161.6 | 2.7 | 26540 | 7.46 | 0.0 | 19.98 |
| | 21:00 | 61.00 | 1161.6 | 2.8 | 27456 | 7.44 | 0.0 | 19.83 |
| | 21:15 | 61.00 | 1161.6 | 2.7 | 28365 | 7.45 | 0.0 | 19.93 |
| | 21:30 | 61.00 | 1161.6 | 2.7 | 29278 | 7.45 | 0.0 | 20.02 |
| | 21:45 | 61.00 | 1161.6 | 2.7 | 30194 | 7.46 | 0.0 | 20.11 |
| | 22:00 | 61.00 | 1161.6 | 2.7 | 31106 | 7.46 | 0.0 | 20.19 |
| | 22:15 | 61.00 | 1161.6 | 2.7 | 32022 | 7.46 | 0.0 | 20.22 |
| | 22:30 | 61.00 | 1161.6 | 2.8 | 32933 | 7.46 | 0.0 | 20.23 |
| | 22:45 | 61.00 | 1161.6 | 2.8 | 33846 | 7.46 | 0.0 | 20.19 |
| | 23:00 | 61.00 | 1161.6 | 2.7 | 34758 | 7.47 | 0.0 | 20.23 |
| | 23:15 | 61.00 | 1161.6 | 2.7 | 35671 | 7.47 | 0.0 | 20.19 |
| | 23:30 | 61.00 | 1161.6 | 2.8 | 36583 | 7.46 | 0.0 | 20.17 |
| | 23:45 | 61.00 | 1161.6 | 2.7 | 37494 | 7.46 | 0.0 | 20.18 |
| 8/4/2016 | 0:00 | 61.00 | 1161.6 | 2.7 | 38407 | 7.47 | 0.0 | 20.15 |
| | 0:15 | 61.00 | 1161.6 | 2.7 | 39323 | 7.46 | 0.0 | 20.06 |
| | 0:30 | 61.00 | 1161.5 | 2.7 | 40242 | 7.47 | 0.0 | 20.05 |
| | 0:45 | 61.00 | 1161.6 | 2.7 | 41159 | 7.47 | 0.0 | 20.04 |
| | 1:00 | 61.00 | 1161.6 | 2.8 | 42071 | 7.46 | 0.0 | 20.01 |
| | 1:15 | 61.00 | 1161.6 | 2.7 | 42990 | 7.47 | 0.0 | 20.02 |
| | 1:30 | 61.00 | 1161.6 | 2.8 | 43905 | 7.47 | 0.0 | 20.04 |
| | 1:45 | 61.00 | 1161.6 | 2.8 | 44816 | 7.47 | 0.0 | 20.05 |
| | 2:00 | 61.00 | 1161.6 | 2.8 | 45728 | 7.48 | 0.0 | 20.10 |
| | 2:15 | 61.00 | 1161.6 | 2.8 | 46642 | 7.47 | 0.0 | 20.07 |
| | 2:30 | 61.00 | 1161.6 | 2.7 | 47557 | 7.47 | 0.0 | 20.08 |

**Table 8.1-5 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal.) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 8/4/2016 | 2:45 | 61.00 | 1161.6 | 2.7 | 48472 | 7.48 | 0.0 | 20.14 |
| | 3:00 | 61.00 | 1161.6 | 2.7 | 49387 | 7.48 | 0.0 | 20.09 |
| | 3:15 | 61.00 | 1161.6 | 2.8 | 50297 | 7.48 | 0.0 | 20.08 |
| | 3:30 | 61.00 | 1161.6 | 2.8 | 51209 | 7.48 | 0.0 | 20.09 |
| | 3:45 | 61.00 | 1161.6 | 2.7 | 52127 | 7.48 | 0.0 | 20.03 |
| | 4:00 | 61.50 | 1161.6 | 2.7 | 53053 | 7.48 | 0.0 | 20.01 |
| | 4:15 | 61.00 | 1161.5 | 2.7 | 53976 | 7.48 | 0.0 | 20.03 |
| | 4:30 | 61.00 | 1161.5 | 2.7 | 54894 | 7.48 | 0.0 | 20.02 |
| | 4:45 | 61.00 | 1161.6 | 2.7 | 55816 | 7.48 | 0.0 | 19.95 |
| | 5:00 | 61.50 | 1161.6 | 2.7 | 56739 | 7.48 | 0.0 | 19.97 |
| | 5:15 | 61.00 | 1161.6 | 2.7 | 57663 | 7.48 | 0.0 | 19.92 |
| | 5:30 | 61.00 | 1161.6 | 2.8 | 58580 | 7.49 | 0.0 | 19.85 |
| | 5:45 | 61.00 | 1161.6 | 2.8 | 59501 | 7.48 | 0.0 | 19.86 |
| | 6:00 | 61.00 | 1161.6 | 2.8 | 60421 | 7.49 | 0.0 | 19.94 |
| | 6:15 | 61.50 | 1161.6 | 2.8 | 61345 | 7.49 | 0.0 | 19.92 |
| | 6:30 | 61.00 | 1161.6 | 2.8 | 62267 | 7.49 | 0.0 | 19.95 |
| | 6:45 | 61.00 | 1161.6 | 2.8 | 63188 | 7.49 | 0.0 | 19.93 |
| | 7:00 | 61.50 | 1161.6 | 2.8 | 64115 | 7.49 | 0.0 | 20.00 |
| | 7:15 | 61.50 | 1161.7 | 2.8 | 65036 | 7.49 | 0.0 | 20.07 |
| | 7:30 | 61.50 | 1161.7 | 2.8 | 65954 | 7.49 | 0.0 | 20.13 |
| | 7:45 | 61.00 | 1161.6 | 2.8 | 66878 | 7.49 | 0.0 | 20.16 |
| | 8:00 | 61.00 | 1161.7 | 2.8 | 67801 | 7.49 | 0.0 | 20.22 |
| | 8:15 | 61.00 | 1161.7 | 2.9 | 68724 | 7.49 | 0.0 | 20.34 |
| | 8:30 | 61.50 | 1161.7 | 2.9 | 69654 | 7.51 | 0.0 | 20.46 |
| | 8:45 | 61.50 | 1161.7 | 2.9 | 70581 | 7.50 | 0.0 | 20.59 |
| | 9:00 | 61.50 | 1161.7 | 2.8 | 71504 | 7.48 | 0.0 | 20.65 |
| | 9:15 | 61.50 | 1161.6 | 2.8 | 72437 | 7.46 | 0.0 | 20.77 |
| | 9:30 | 61.50 | 1161.6 | 2.8 | 73366 | 7.42 | 0.0 | 20.89 |
| | 9:45 | 62.00 | 1161.7 | 2.8 | 74294 | 7.38 | 0.0 | 20.83 |
| | 10:00 | 62.00 | 1161.6 | 2.8 | 75216 | 7.35 | 0.0 | 20.80 |
| | 10:15 | 61.50 | 1161.7 | 2.8 | 76141 | 7.32 | 0.0 | 20.80 |
| | 10:30 | 62.00 | 1161.7 | 2.8 | 77064 | 7.31 | 0.0 | 20.80 |
| | 10:45 | 62.00 | 1161.7 | 2.9 | 77985 | 7.31 | 0.0 | 20.88 |
| | 11:00 | 61.00 | 1161.7 | 2.8 | 78910 | 7.32 | 0.0 | 20.86 |
| | 11:15 | 61.00 | 1161.7 | 2.8 | 79844 | 7.35 | 0.0 | 20.91 |
| | 11:30 | 61.00 | 1161.7 | 2.8 | 80759 | 7.37 | 0.0 | 20.90 |
| | 11:45 | 61.00 | 1161.7 | 2.9 | 81686 | 7.38 | 0.0 | 20.91 |

**Table 8.1-5 (continued)**

| Date | Time | Pumping Rate (gpm[a]) | Depth to Water (ft btoc[b]) | Drawdown (ft) | Cumulative Purge Volume (gal) | pH | Turbidity (NTU[c]) | Temperature (Degree C) |
|---|---|---|---|---|---|---|---|---|
| **24-h Aquifer Test** | | | | | | | | |
| 8/4/2016 | 12:00 | 61.00 | 1161.7 | 2.9 | 82617 | 7.38 | 0.0 | 21.07 |
| | 12:15 | 61.00 | 1161.7 | 2.9 | 83545 | 7.34 | 0.0 | 21.35 |
| | 12:30 | 62.00 | 1161.7 | 2.8 | 84471 | 7.32 | 0.0 | 21.30 |
| | 12:45 | 62.00 | 1161.7 | 2.9 | 85404 | 7.30 | 0.0 | 21.62 |
| | 13:00 | 62.00 | 1161.7 | 2.8 | 86335 | 7.27 | 0.0 | 21.64 |
| | 13:15 | 62.00 | 1161.6 | 2.8 | 87266 | 7.23 | 0.0 | 21.70 |
| | 13:30 | 62.00 | 1161.7 | 2.8 | 88196 | 7.19 | 0.0 | 21.42 |
| | 13:45 | 61.50 | 1161.7 | 2.8 | 89124 | 7.16 | 0.0 | 21.62 |
| | 14:00 | 61.50 | 1161.6 | 2.8 | 90056 | 7.16 | 0.0 | 21.82 |
| | 14:15 | 62.00 | 1161.7 | 2.8 | 90987 | 7.12 | 0.0 | 21.84 |
| | 14:30 | 61.00 | 1161.6 | 2.8 | 91921 | 7.08 | 0.0 | 22.13 |
| | 14:45 | 62.00 | 1161.6 | 2.8 | 92849 | 7.06 | 0.0 | 22.16 |
| | 15:00 | 62.00 | 1161.6 | 2.8 | 93781 | 7.00 | 0.0 | 21.79 |
| | 15:15 | 61.50 | 1154.8 | 4.0 | 94706 | 6.96 | 0.0 | 21.34 |
| | 15:30 | 62.00 | 1156.0 | 2.8 | 95636 | 6.92 | 0.0 | 21.34 |
| | 15:45 | 62.00 | 1156.0 | 2.8 | 96562 | 6.89 | 0.0 | 21.36 |
| | 16:00 | 62.00 | 1156.0 | 2.8 | 96989 | 6.87 | 0.0 | 21.33 |
| | 16:04 | NR | 1156.0 | 2.8 | 97737 | NR | NR | NR |

[a] gpm = Gallon per minute.

[b] ft btoc = Feet below top of casing.

[c] NTU = Nephelometric turbidity unit.

[d] NR = Not reported.

**Table 8.2-1**
**CrIN Aquifer Testing Summary**

| Well | Step Tests Date | Rates (gpm*) | Constant Rate Date | Rate (gpm) |
|---|---|---|---|---|
| CrIN-2 | 5/31/16 | 30, 50, 70 | 6/1/16 | 58 |
| CrIN-4 | 6/21/16 | 38, 60, 75 | 6/21/16 | 62 |
| CrIN-1 | 7/18/16 | 30, 50 70 | 7/19/16 | 70 |
| CrIN-5 | 8/3/16 | 32, 50, 68 | 8/3/16 | 61 |
| CrIN-3 | 9/8/16 | 50, 60, 80 | 9/8/16 | 81 |

* gpm = Gallon per minute.

**Table 8.5-1**
**CrIN Wells Survey Coordinates**

| Identification | Northing | Easting | Elevation |
|---|---|---|---|
| CrIN-1 ground surface near vault | 1768282.466 | 1640104.877 | 6704.634 |
| CrIN-1 brass cap embedded in vault | 1768296.963 | 1640089.494 | 6705.362 |
| CrIN-1 top of well casing | 1768293.719 | 1640089.572 | 6702.379 |
| | | | |
| CrIN-2 ground surface near vault | 1767800.123 | 1639781.404 | 6731.978 |
| CrIN-2 brass cap embedded in vault | 1767800.805 | 1639791.482 | 6732.415 |
| CrIN-2 top of well casing | 1767797.468 | 1639791.835 | 6729.616 |
| | | | |
| CrIN-3 ground surface near vault | 1767144.868 | 1639884.564 | 6721.625 |
| CrIN-3 brass cap embedded in vault | 1767139.006 | 1639887.412 | 6722.301 |
| CrIN-3 top of well casing | 1767135.850 | 1639888.440 | 6719.201 |
| | | | |
| CrIN-4 ground surface near vault | 1767025.389 | 1638874.060 | 6895.295 |
| CrIN-4 brass cap embedded in vault | 1767032.919 | 1638863.128 | 6895.950 |
| CrIN-4 top of well casing | 1767029.532 | 1638871.688 | 6892.871 |
| | | | |
| CrIN-5 ground surface near vault | 1767028.501 | 1638688.837 | 6902.375 |
| CrIN-5 brass cap embedded in vault | 1767025.241 | 1638678.338 | 6902.980 |
| CrIN-5 top of well casing | 1767023.434 | 1638680.808 | 6900.291 |

Notes: All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in ft amsl using the National Geodetic Vertical Datum of 1929. Provisional survey conducted. Wells will be resurveyed when vault is installed.

**Table 8.6-1**
**Chromium Injection Well CrIN-1 Sample Information**

| Event ID | Sample ID | Date Collected | Description | Sample Matrix |
|---|---|---|---|---|
| 10718 | WSTMO-16-121713 | 05/31/2016 | Drilling fluids (top) | Fluid |
| 10718 | WSTMO-16-121717 | 05/31/2016 | Drilling fluids (top) field duplicate | Fluid |
| 10718 | WSTMO-16-121720 | 05/31/2016 | Drilling fluids (top) trip blank | Fluid |
| 10718 | WSTMO-16-121714 | 06/20/2016 | Drilling fluids (middle) | Fluid |
| 10718 | WSTMO-16-121716 | 06/20/2016 | Drilling fluids (middle) field duplicate | Fluid |
| 10718 | WSTMO-16-121721 | 06/20/2016 | Drilling fluids (middle) trip blank | Fluid |
| 10718 | WSTMO-16-121715 | 06/20/2016 | Drilling fluids (bottom) | Fluid |
| 10718 | WSTMO-16-121718 | 06/20/2016 | Drilling fluids (bottom) field duplicate | Fluid |
| 10718 | WSTMO-16-121719 | 06/20/2016 | Drilling fluids (bottom) trip blank | Fluid |
| 10890 | WSTMO-16-124932 | 08/22/2016 | Drill fluids composite | Fluid |
| 10716 | WSTMO-16-124933 | 08/22/2016 | Drill fluids composite | Fluid |
| 10716 | WSTMO-16-124934 | 08/25/2016 | Drill fluids composite field duplicate | Fluid |
| 10716 | WSTMO-16-121722 | 05/31/2016 | Drill cuttings (top) | Soil |
| 10716 | WSTMO-16-121725 | 05/31/2016 | Drill cuttings (top) trip blank | Soil |
| 10716 | WSTMO-14-86601 | 06/20/2016 | Drill cuttings (middle) | Soil |
| 10716 | WSMTO-14-86603 | 06/20/2016 | Drill cuttings (middle) trip blank | Soil |
| 10716 | WSTMO-16-121724 | 06/20/2016 | Drill cuttings (middle) | Soil |
| 10716 | WSTMO-16-121727 | 06/20/2016 | Drill cuttings (middle) trip blank | Soil |
| 10889 | WSTMO-16-124931 | 08/22/2016 | Drill cuttings (composite) | Soil |

**Table 8.6-2**
**Chromium Injection Well CrIN-2 Sample Information**

| Event ID | Sample ID | Date Collected | Description | Sample Matrix |
|---|---|---|---|---|
| 10670 | WSTMO-16-116116 | 04/19/2016 | Drilling fluids (top) | Fluid |
| 10670 | WSTMO-16-116115 | 04/19/2016 | Drilling fluids field duplicate | Fluid |
| 10670 | WSTMO-16-116114 | 04/19/2016 | Drilling fluids trip blank | Fluid |
| 10671 | WSTMO-16-116118 | 05/02/2016 | Drilling fluids (middle) | Fluid |
| 10671 | WSTMO-16-116120 | 05/02/2016 | Drilling fluids (middle) field duplicate | Fluid |
| 10671 | WSTMO-16-116121 | 05/02/2016 | Drilling fluids (middle) trip blank | Fluid |
| 10671 | WSTMO-16-116117 | 05/10/2016 | Drilling fluids (bottom) | Fluid |
| 10671 | WSTMO-06-116119 | 05/10/2016 | Drilling fluids (bottom) field duplicate | Fluid |
| 10671 | WSTMO-16-116122 | 05/10/2016 | Drilling fluids (bottom) trip blank | Fluid |
| 10719 | WSTMO-16-121729 | 07/20/2016 | Drill fluids composite | Fluid |
| 10719 | WSTMO-16-121730 | 07/20/2016 | Drill fluids composite | Fluid |
| 10719 | WSTMO-16-121731 | 07/20/2016 | Drill fluids composite field duplicate | Fluid |
| 10669 | WSTMO-16-111608 | 04/19/2016 | Drill cuttings (top) | Soil |
| 10669 | WSTMO-16-116111 | 04/19/2016 | Drill cuttings (top) trip blank | Soil |
| 10669 | WSTMO-16-116109 | 05/02/2016 | Drill cuttings (middle) | Soil |
| 10669 | WSTMO-16-116112 | 05/02/2016 | Drill cuttings (middle) trip blank | Soil |
| 10669 | WSTMO-16-116110 | 05/10/2016 | Drill cuttings (bottom) | Soil |
| 10669 | WSTMO-16-116113 | 05/10/2016 | Drill cuttings (bottom) trip blank | Soil |
| 10720 | WSTMO-16-121732 | 07/20/2016 | Drill cuttings (composite) | Soil |

**Table 8.6-3**
**Chromium Injection Well CrIN-3 Sample Information**

| Event ID | Sample ID | Date Collected | Description | Sample Matrix |
|---|---|---|---|---|
| 10867 | WSTMO-16-124656 | 08/01/2016 | Drilling fluids (top) | Fluid |
| 10867 | WSTMO-16-124659 | 08/01/2016 | Drilling fluids (top) field duplicate | Fluid |
| 10867 | WSTMO-16-124662 | 08/01/2016 | Drilling fluids (top) trip blank | Fluid |
| 10867 | WSTMO-16-124658 | 08/10/2016 | Drilling fluids (middle) | Fluid |
| 10867 | WSTMO-16-124660 | 08/10/2016 | Drilling fluids (middle) field duplicate | Fluid |
| 10867 | WSTMO-16-124663 | 08/10/2016 | Drilling fluids (middle) trip blank | Fluid |
| 10867 | WSTMO-16124657 | 08/16/2016 | Drilling fluids (bottom) | Fluid |
| 10867 | WSTMO-16-124661 | 08/16/2016 | Drilling fluids (bottom) field duplicate | Fluid |
| 10867 | WSTMO-16-124664 | 08/16/2016 | Drilling fluids (bottom) trip blank | Fluid |
| 10949 | WSTMO-16-126034 | 09/15/2016 | Drilling fluids (composite) | Fluid |
| 10949 | WSTMO-16-126035 | 09/15/2016 | Drilling fluids (composite) | Fluid |
| 10949 | WSTMO-16-126036 | 09/15/2016 | Drilling fluids (composite) field duplicate | Fluid |
| 10866 | WSTMO-16-124650 | 08/01/2016 | Drill cuttings (top) | Soil |
| 10866 | WSTMO-16-124653 | 08/01/2016 | Drill cuttings (top) trip blank | Soil |
| 10866 | WSTMO-16-124651 | 08/10/2016 | Drill cuttings (top) | Soil |
| 10866 | WSTMO-16-124654 | 08/10/2016 | Drill cuttings (top) trip blank | Soil |
| 10866 | WSTMO-16-124652 | 08/16/2016 | Drill cuttings (top) | Soil |
| 10866 | WSTMO-16-124655 | 08/16/2016 | Drill cuttings (top) trip blank | Soil |
| 10950 | WSTMO-16-126037 | 09/15/2016 | Drill cuttings (composite) | Soil |

**Table 8.6-4**
**Chromium Injection Well CrIN-4 Sample Information**

| Event ID | Sample ID | Date Collected | Description | Sample Matrix |
|---|---|---|---|---|
| 10646 | WSTMO-16-115216 | 04/01/2016 | Drilling fluids (top) | Fluid |
| 10646 | WSTMO-16-115219 | 04/01/2016 | Drilling fluids (top) field duplicate | Fluid |
| 10646 | WSTMO-16-115220 | 04/01/2016 | Drilling fluids (top) trip blank | Fluid |
| 10646 | WSTMO-16-115215 | 04/15/2016 | Drilling fluids (middle) | Fluid |
| 10646 | WSTMO-16-115218 | 04/15/2016 | Drilling fluids (middle) field duplicate | Fluid |
| 10646 | WSTMO-16-115221 | 04/15/2016 | Drilling fluids (middle) trip blank | Fluid |
| 10646 | WSTMO-16-115214 | 05/11/2016 | Drilling fluids (bottom) | Fluid |
| 10646 | WSTMO-16-115217 | 05/11/2016 | Drilling fluids (bottom) field duplicate | Fluid |
| 10646 | WSTMO-16-115222 | 05/11/2016 | Drilling fluids (bottom) trip blank | Fluid |
| 10849 | WSTMO-16-124363 | 07/25/2016 | Drilling fluids (composite) | Fluid |
| 10849 | WSTMO-16-124364 | 07/25/2016 | Drilling fluids (composite) | Fluid |
| 10849 | WSTMO-16-124365 | 07/25/2016 | Drilling fluids (composite) field duplicate | Soil |
| 10647 | WSTMO-16-115223 | 04/01/2016 | Drill cuttings (top) | Soil |
| 10647 | WSTMO-16-115228 | 04/01/2016 | Drill cuttings (top) trip blank | Soil |
| 10647 | WSTMO-16-115224 | 04/15/2016 | Drill cuttings (middle) | Soil |
| 10647 | WSTMO-16-115226 | 04/15/2016 | Drill cuttings (middle) trip blank | Soil |
| 10647 | WSTMO-16-115225 | 05/11/2016 | Drill cuttings (bottom) | Soil |
| 10647 | WSTMO-16-115227 | 05/11/2016 | Drill cuttings (bottom) trip blank | Soil |
| 10848 | WSTMO-16-124362 | 07/25/2016 | Drill cuttings (composite) | Soil |

**Table 8.6-5**
**Chromium Injection Well CrIN-5 Sample Information**

| Event ID | Sample ID | Date Collected | Description | Sample Matrix |
|---|---|---|---|---|
| 10749 | WSTMO-16-122902 | 06/13/2016 | Drilling fluids (top) | Fluid |
| 10749 | WSTMO-16-122905 | 06/13/2016 | Drilling fluids (top) field duplicate | Fluid |
| 10749 | WSTMO-16-122908 | 06/13/2016 | Drilling fluids (top) trip blank | Fluid |
| 10749 | WSTMO-16-122903 | 06/21/2016 | Drilling fluids (middle) | Fluid |
| 10749 | WSTMO-16-122906 | 06/21/2016 | Drilling fluids (middle) field duplicate | Fluid |
| 10749 | WSTMO-16-122909 | 06/21/2016 | Drilling fluids (middle) trip blank | Fluid |
| 10749 | WSTMO-16-122904 | 07/01/2016 | Drilling fluids (bottom) | Fluid |
| 10749 | WSTMO-16-122907 | 07/01/2016 | Drilling fluids (bottom) field duplicate | Fluid |
| 10749 | WSTMO-16-122910 | 07/01/2016 | Drilling fluids (bottom) trip blank | Fluid |
| 10558 | WSTMO-16-124558 | 08/01/2016 | Drilling fluids (composite) | Fluid |
| 10558 | WSTMO-16-124559 | 08/01/2016 | Drilling fluids (composite) | Fluid |
| 10558 | WSTMO-16-124560 | 08/01/2016 | Drilling fluids (composite) field duplicate | Fluid |
| 10748 | WSTMO-16-122893 | 06/13/2016 | Drill cuttings (top) | Soil |
| 10748 | WSTMO-16-122896 | 06/13/2016 | Drill cuttings(top) field duplicate | Soil |
| 10748 | WSTMO-16-122894 | 06/21/2106 | Drill cuttings (middle) | Soil |
| 10748 | WSTMO-16-122748 | 06/21/2016 | Drill cuttings (middle) field duplicate | Soil |
| 10748 | WSTMO-16-122895 | 07/01/2016 | Drill cuttings (bottom) | Soil |
| 10748 | WSTMO-16-122898 | 07/01/2106 | Drill cuttings (bottom) field duplicate | Soil |
| 10859 | WSTMO-16-124562 | 08/01/2016 | Drill cuttings composite | Soil |

# Appendix A

*Stratigraphic and Lithologic Descriptions*

## A-1.0 CRIN-1 WELL

### Alluvium (0–100 ft below ground surface [bgs])

The light brownish-gray alluvium consists of a mixture of minor devitrified tuff, pumice, dacite, and sandstone fragments in a tuffaceous matrix. The fragments are partially coated with silty matrix. The sediment is moderately sorted and unconsolidated. The mineral and sandstone contents appear to increase with depth. The lower part of the tuffaceous sediment is light pinkish gray, poorly sorted, and unconsolidated. With depth, abundant gray and pinkish pumice fragments and minor devitrified tuff and variable amounts of dacite lava fragments are noted. The crystal content also appears to be lower.

### Otowi Member of the Bandelier Tuff (100–240 ft bgs)

The cuttings consist of poorly sorted, clast-supported gray pumice with minor light brownish-gray wood-chip-like pumices. Variable amounts of dacite fragments are mixed with the pumices in the upper part of the ash-flow tuff. Abundant quartz and feldspar grains are also noted. The pumices, crystals, and dacite fragments are lightly coated with tuffaceous silt. Lithic-rich ash-flow tuff is dominant with depth, and in some cases, more dacite fragments are present than gray pumice in the cuttings. Some pumice clasts exhibit-rust like stains on the surface.

### Guaje Pumice Bed of the Bandelier Tuff (240–260 ft bgs)

The upper part of the pumice deposit is lithic-rich and contains more dacite lava fragments than white pumice and abundant coarse minerals. The lava fragments consist of light to medium gray and pale red dacite. It is poorly sorted, clast-supported, and unconsolidated. In contrast, the lower part is dominated by fallout of gravely white pumice of comparable clast sizes. Fewer medium-gray dacite and scoriaceous basalt fragments were noted within the lower cuttings.

### Cerros del Rio Volcanic Rocks (260–675 ft bgs)

No upper Puye Formation sediments were encountered below the Guaje Pumice Beds. Instead, a thick (40-ft) reddish to dark brown clast-supported and poorly to moderately sorted scoria deposit unconformably underlies the Guaje Pumice Bed. Medium-gray vesicular basalt mixed with reddish-brown scoria occurs beneath the scoria deposit. The lava sequence is dominated by porphyritic medium-gray flow that contains plagioclase and partially altered and fractured pyroxene and olivine mostly in the microcrystalline matrix. Porphyritic dark gray lava with abundant plagioclase, olivine, and pyroxene embedded in a microcrystalline matrix was intersected below the medium gray flow and above oxidized and partially altered lava. The lower half of the lava sequence (430–700 ft bgs) consists of medium-gray lava that is porphyritic and contains abundant pyroxene olivine phenocrysts within a microcrystalline matrix. The mafic minerals are coarse and partially fractured. A minor fraction of scoria and oxidized lava fragments occur with the medium-gray fragments.

Homogeneous cuttings of a medium-gray lava that is sparsely vesicular and porphyritic, devoid of scoria or oxidized fragments was encountered in the lowermost part of the volcanic sequence mixed with abundant light pinkish-gray siltstone (570–590 ft bgs). No cuttings were recovered from the interval 590 to 700 ft bgs. However, at 700 ft bgs, the cuttings consisted of medium-gray lava fragments mixed with light to medium-gray subrounded to rounded dacite clasts that are lightly coated with light grayish-brown silt.

### Puye Formation (675–960 ft bgs)

Mixture of abundant basalt fragments and minor sandstone and dacite clasts coated with silty matrix define the transition from the Cerro del Rio volcanic lava to the Puye Formation sedimentary deposit. The Puye Formation is dominated by gravely to coarse sand sediments with minor amounts of minerals and matrix fractions. The gravel to coarse sand fragments consist of mostly subangular to subrounded, clast-supported, and moderately to poorly sorted clasts. At least two types of lithic fragments with variable abundances are present within the sedimentary sequence. In most cases, light- to medium-gray dacite fragments are the dominant fractions but sometimes, pale red lava clasts are either of comparable abundance or more. Except for a few intervals, the Puye Formation sequence is dominated by gravely sand of light- to medium-gray and pale red dacite fragments. The sandy intervals that occur within the upper and lower parts of the sedimentary sequence also contain similar lithologic fragments and represent well-sorted fractions.

More pale red lava fragments than the light- to medium-gray dacite fractions are noted in the lowermost part of the sequence. White pumice fragments also occur in the lowermost part of the well. The pumice clasts are rounded and increase in abundance with depth even though the light- to medium-gray and pale red lava fragments are more abundant.

### Miocene Pumiceous and Miocene Jemez Alluvial (960–1040 ft bgs)

The Miocene pumiceous deposit is defined by pumiceous sand with minor dacite fragments up to 1 in. in diameter. The pumice fragments are lightly coated with light brownish-gray tuffaceous silt. Quartz and feldspar minerals are present but less abundant compared with the pumice clasts. The pumiceous sand deposits become coarser and gravely with depth. Two types of pumice fragments of comparable amounts are present in the lower part of the unit. The reworked pumice is subrounded to rounded and light brownish-gray on the outside and white inside. The white pumice clasts are angular to subangular. Some of the pumice fragments are up to 0.5 in. in length. The white pumice decreases with depth and is completely replaced with the reworked pumice in the lowermost part of the deposit. Minor lava fragments of dacite, basalt, and scoria were also noted. Quartz and feldspars are sparse.

## A-2.0 CRIN-2 WELL

### Alluvium (0–60 ft bgs)

The alluvium sequence consists of silty to sandy tuffaceous sediments containing abundant quartz and feldspar minerals mixed with minor sandstone, tuff, and lava fragments, which are lightly coated with tuffaceous silt. The sediments are generally sorted and unconsolidated. The crystal contents vary randomly with depth. In the middle part of the section, well-sorted quartz and feldspar grains that are lightly coated with pulverized silty glass mostly dominate the sediments. At the base of the sequence, the tuffaceous alluvium is medium-gray, matrix-supported, moderately sorted, and partially consolidated. Crystals are sparse within the silty tuffaceous sand but light- to medium-gray dacite clasts and pumice were noted.

### Cerro Toledo Formation (60–110 ft bgs)

The tuffaceous alluvium directly overlies light- to medium-gray pumice deposit that is well sorted and clast-supported. Minerals and lithic fragments are sparse. The pumice fragments are angular to subrounded and lightly coated with light brown and light pinkish-gray silty tuffaceous matrix. The lower half of the sequence is crystal- and lithic-rich tuffaceous sand. It is matrix-supported. The pumice fragments are white to light gray and angular to subrounded. Lithic fragments and the mineral grains are lightly coated with silty glass fraction. The felsic lava fragments are subrounded and light pinkish to reddish gray. A few grains of obsidian and perlite fragment that are mostly present within the Cerro Toledo Formation were also noted.

**Otowi Member (110–270 ft bgs)**

The tuff is pinkish-gray, matrix-supported and poorly sorted. It contains abundant quartz and feldspar minerals, pumice and less abundant lava fragments. The minerals and lithic fragments are moderately coated with pinkish silt of glass shards. Lava fragments are less abundant compared with pumice fragments. The pinkish color may be the result of alteration.

The pinkish-gray ash-flow tuff transitions to gray, matrix-supported, poorly sorted pumice mixed with abundant quartz and feldspar grains. The pumice clasts are subrounded. The dacite fragments are gray to light pinkish-gray and light brown and are less abundant compared with the gray pumice fraction. The pumice, minerals, and lithic fragments are lightly coated with silty tuffaceous fraction. Some of the gray pumice fragments have isolated rusty patches that are more prevalent in the upper part of the lower half of the sequence. Also, the amount of dacite fragments randomly varies with depth.

**Guaje Pumice Bed of the Bandelier Tuff (270–300 ft bgs)**

The pumice fallout unit consists of well-sorted, clast-supported white pumice. It is mixed with abundant quartz and feldspar grains and minor amounts of lava fragments. Pumice fragments are mostly angular. The mineral grains, pumices, and the lava fragments are lightly coated with silty tuffaceous matrix. White pumice is the dominant fraction, but the amount of lava fragments appears to increase with depth.

**Cerros del Rio Volcanic Rocks (300–740 ft bgs)**

The upper Puye Formation is generally occurs beneath the Guaje Pumice Bed. However, in the CrIN-2 well, scoriaceous basaltic lava directly underlies the Gujae Pumice Bed. The lava flow is dark gray, vesicular, partially glassy, and fairly porphyritic with phenocrysts of olivine, pyroxene, and plagioclase. The lava flow becomes more scoriaceous and pulverized with depth and contains mixed reddish and medium-brown scoria fragments. The scoriaceous deposits transition with depth to medium-gray lava, which contains olivine, pyroxene, and plagioclase. In the middle section of the volcanic sequence, the medium-gray lava is mixed with light pinkish-gray claystone fragments (520–530 ft bgs) and a few glassy scoria fragments.

In the upper part of the lower half of the volcanic sequence, comparable amounts of medium gray and vesicular dark gray lava fragments were noted. The dark gray fraction appears more porphyritic. However, the medium-gray lava is the dominant lava flow in the lower half of the volcanic sequence. More light pinkish-gray claystone fragments (630–640 ft. bgs) were noted in the lower part of the section. Porphyritic and sparsely vesicular dark gray lava with minor palagonitized fragments defines the base of the Cerro del Rio section. Abundant pinkish-gray claystone and a few light gray dacite fragments were also noted.

**Puye Formation (740–990 ft bgs)**

In the uppermost part, the Puye Formation consists of fairly sorted coarse sand, containing light gray, angular to subrounded felsic fragments mixed with abundant basaltic and quartz and feldspar grains. Few pumice fragments were also noted. The coarse sand transitions to clast-supported gravel (≤0.75 in.) beds that are mostly sorted. The subrounded lithic fragments are mostly dacitic, but rhyolite clasts were also noted. The rest of the section contains alternating beds of gravel and coarse sand. The coarse sand to gravely sand fractions are generally matrix-supported and fairly sorted, whereas the gravel beds are mostly sorted, clast-supported and lightly coated with light brownish-gray tuffaceous silt. Most fragments are ≤1 in. in diameter. Abundant quartz and feldspar grains plus minor mafic minerals occur within the sandy layers. Rendija Canyon dacite fragments were noted, starting at a depth of 900–910 ft. bgs. Gravel deposits that transitions to gravely sand dominate the lowermost part of the Puye Formation. Even though the lava fragments are clast-supported and matrix-free, all clasts are lightly coated with tuffaceous silt.

#### Miocene Pumiceous (990–1062 ft bgs)

The Miocene pumiceous deposit is defined by pumiceous sand with minor dacite fragments up to 1 in. in diameter. The pumice fragments are lightly coated with light brownish-gray tuffaceous silt. Quartz and feldspar minerals are present but less abundant compared with the pumice clasts. The pumiceous sand deposits become coarser and gravely with depth. Two types of pumice fragments of comparable amounts are present in the lower part of the unit. The reworked pumice is subrounded to rounded and light brownish-gray on the outside and white inside. The white pumice clasts are angular to subangular. Some of the pumice fragments are up to 0.5 in. in length. The white pumice decreases with depth and is totally replaced with the reworked pumice in the lowermost part of the deposit. Minor lava fragments of dacite, basalt, and scoria were also noted. Quartz and feldspars are sparse.

### A-3.0 CRIN-3 WELL

#### Alluvium, Qal (0–30 ft bgs)

The cuttings consist of light brownish-gray sand that is poorly sorted and contains unconsolidated rock fragments of variable amounts of pumice, tuff, dacite lava plus abundant crystals and organic matter. With depth, the sediments transition to tuffaceous silty sand that is fairly consolidated and sorted. The rock fragments and minerals are lightly coated with tuffaceous silt. The lowermost part of the alluvium is gravelly silty sand, poorly sorted, and unconsolidated. Minerals and partially rounded pumice clasts are heavily coated with brownish silt.

#### Tshirege Member Unit 1g (30–70 ft bgs)

The ash-flow tuff cuttings consist of light brownish-gray pumice clasts, coarse minerals, and minor dacite lava fragments that are lightly coated with pulverized glassy silt. The cuttings are poorly sorted and unconsolidated. More crystals and dacite lava fragments mixed with abundant pumice are noted in the lower part of the unit. The cuttings are mostly clast-supported with light coating of pulverized glass. A couple of perlite grains were noted in the lower part of the unit mixed with partially rounded pumice and dacite lava fragments.

#### Cerro Toledo Formation (70–110 ft bgs)

The unit consists of lithic-rich, clast-supported reworked pumiceous sand containing abundant rounded to subrounded white to medium gray pumices that are moderately sorted and unconsolidated. Light- to medium-gray dacite lava fragments are less abundant compared with the amount of pumice. A few perlite and banded rhyolite fragments were also noted. Minerals are fine-grained and less abundant. The pumiceous sand transitions to poorly sorted gravelly coarse sand that is dominated by pumice with variable amounts of light- to medium-gray and pale red dacite fragments. In some cases, the dacite fragments are coarser than the pumices. The crystal contents are also higher and variable in size. The cuttings from the basal section are light brownish-gray, moderately sorted and contain comparable amounts of pumice and dacite clasts that are lightly coated with tuffaceous glassy matrix. Minerals from the lowermost cuttings are coarser and more abundant and are also lightly coated with glassy silt. A few perlite grains were also noted.

**Otowi Member (110–330 ft bgs)**

The uppermost part of the unit consists of lightly weathered light-pinkish-gray ash-flow tuff, containing abundant pumices and crystals and minor light- to medium-gray and pale red dacite lava fragments that are partially covered with tuffaceous glassy matrix. More abundant pale red dacite fragments are noted than the light- to medium-gray fraction in deeper samples. The light pinkish-gray layer transitions with depth to light gray pumiceous coarse sand that is sorted, matrix-poor, and unconsolidated. Pumices and crystals are abundant, and more pale red dacite lava fragments are present. The minerals, pumices, and dacite fragments are lightly coated with glassy tuffaceous silt. In some cases, the cuttings (140–220 ft bgs) are pulverized, resulting in matrix-supported light gray fraction that is dominated by crushed pumice and crystals. In the lower part of the section, the Otowi Member cuttings are lithic-rich, clast-supported, and poorly to moderately sorted. Crystals are abundant and light- to medium-gray dacite lava clasts are more abundant than the pale red fraction. Pumice clasts are light gray to white.

**Guaje Pumice Bed of the Bandelier Tuff (330–340 ft bgs)**

The cuttings consist of clast-supported and moderately sorted equant fragments of white pumice mixed with abundant dark gray and pale red dacite fragments. Quartz and feldspar grains are fairly abundant. No matrix-glass coating was noted on the pumice, dacite lava fragments, or crystals.

**Upper Puye Formation (340–350 ft bgs)**

The clast-supported sediment is sorted and consists of abundant pumice and dacite lava fragments that are heavily coated with light reddish silty clay. The silt-coated pumice is from the overlying Guaje Pumice Bed that contaminated the underlying upper Puye Formation sediment during sampling.

**Cerros del Rio Volcanic Rocks (350–755 ft bgs)**

The uppermost cuttings consist of abundant fine-grained and dark gray basaltic lava fragments that are mixed with minor light to medium gray dacite and pumice clasts. Some basaltic fragments are scoriaceous and oxidized. With depth, the cuttings consist of partially oxidized medium- to dark-gray vesicular basalt with phenocrysts of plagioclase and fractured and weathered pyroxene and olivine. Most vesicle walls are coated with vapor-phase minerals and some are completely filled with secondary minerals. Medium-gray lava and minor dark gray vesicular basaltic fragments sparsely mixed with scoria are commonly noted in the cuttings from the upper and middle parts of the basaltic section. Generally the lower half of the lava sequence contains mostly medium-gray fragments and minor amounts of oxidized brown lava and scoria clasts. The medium-gray lava fragments are porphyritic and microcrystalline. Fractured and partially altered plagioclase, olivine, and pyroxene are the dominant phenocrysts. Moreover, minor light orange claystone fragments were encountered within the medium-gray lava-dominated cuttings (610–640 ft bgs).

### Cerros del Rio Volcanic Rocks–Hydrovolcanic Sediment (745–755 ft bgs)

The lowermost part of the Cerros del Rio volcanic sequence in CrIN-3 consists of microcrystalline and porphyritic medium-gray lava fragments that are mixed with minor fraction of medium gray, fine-grained, and platy clasts of weathered basaltic tuff deposit (Maar). The altered basaltic tuff appears similar to outcrops in Sandia and Los Alamos Canyons.

### Puye Formation (755–1021 ft bgs)

The cuttings from the Cerros del Rio volcanics and Puye Formation contact zone are heavily contaminated with medium gray basalt fragments (755–765 ft bgs). However, the next batch (765-770 ft bgs) contains very little or no basaltic lava fragment. Instead, the cuttings are dominated by a mixture of variable grain sizes and amounts of light to medium gray and pale red dacite fragments and a minor fraction of Rendija Canyon dacite fragments that are present throughout the Puye Formation. Fine- to coarse-grained and variable amounts of quartz, feldspar, and minor mafic minerals were mostly noted within the Puye Formation cuttings. In most cases, the cuttings are moderately sorted, clast-supported, and range in size from coarse to gravelly coarse sand. Fine-grained matrix fractions were insignificant or absent from the Puye Formation cuttings.

## A-4.0 CRIN-4 WELL

### Tshirege Member Unit 2 (0–30 ft bgs)

The partially pulverized and devitrified light brownish-gray ash-flow tuff consists of abundant nonwelded devitrified fragments mixed with significant amounts of quartz and feldspar that are lightly to heavily coated with pulverized tuffaceous silt. The pulverized fraction is poorly sorted and mostly clast-supported. The abundance of tuff fragments decreases with depth because of strong pulverization. Cuttings from the lower part of the unit are totally pulverized and are transformed to crystal-rich powdery fraction. The sandy fraction is light brownish-gray and sorted. Very few partially weathered lava fragments were noted within the pulverized cuttings.

### Tshirege Member Unit 1v (30–150 ft bgs)

The crystal-rich tuff is light to medium-gray, crystal-rich, and devitrified. The tuff fragments are nonwelded and mostly pulverized. Microcrystalline mineral aggregates are noted in cavities, and pumice clasts are totally replaced by fine-grained minerals. Abundant quartz and feldspars and minor lithic fragments are noted and are lightly coated with silty matrix of devitrified glass. The amount of the light- to medium-gray dacite lava fragments randomly varies within the unit.

### Tshirege Member Unit 1g (150–230 ft bgs)

The gray tuff is crystal- and lithic-rich and partially pulverized. The minerals and lithic fragments are lightly coated with silty matrix of pulverized glass shards. Angular to subrounded gray pumice clasts are commonly noted. In the middle part of the unit, the pumices and lithic fragments are coated with light pinkish-gray glassy matrix, whereas in the lower part, white and light pinkish-gray pumice clasts are present. A few grains of perlite were also noted.

**Cerro Toledo Formation (230–250 ft bgs)**

The reworked pumices are clast-supported, poorly sorted, light pinkish to reddish-gray, subrounded to rounded, and are coated with tuffaceous silt. A few subrounded white pumice fragments are also present. Considerable amount of light- to medium-gray and minor pale red lava fragments are mixed with the pumices. Minerals are fine-grained and sparse, and a few rounded perlite clasts were also noted.

**Otowi Member (250–500 ft bgs)**

The ash-flow tuff is poorly sorted, mostly clast supported, and contains abundant angular to subrounded light-pinkish-gray pumices and minor light- to medium-gray lava fragments. The amounts of the pumice and lava fragments randomly vary within the unit. The quartz and feldspar minerals are also variable. In the middle section of the unit, light to medium and pale red angular to subrounded lithic fragments are more abundant than the pumice contents. Unlike in the upper part of the unit, the pumices are mostly gray with rusty patches. The lithic and pumice contents vary with depth, and more white pumices are noted in the lower part of the unit.

**Guaje Pumice Bed of the Bandelier Tuff (500–540 ft bgs)**

The pumice-rich deposit is moderately sorted, clast-supported, and contains minor medium- to dark-gray and pale red lava fragments that vary in abundance with depth. White pumice is the dominant fraction and the clasts are generally angular to subangular. Quartz and feldspar grains are fairly abundant. The mineral grains, pumices, and the lava fragments are lightly coated with silty glass shards matrix.

**Upper Puye Formation (540–560 ft bgs)**

The sedimentary unit is poorly sorted and consists of abundant pinkish-gray silty sandstone mixed with medium- to dark-gray dacite and pumice clasts. The silty sandstone fragments are fine grained and indurated. The lava fragments and pumices are subrounded and are lightly coated with tuffaceous silty matrix.

**Cerros del Rio Volcanic Rocks (560–900 ft bgs)**

Dark gray, fine-grained, and sparsely vesicular basalt underlies the upper Puye Formation. The vesicle walls are partially filled with secondary minerals. The underlying lava is medium-gray, fairly vesicular, and sparsely porphyritic, containing fractured and partially altered pyroxene, plagioclase, and olivine. Mixtures of medium-gray porphyritic lava and medium-brown scoriaceous fragments occur in the middle part of the volcanic sequence that transitions to underlying reddish-brown scoriaceous lava. The scoriaceous deposit is underlain by thick sequence of medium-gray porphyritic lava containing olivine, pyroxene, and plagioclase phenocrysts embedded in a matrix of microcrystalline mineral phases. The medium-gray lava fragments are vesicular, platy, and partially altered. A few pinkish-gray siltstone fragments were noted in the middle part of the lava sequence.

**Puye Formation (900–1202 ft bgs)**

Mixture of abundant basalt fragments and minor sandstone and dacite clasts coated with silty matrix define the transition from the Cerro del Rio volcanic lava to the Puye Formation sedimentary deposit. The Puye Formation is dominated by gravely to coarse sand sediments with minor amounts of minerals and matrix fractions. The gravel to coarse sand fragments consist of mostly subangular to subrounded, clast-supported and moderately to poorly sorted clasts. At least two types of lithic fragments with variable abundances are present within the sedimentary sequence. In most cases, light- to medium-gray dacite fragments are the dominant fractions, but sometimes pale red lava clasts are either of comparable abundance or more. Except for a few intervals, the Puye Formation sequence is dominated by gravely sand of light- to medium-gray and pale red dacite fragments. The sandy intervals that occur within the upper and lower parts of the sedimentary sequence also contain similar lithologic fragments and represent well-sorted fractions.

More pale red lava fragments than the light- to medium-gray dacite fractions are noted in the lowermost part of the sequence. White pumice fragments also occur in the lowermost part of the well. The pumice clasts are rounded and increase in abundance with depth even though the light- to medium-gray and pale red lava fragments are more abundant.

## A-5.0 CRIN-5 WELL

### Tshirege Member, Unit Qbt 2 (0–40 ft bgs)

The partially pulverized and devitrified light-brownish-gray ash-flow tuff consists of abundant nonwelded devitrified fragments mixed with significant amounts of quartz and feldspar that are lightly to heavily coated with pulverized tuffaceous silt. The pulverized fraction is poorly sorted and mostly clast-supported. The abundance of tuff fragments decreases with depth because of strong pulverization. Cuttings from the lower part of the unit are totally pulverized and are transformed to crystal-rich powdery fraction. The sandy fraction is light brownish-gray and sorted. Very few partially weathered lava fragments were noted within the pulverized cuttings.

### Tshirege Member Unit Qbt 1v (40–160 ft bgs)

The ash-flow tuff is nonwelded, poorly sorted, light- to medium-gray, devitrified, crystal-rich, and partially to mostly pulverized cuttings. The transition from Qbt 2 to Qbt 1v is marked by the appearance of devitrified or recrystallized well-preserved pumice morphology. The devitrified clasts form aggregates of clear, fine-grained crystals. In other cases, glassy matrix is recrystallized to microcrystalline groundmass. Dacite lava fragments are generally sparse. Cuttings from the lowermost part of the unit appear to contain more tuff fragments, crystals, and dacite lava fragments. The tuff fragments and the quartz and feldspar grains are lightly coated with light- to medium-gray powdery silt that is devitrified glass.

### Tshirege Member Unit Qbt 1g (160–250 ft bgs)

The ash-flow tuff consists of brick-red glassy pumice clasts mixed with minor medium- to dark-gray dacite lava fragments, and abundant clear quartz and feldspars. The tuff is sorted and clast-supported, and the fragments are not coated with matrix of pulverized glassy silt. The pumice clasts are subangular to subrounded and lava fragments are sparse. The brick-red pumices disappear with depth and are replaced by gray pumice, abundant crystals (i.e., feldspar and quartz), and lava fragments set within pulverized glassy matrix. A few obsidian fragments were also noted. The basal part of the unit consists of abundant clast-supported and sorted white to gray pumice mixed with minor dacite lava fragments and banded rhyolite.

**Cerro Toledo Formation (250–280 ft bgs)**

The reworked pumice bed consists of mixed reddish-gray and rounded white pumices, minor dacite, few obsidian fragments, and crystals of variable grain sizes coated with tuffaceous silty matrix. Cuttings from the lowermost part of the unit is characterized by lithic-rich pumiceous sand of lithic-rich, clast-supported reworked pumiceous sand and few perlite grains coated with light reddish silt.

**Otowi Member (280–560 ft bgs)**

The ash-flow tuff cuttings are crystal-rich, medium-gray, fairly sorted, clast-supported, and lightly coated with pulverized volcanic glass. Less abundant medium- to dark-gray lavas and other clasts are mixed with the crystals and pumices in the upper part of the unit. More varieties of lithic fragments, consisting of medium- to dark-gray and pale-red lavas, angular to subrounded light pinkish pumices, and less abundant crystals were noted in subsequent cuttings. With depth, more light brownish-gray pumices were encountered. In the middle part of the unit, the ash-flow tuff cuttings and pumices are mostly pulverized into sandy glassy matrix. A few grains of rounded obsidian and perlite grains mixed with abundant medium- to dark-gray lava clasts, gray pumices, and crystals occur in the lower half of the section. All fragments are lightly coated with pulverized glassy silt. The amounts of crystals and light to medium lava fragments appears to be more abundant than the coarse white to gray subrounded pumices in the lower half of the unit. The cuttings from the lower part of the unit contain variable amounts of pulverized glassy matrix.

**Guaje Pumice Bed of the Bandelier Tuff (560–580 ft bgs)**

The cuttings are characterized by white, dense pumice clasts that are clast-supported and mixed with abundant coarse, clear crystals and medium- to dark-gray dacite lava fragments. The pumice clasts are moderately sorted and of comparable clast sizes. The crystals are also sorted and consist of quartz and feldspars. The cuttings are matrix-poor and unconsolidated.

**Upper Puye Formation (580–610 ft bgs)**

The cuttings are dominated by reworked pumice sand that are coated with light brown silty matrix. Abundant lithic lava fragments that are similar to those noted in the overlying Guaje Pumice Bed are also present. With depth, the reworked pumiceous sand contains a mixture of white and light-brownish-gray pumice clasts and light- to dark-gray dacite fragments within light brown silty glassy matrix. In most cases, the upper Puye Formation consist of reddish-brown silty sandstone fragments that are massive and moderately indurated. The abundant pumice and lava fragments are most likely contaminants from the overlying Guaje Pumice Bed mixed during recovery of the cuttings.

**Cerros del Rio Volcanic Rocks (610–970 ft bgs)**

Sparsely vesicular basaltic lava cuttings coated with silty tuffaceous glass matrix mixed with sandstone and pumice clasts were encountered directly below the upper Puye Formation (610–630 ft bgs). The basaltic fragments are porphyritic with microcrystalline matrix and are partially altered. Plagioclase and pyroxene were noted. Sparsely vesicular and partially weathered dark gray porphyritic lava, containing plagioclase, olivine, and fractured and altered pyroxene occurs below the contaminated cuttings. A few scoriaceous fragments were noted. At 660–690 ft bgs, sparsely vesicular, fine-grained, and medium-gray porphyritic lava with phenocrysts of plagioclase, olivine, and pyroxene was encountered. Vesicles walls are coated with microcrystalline vapor-phase minerals. A mixture of medium-gray and oxidized scoriaceous fragments were encountered about 30 ft (690–710 ft bgs) below the uppermost lava flow. Pulverized medium-gray porphyritic lava fragments with phenocrysts of plagioclase, olivine, and fractured pyroxene underlie the scoriaceous flow. The medium-gray lava is thick and persists with depth except for occasional dark gray lava fragments (850–860 ft bgs and 890–920 ft bgs) and minor contents of light pinkish-gray silty clay fragments (880–890 ft bgs). Medium-gray porphyritic lava fragments were intersected to the base of the Cerro del Rio lava sequence (960–970 ft bgs).

**Puye Formation (970–1292 ft bgs)**

Clasts of light gray to pale red dacite, rounded quartzite, and sparse minerals in a coarse sandy fraction contaminated by abundant medium-gray lava fragments define the upper part of the Puye Formation. A few clasts of Rendija Canyon lava fragments were noted. More sorted and matrix-poor rounded to subangular dacite fragments are the dominant lithologic unit within the upper half (970–1140 ft bgs) of the formation. A layer of tuffaceous sand with dacite lava and minor Rendija Canyon clasts embedded in a silty matrix was intersected below the matrix-poor coarse sand. The silty sand transitioned back to sorted coarse sand with sparse mineral contents. The coarse fragments consisted of mixtures of light- to medium- and pale red dacite clasts. More dark gray rounded lava fragments and Rendija Canyon clasts were noted with depth. Crystal-poor and sorted coarse sand, consisting of light gray and light pale red dacite clasts mixed with Rendija Canyon lava fragments minor white pumice, were noted in the lower part of the drill hole (1240–1290 ft bgs).

# Appendix B

*Geophysical Logs*
*(on CD included with this document)*

**JET WEST GEOPHYSICAL SERVICES, LLC.**

| | |
|---|---|
| COMPANY | Las Alamos National Labs |
| WELL ID | Crin No.1 |
| FIELD | LANL (Los Alamos National Labs) |
| COUNTY | Los Alamos |
| STATE | New Mexico |

**TYPE OF LOG: Gamma Ray, Neutron Log**

OTHER SERVICES: None

LOCATION

State Plane 1927

Northing:

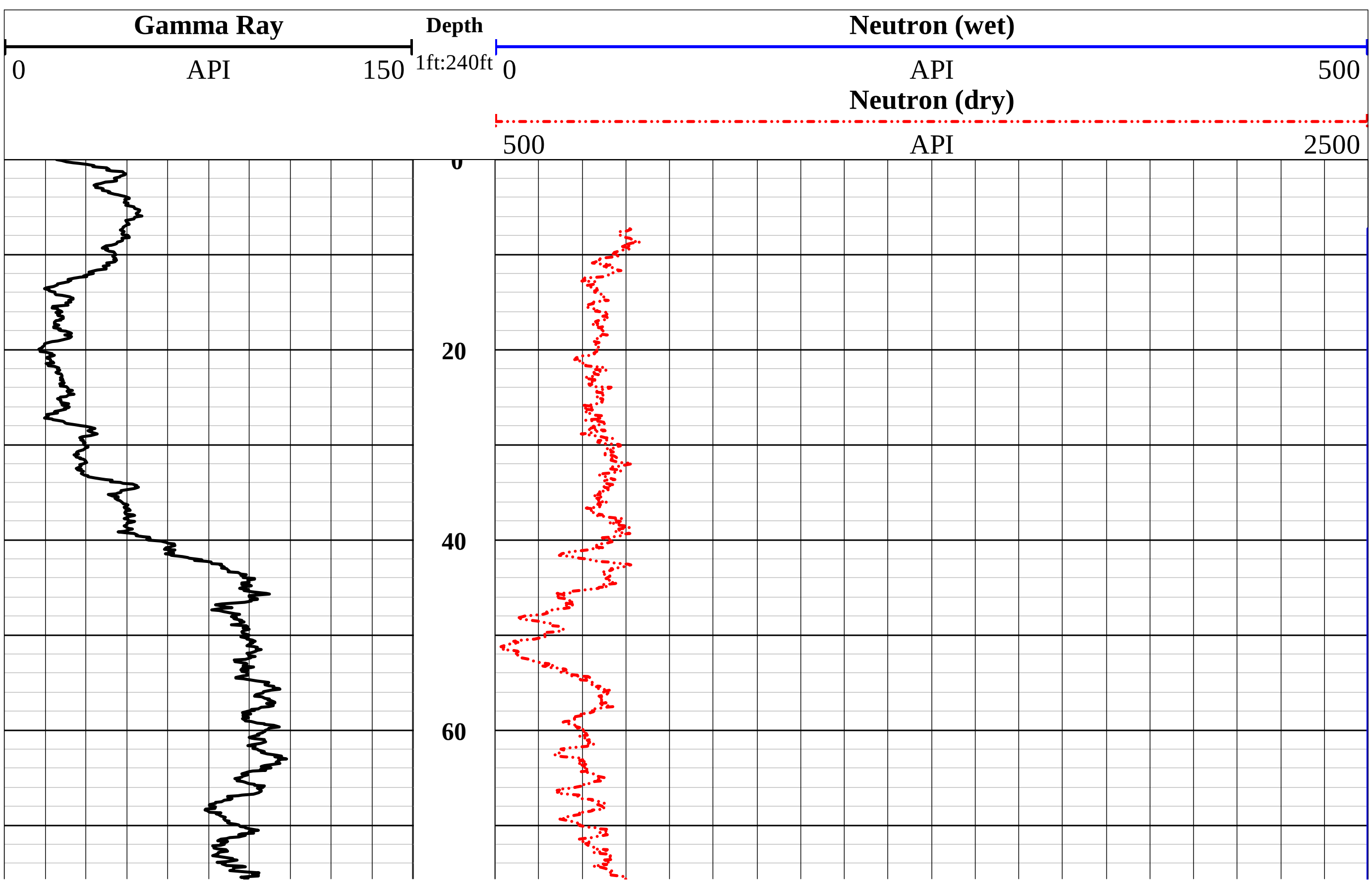
Easting:

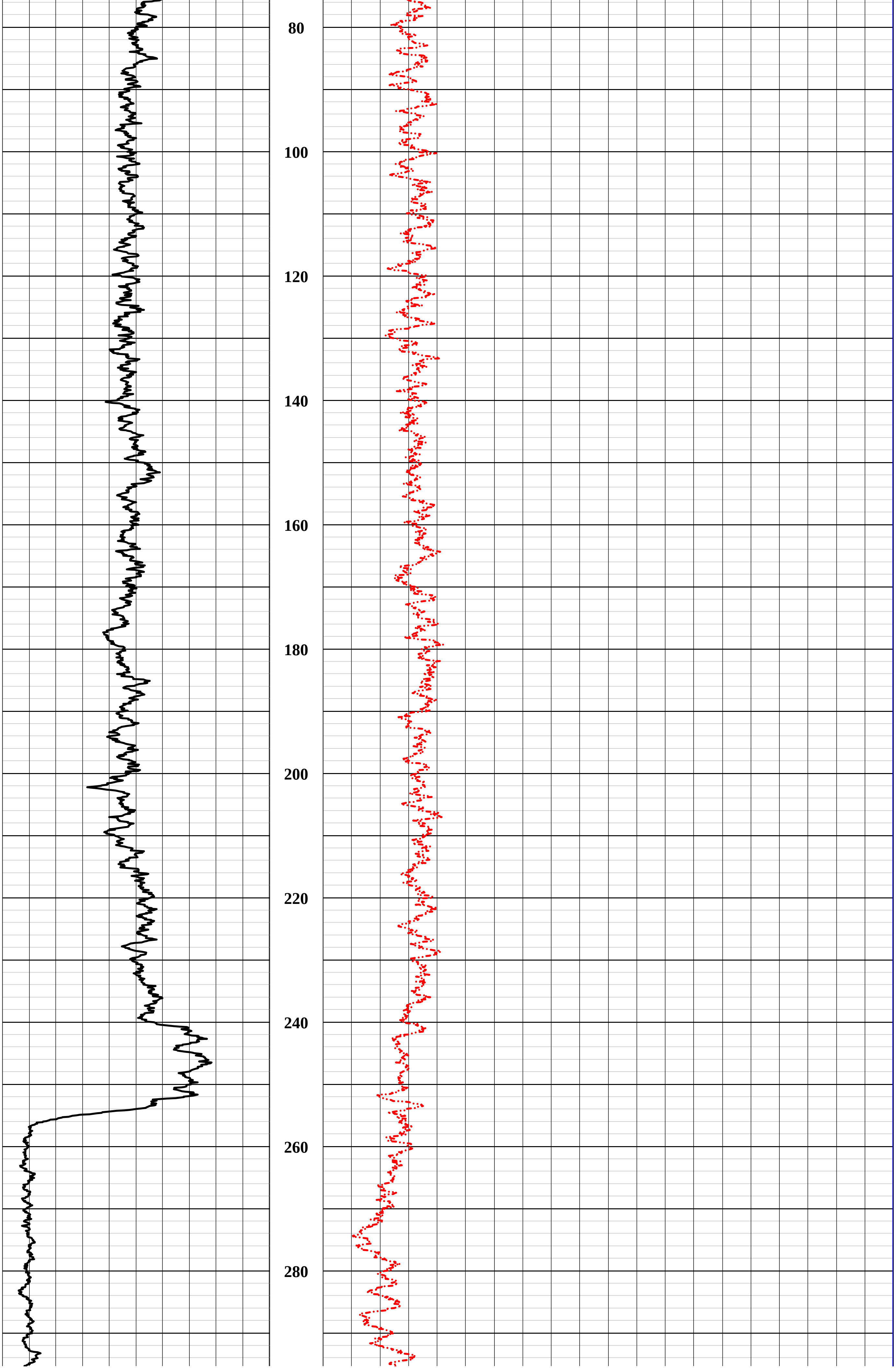
| SEC | TWP | RGE | API No. |
|---|---|---|---|
| | | | |

| | | | | | |
|---|---|---|---|---|---|
| PERMANENT DATUM | Ground Level | ELEVATION | | K.B. | |
| LOG MEAS. FROM | Ground Level | ABOVE PERM. DATUM | | T.O.C | |
| DRILLING MEAS. FROM | Ground Level | | | G.L. | |
| DATE | 06-20-2016 | TYPE FLUID IN HOLE | | Air/water | |
| RUN No. | one | SALINITY | | | |
| TYPE LOG | QL-NB730 | DENSITY | | | |
| DEPTH-DRILLER | 1015 ft. | LEVEL | | 884 ft. | |
| DEPTH-LOGGER | 1012 ft. | MAX. REG. TEMP | | | |
| BTM LOGGED INTERVAL | 1011 ft. | DIGITIZE INTERVAL | | 0.1 ft. | |
| TOP LOGGED INTERVAL | Surface | | | | |
| OPERATING RIG TIME | | | | | |
| RECORDED BY | A.Henderson | | | | |
| WITNESSED BY | YellowJacket Drlg. | | | | |

| RUN | BOREHOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | WGT. | FROM | TO |
| 1 | | | | 20 inch | steel | 0 ft. | 42 ft. |
| 2 | | | | 18 inch | steel | 0 ft. | 307 ft. |
| 3 | | | | 14 inch | steel | 0 ft. | 1040 ft. |

REMARKS:

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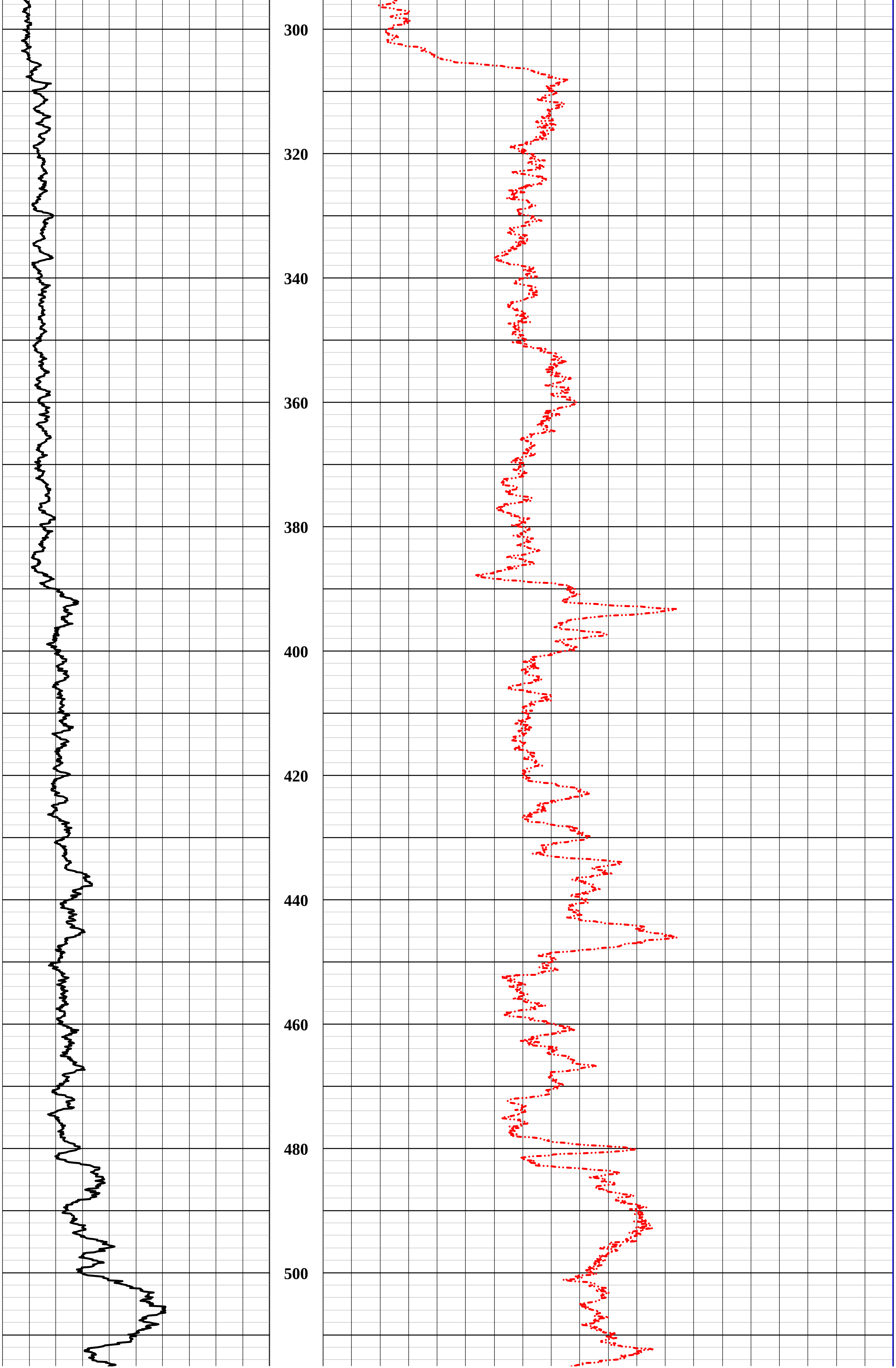
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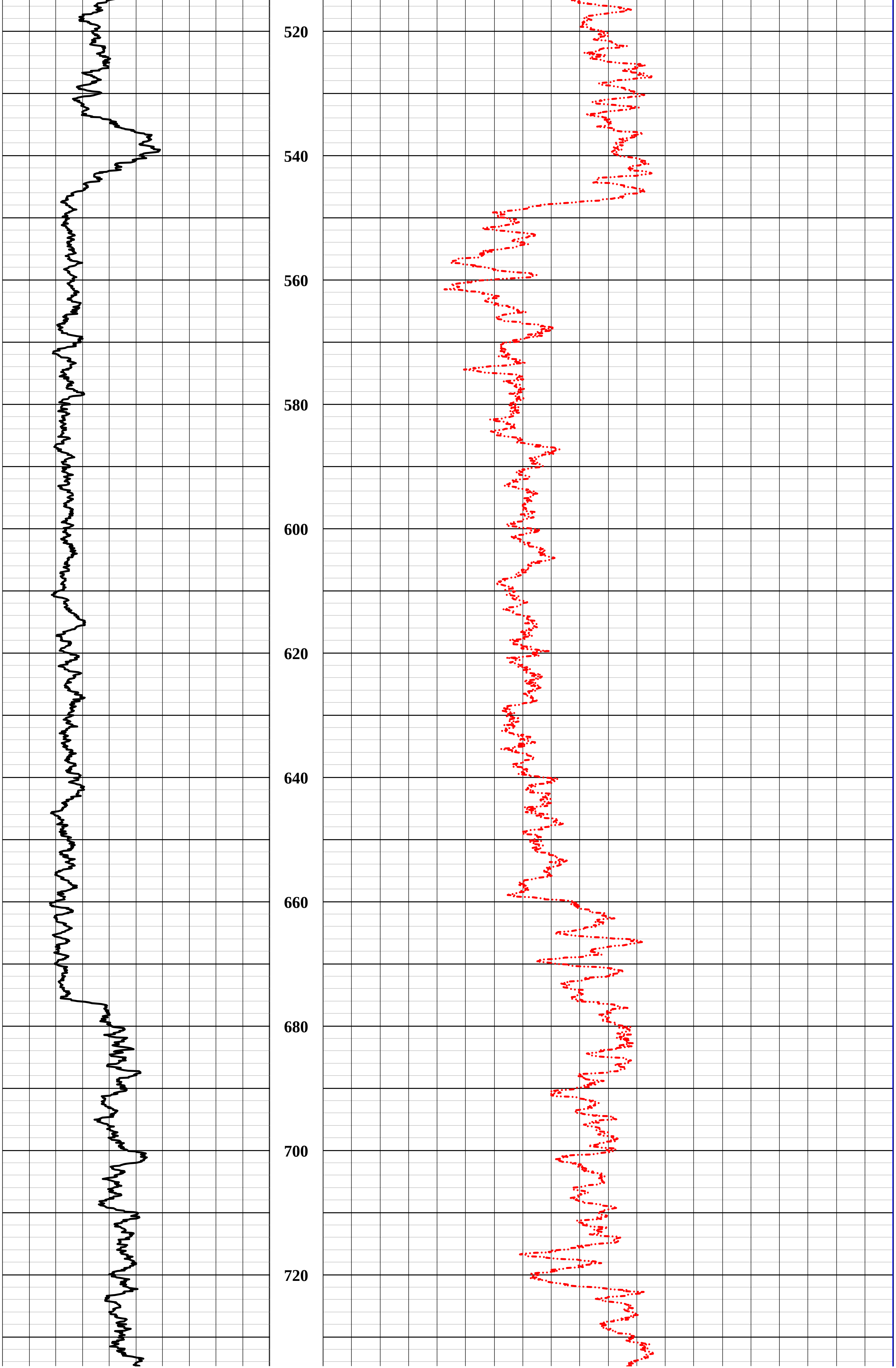

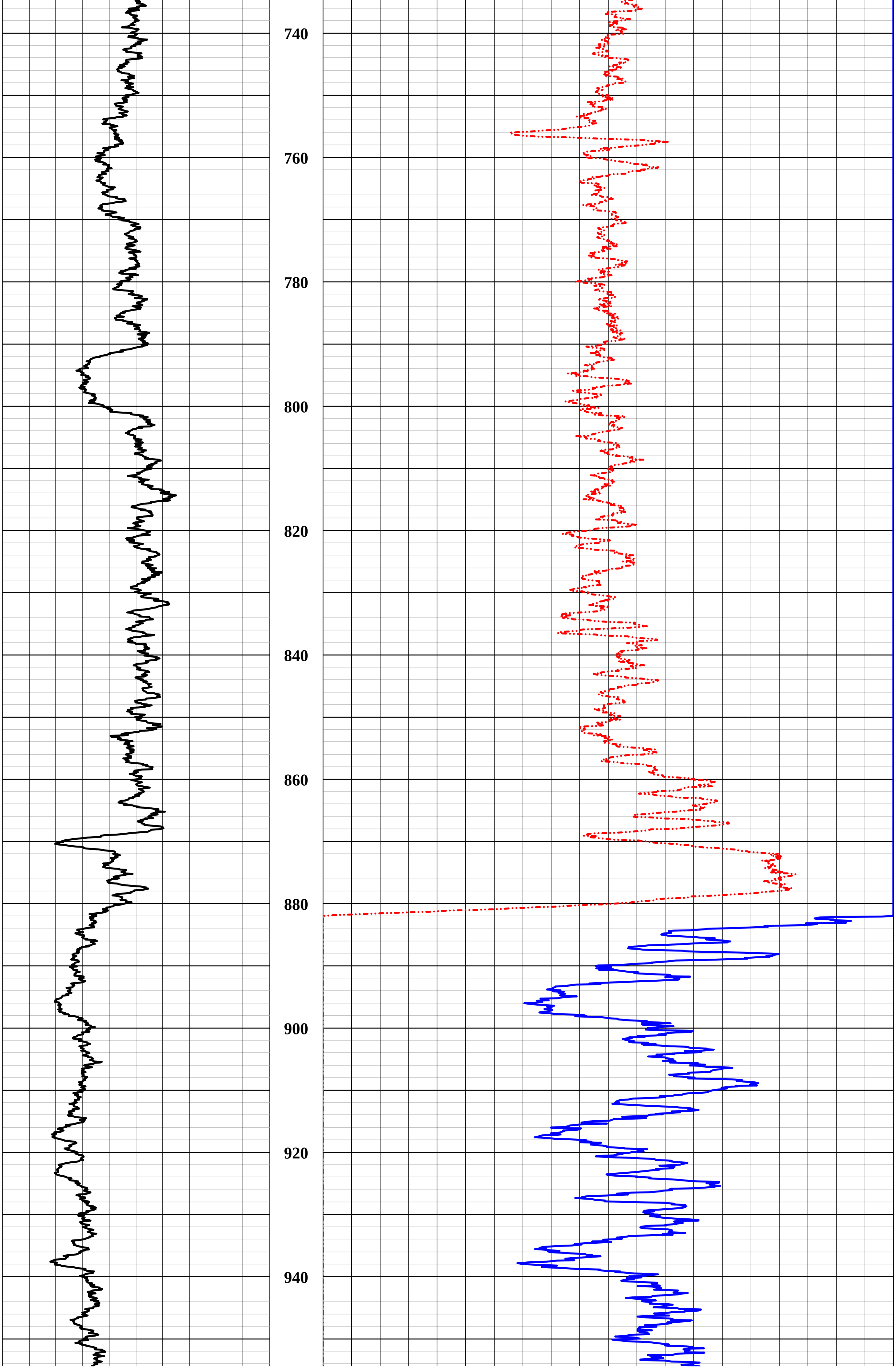
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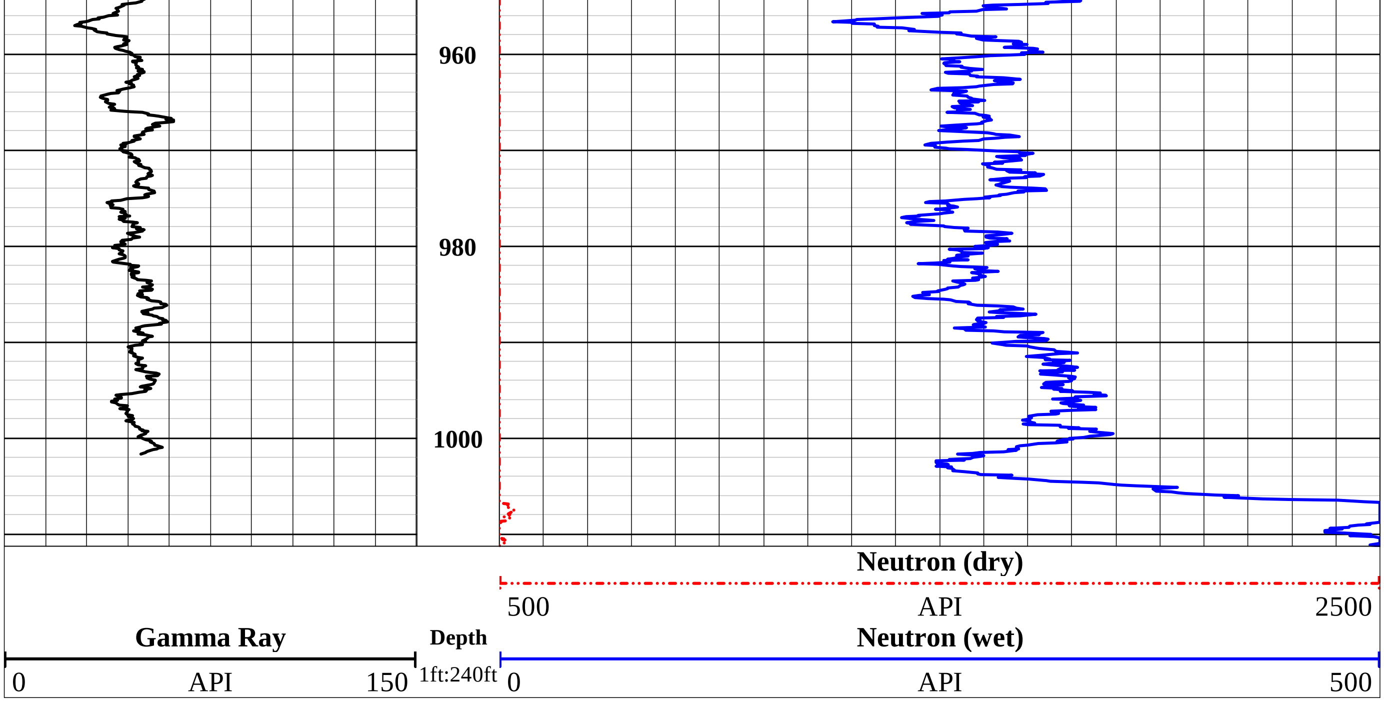
820
840
860
880
900
920
940



960
980
1000
Neutron (dry)
500
API
2500
Gamma Ray
Depth
Neutron (wet)
0
API
150
1ft:240ft
0
API
500

**JET WEST GEOPHYSICAL SERVICES, LLC.**

| | | | |
|---|---|---|---|
| COMPANY | Las Alamos National Labs | | |
| WELL ID | Crin No.2 | | |
| FIELD | LANL (Los Alamos National Labs) | | |
| COUNTY | Los Alamos | STATE | New Mexico |

**TYPE OF LOG: Gamma Ray, Neutron Log**

OTHER SERVICES
Density
Gamma Ray

LOCATION

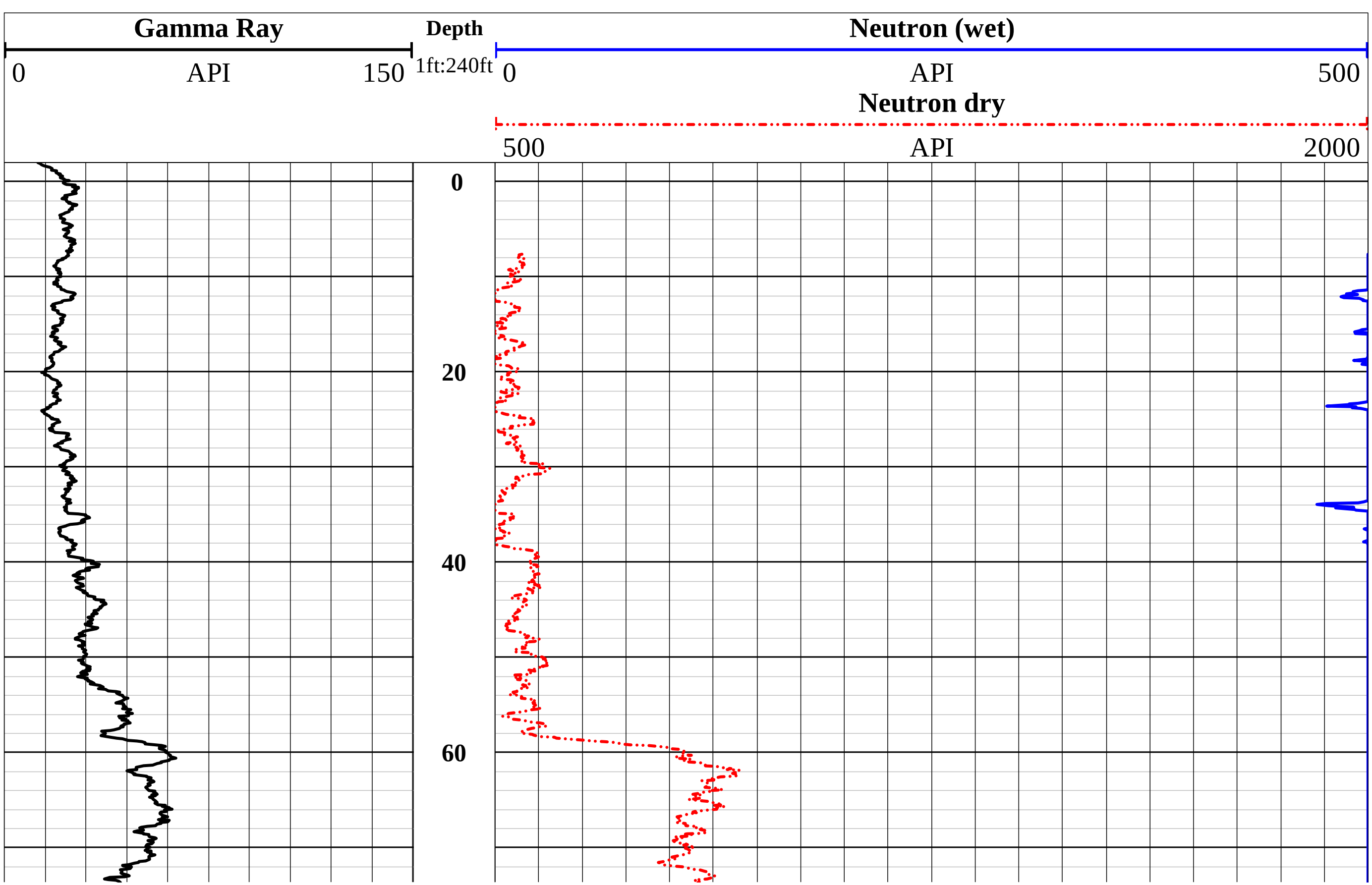
State Plane 1927
Northing:
Easting:

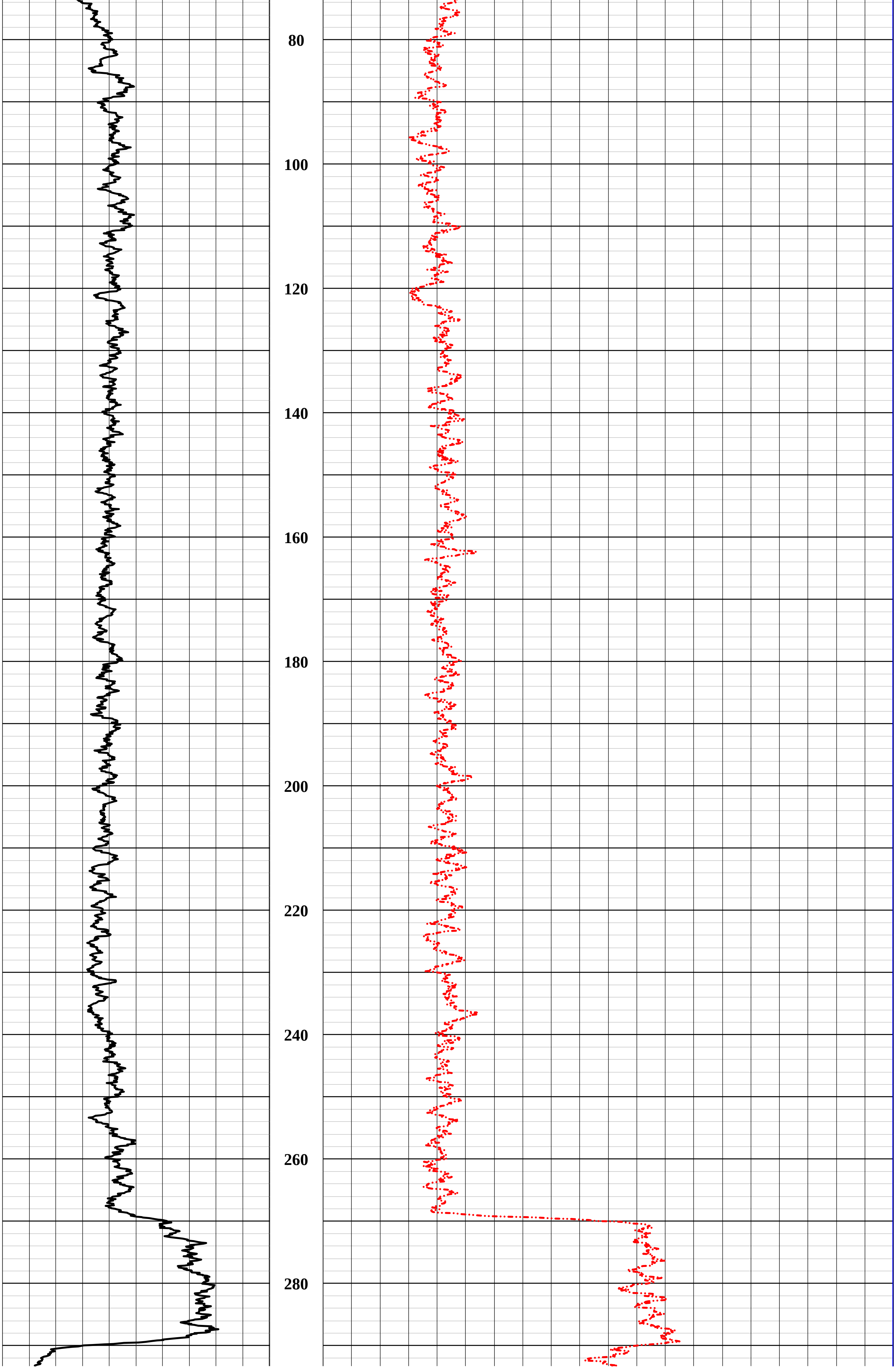
| SEC | TWP | RGE | API No. |
|---|---|---|---|

| | | | |
|---|---|---|---|
| PERMANENT DATUM | Ground Level | ELEVATION | K.B. |
| LOG MEAS. FROM | Ground Level | ABOVE PERM. DATUM | T.O.C |
| DRILLING MEAS. FROM | Ground Level | | G.L. |
| DATE | 05-09-2016 | TYPE FLUID IN HOLE | Air/water |
| RUN No. | one | SALINITY | |
| TYPE LOG | QL-NB696 | DENSITY | |
| DEPTH-DRILLER | 1062 ft. | LEVEL | 896 ft. |
| DEPTH-LOGGER | 1052 ft. | MAX. REC. TEMP | |
| BTM LOGGED INTERVAL | 1051 ft. | DIGITIZE INTERVAL | 0.1 ft. |
| TOP LOGGED INTERVAL | Surface | | |
| OPERATING RIG TIME | | | |
| RECORDED BY | A.Henderson | | |
| WITNESSED BY | YellowJacket Drlg. | | |

| RUN | BOREHOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | WGT. | FROM | TO |
| 1 | | | | 20 inch | steel | 0 ft. | 60 ft. |
| 2 | | | | 18 inch | steel | 0 ft. | 273 ft. |
| 3 | | | | 14 inch | steel | 0 ft. | 1062 ft. |

REMARKS:

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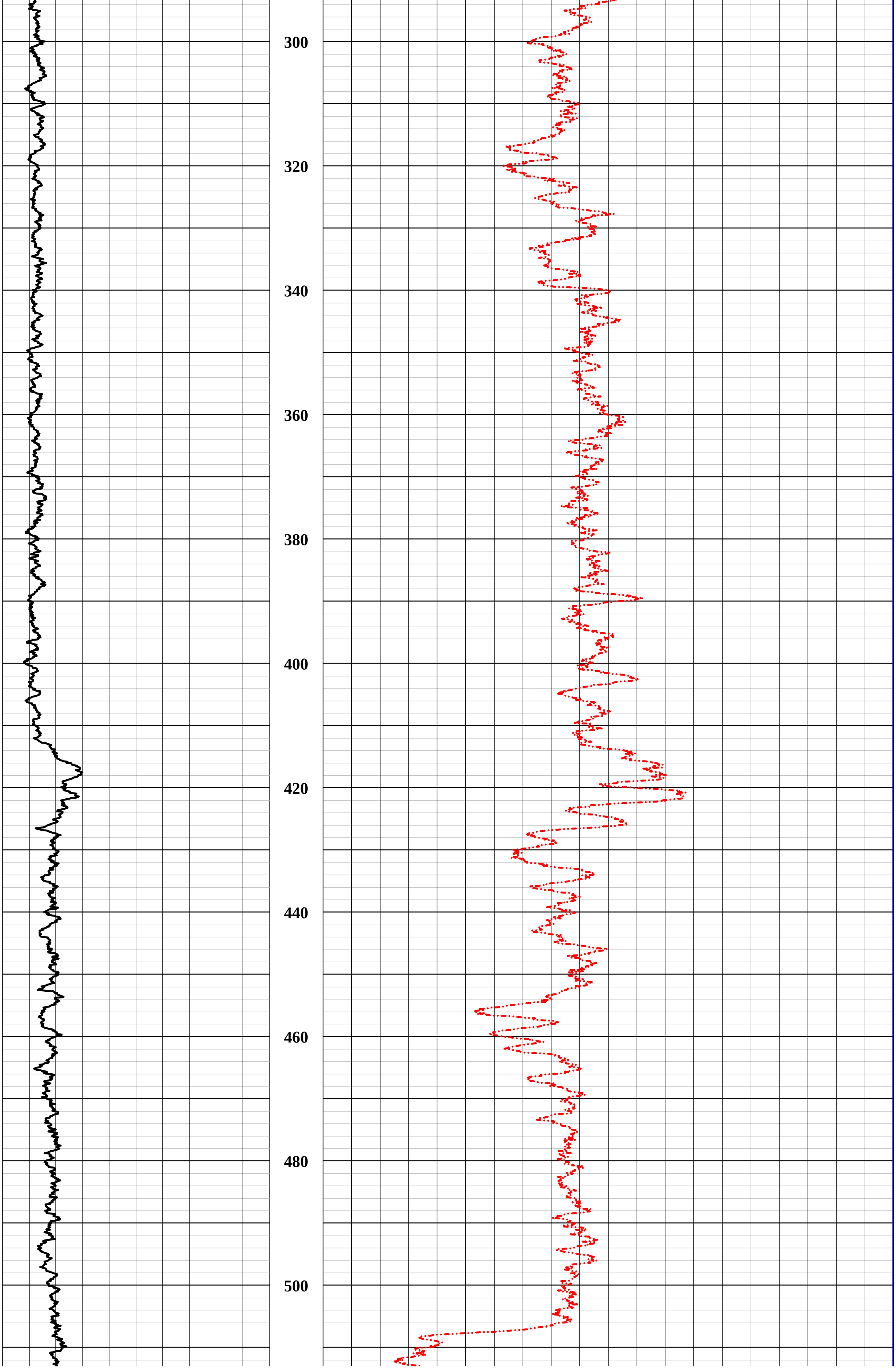
280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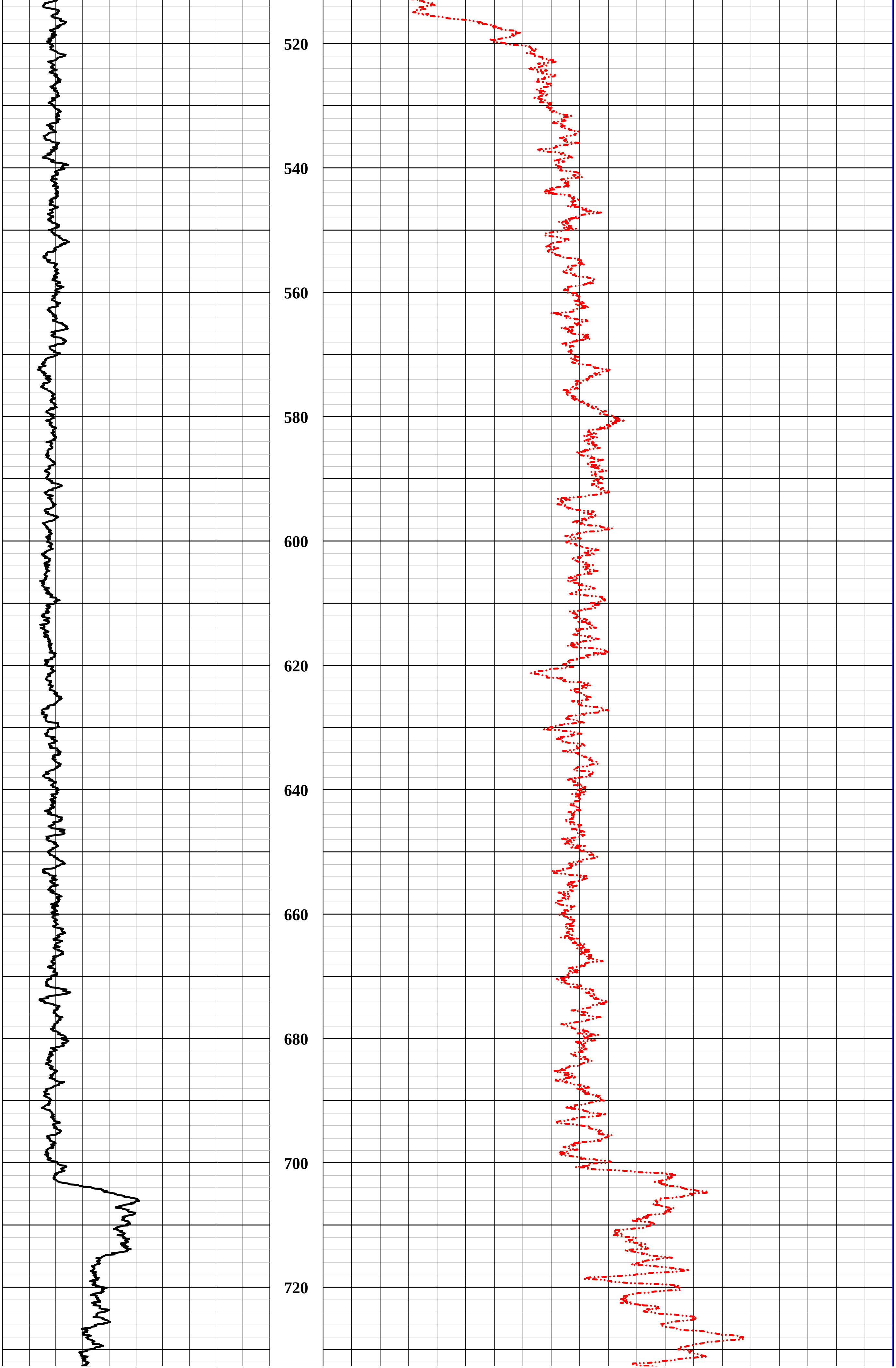
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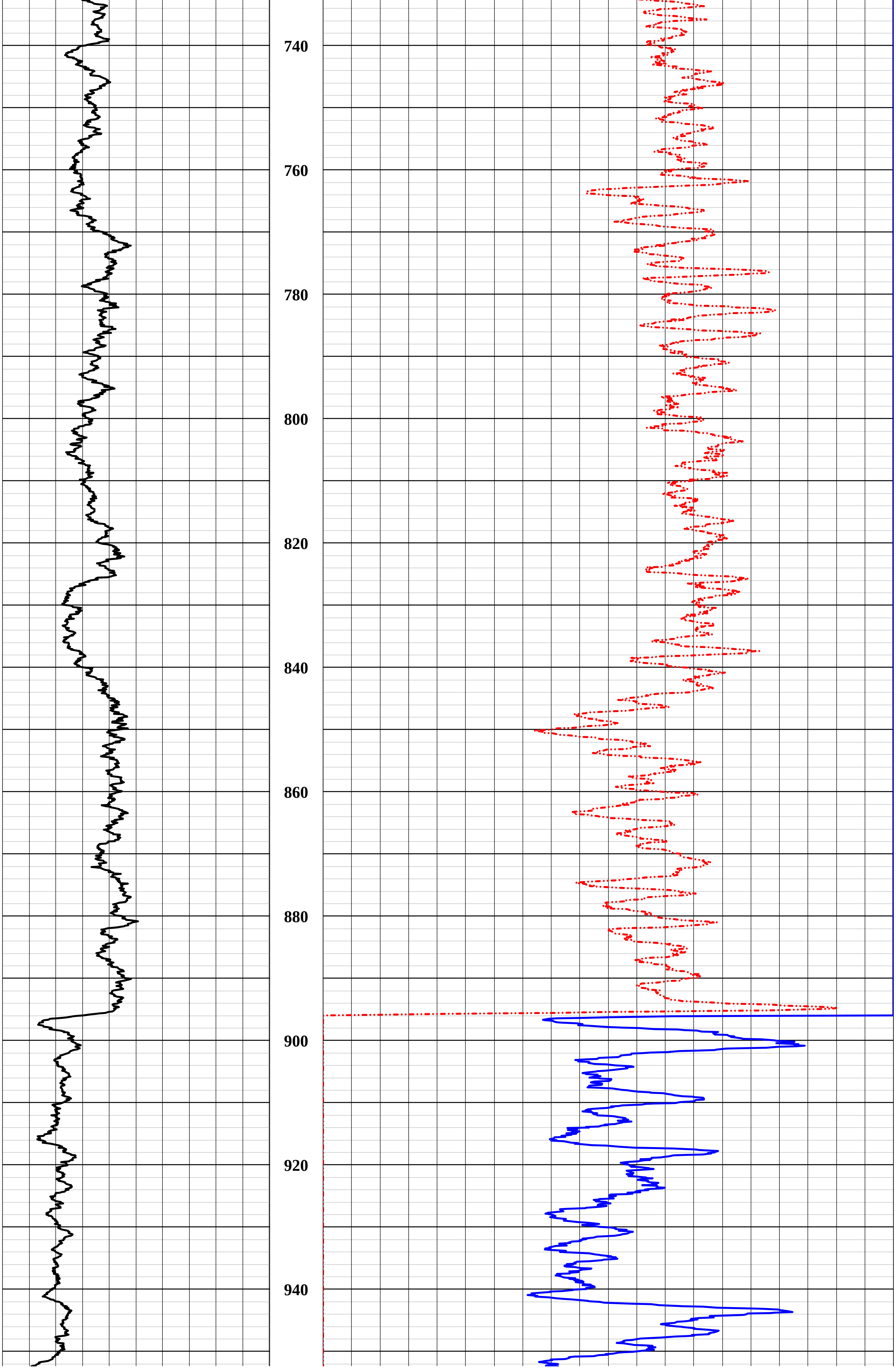
740
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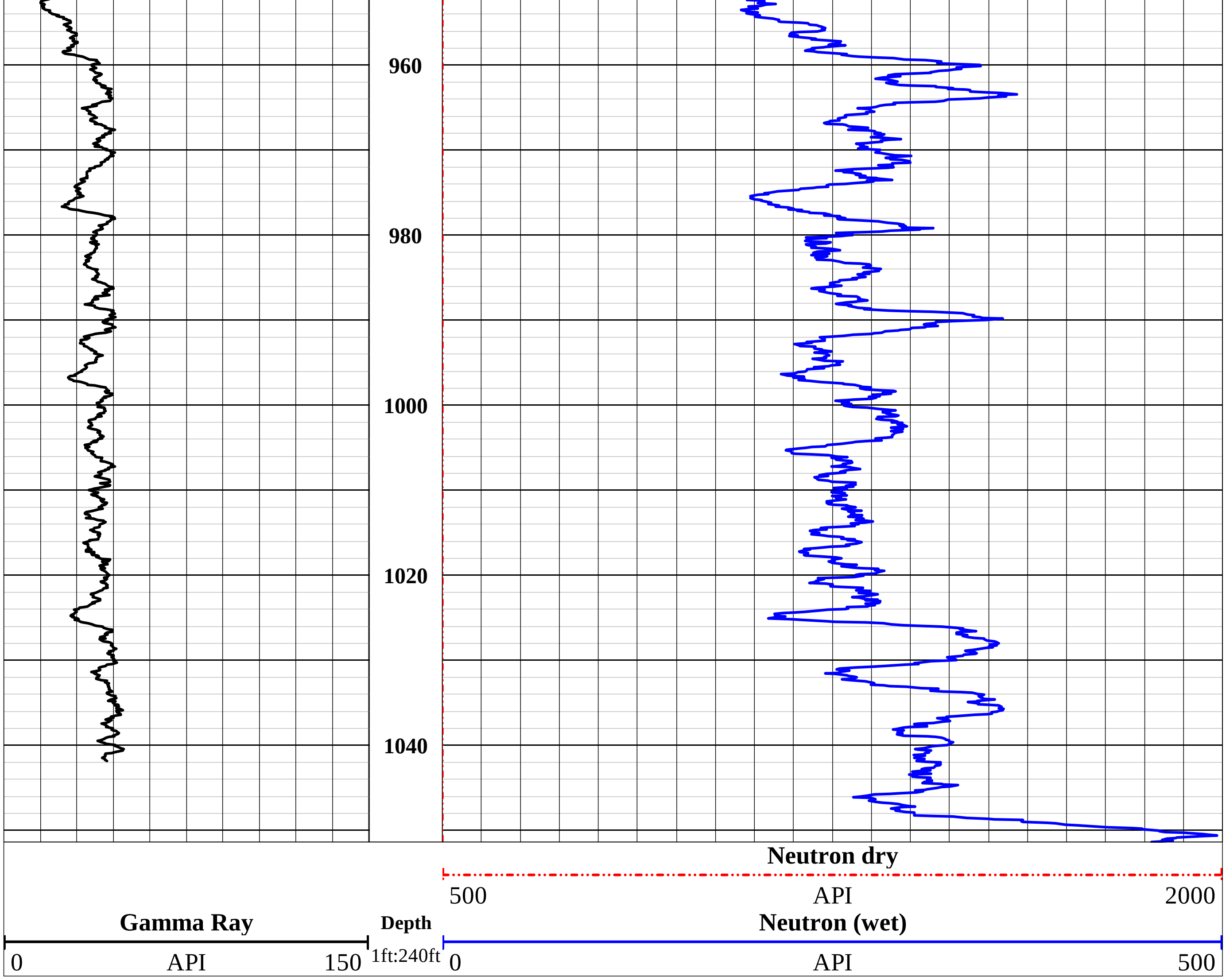

960
980
1000
1020
1040
Neutron dry
500
API
2000
Gamma Ray
Depth
Neutron (wet)
0
API
150
1ft:240ft
0
API
500

# JET WEST GEOPHYSICAL SERVICES, LLC.

State Plane 1927
Northing:
Easting:

| | | | |
|---|---|---|---|
| COMPANY | Las Alamos National Labs | | |
| WELL ID | Crin No.3 | | |
| FIELD | LANL (Los Alamos National Labs) | | |
| COUNTY | Los Alamos | STATE | New Mexico |

**TYPE OF LOG: Gamma Ray, Neutron Log**

OTHER SERVICES
None

LOCATION

SEC TWP RGE

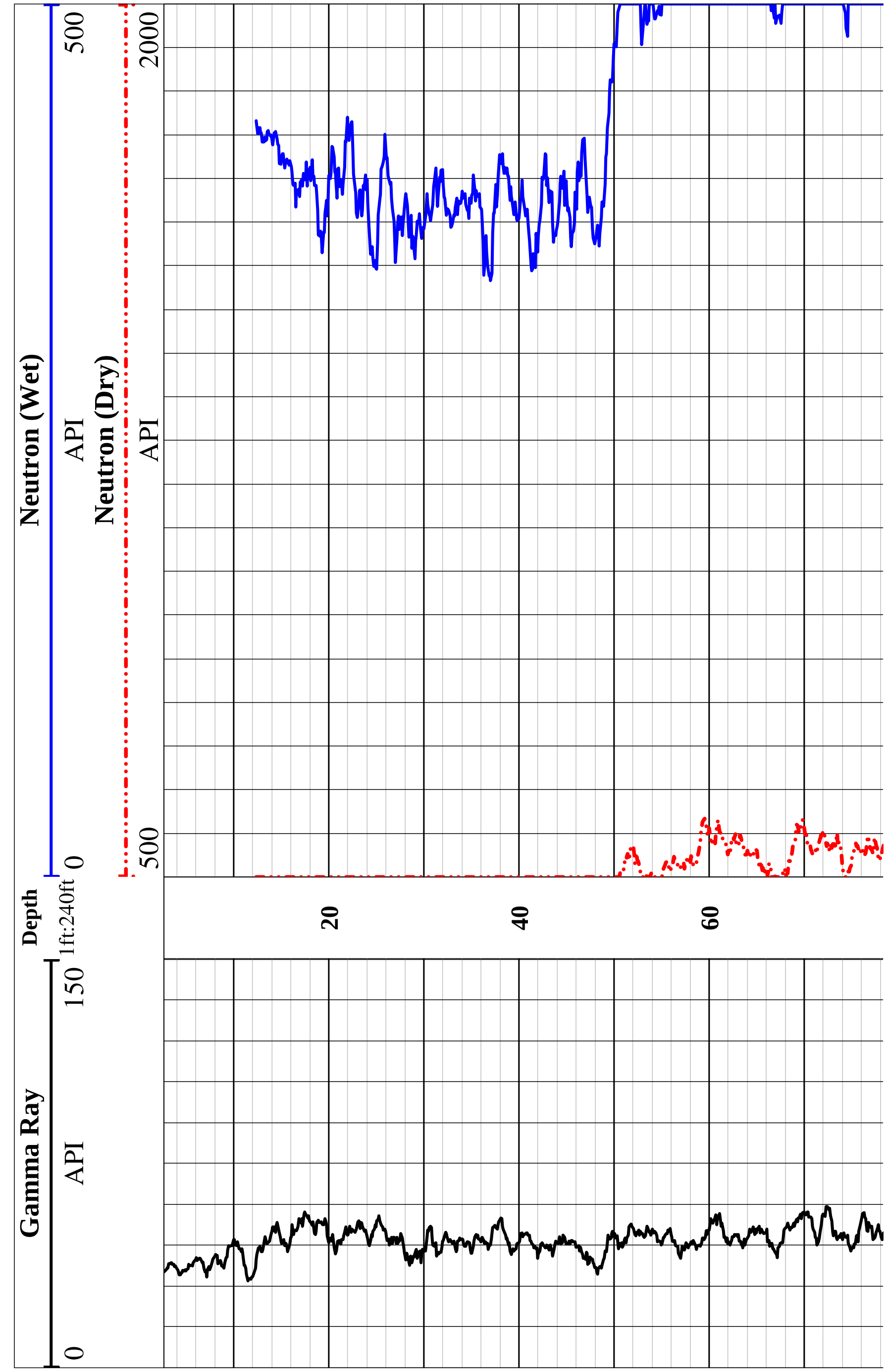
API No.

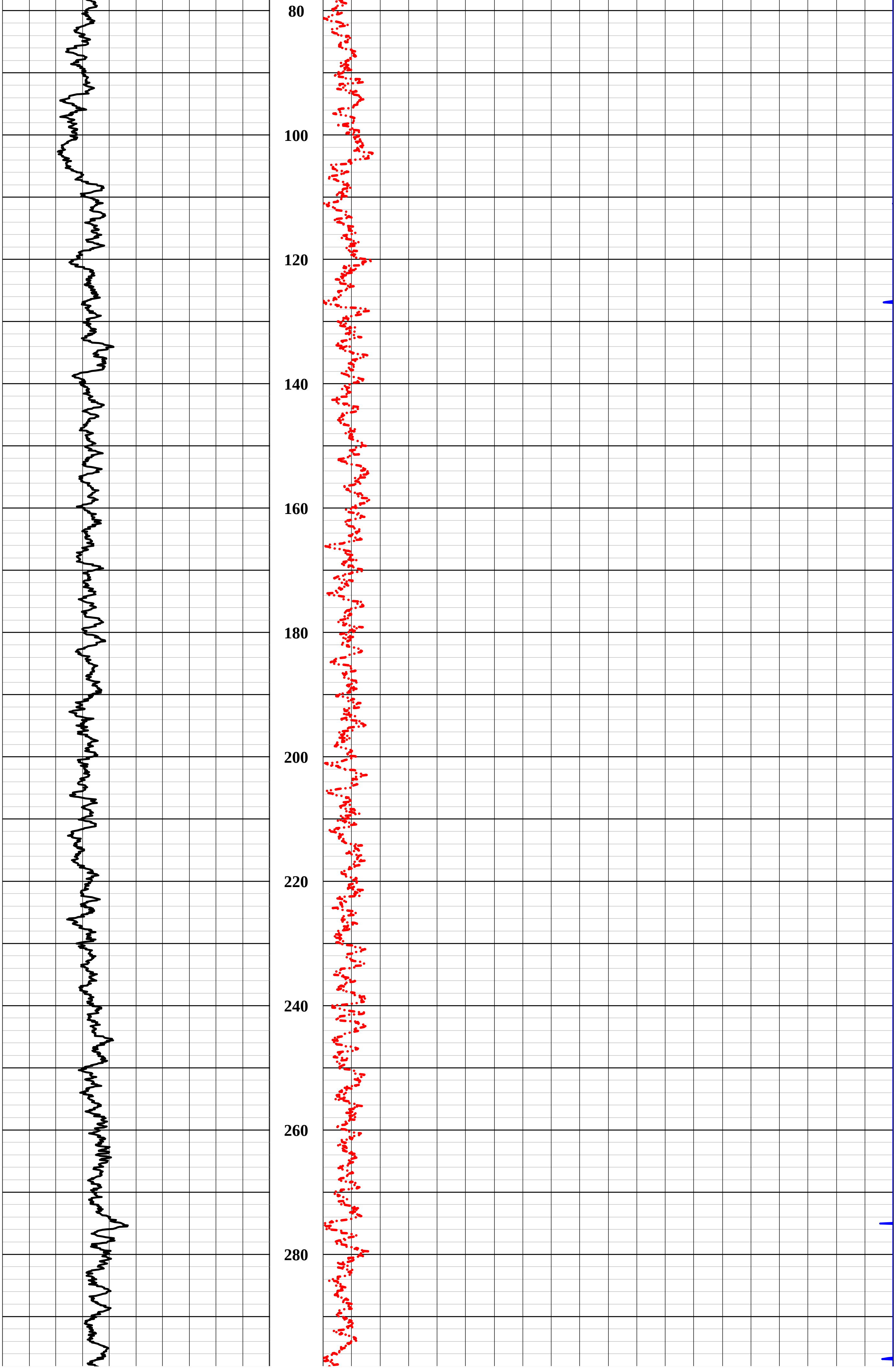
| | | | |
|---|---|---|---|
| PERMANENT DATUM | Ground Level | ELEVATION | K.B. |
| LOG MEAS. FROM | Ground Level | ABOVE PERM. DATUM | T.O.C |
| DRILLING MEAS. FROM | Ground Level | | G.L. |

| | | | |
|---|---|---|---|
| DATE | 08-15-2016 | TYPE FLUID IN HOLE | Air/water |
| RUN No. | one | SALINITY | |
| TYPE LOG | QL-NB696 | DENSITY | |
| DEPTH-DRILLER | 1025.08 ft. | LEVEL | 954 ft. |
| DEPTH-LOGGER | 1003.67 ft. | MAX. REG. TEMP | |
| BTM LOGGED INTERVAL | 1003.00 ft. | DIGITIZE INTERVAL | 0.1 ft. |
| TOP LOGGED INTERVAL | Surface | | |
| OPERATING RIG TIME | | | |
| RECORDED BY | A.Henderson | | |
| WITNESSED BY | Holt Services | | |

| RUN | BOREHOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | WGT. | FROM | TO |
| 1 | | | | 20 inch | steel | 0 ft. | 49.45 ft. |
| 2 | | | | 18 inch | steel | 0 ft. | 359.76 ft. |
| 3 | | | | 16 inch | steel | 0 ft. | 763.52 ft. |
| | | | | 14 inch | steel | 0 ft. | 1025.08 ft. |

REMARKS: Well is 17° angle from vertical.

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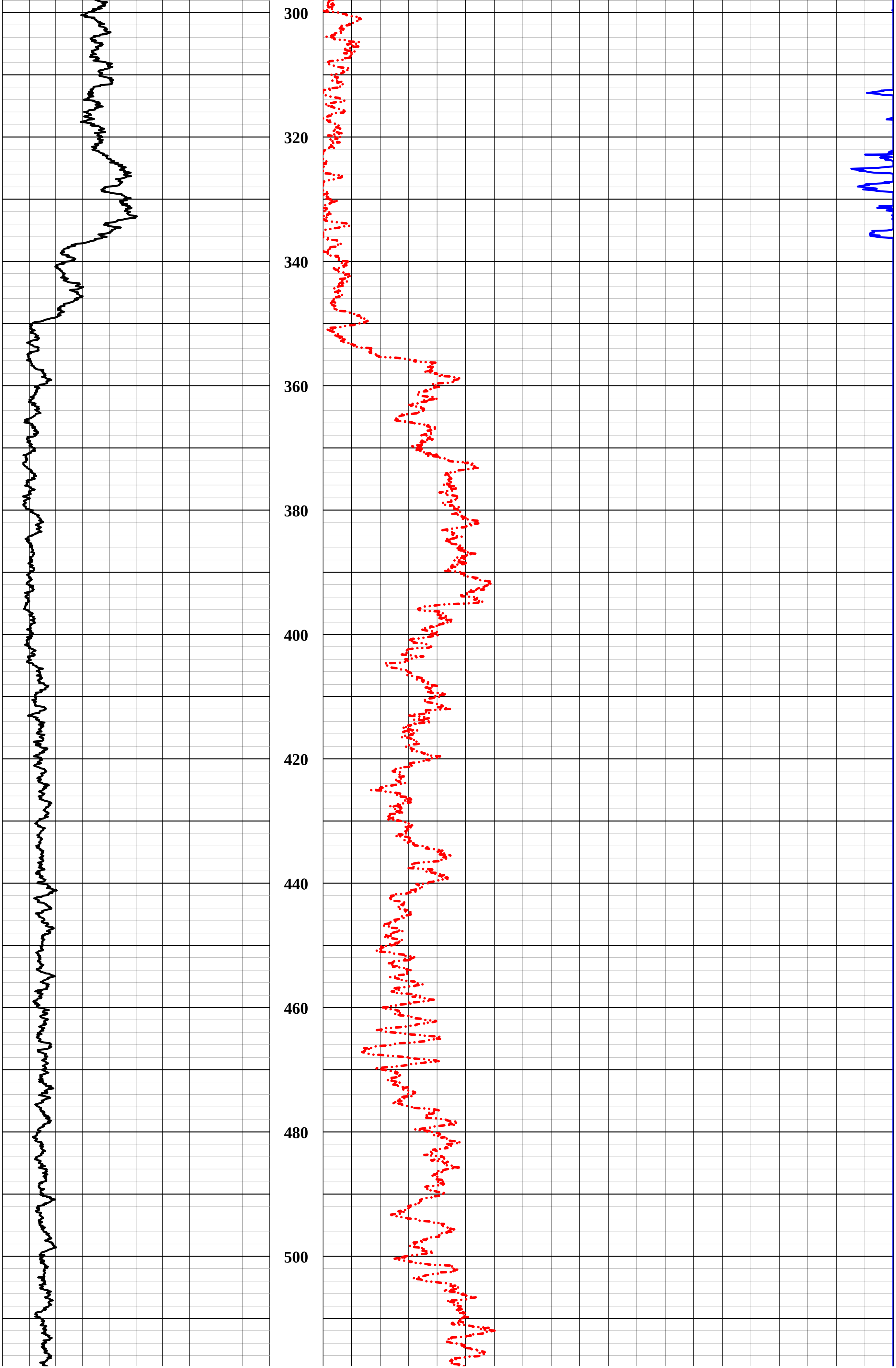
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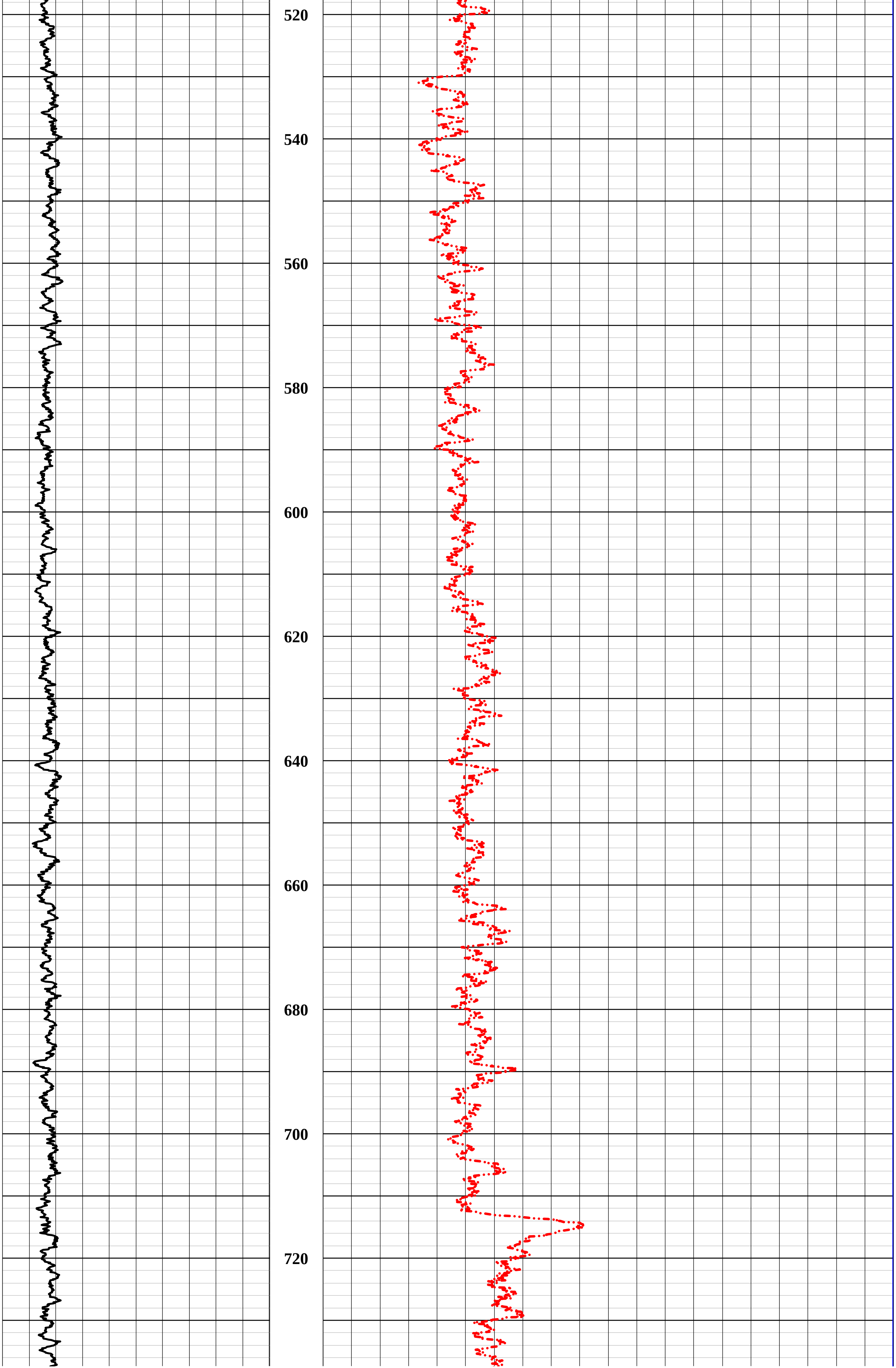
320
340
360
380
400
420
440
460
480
500


520
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620
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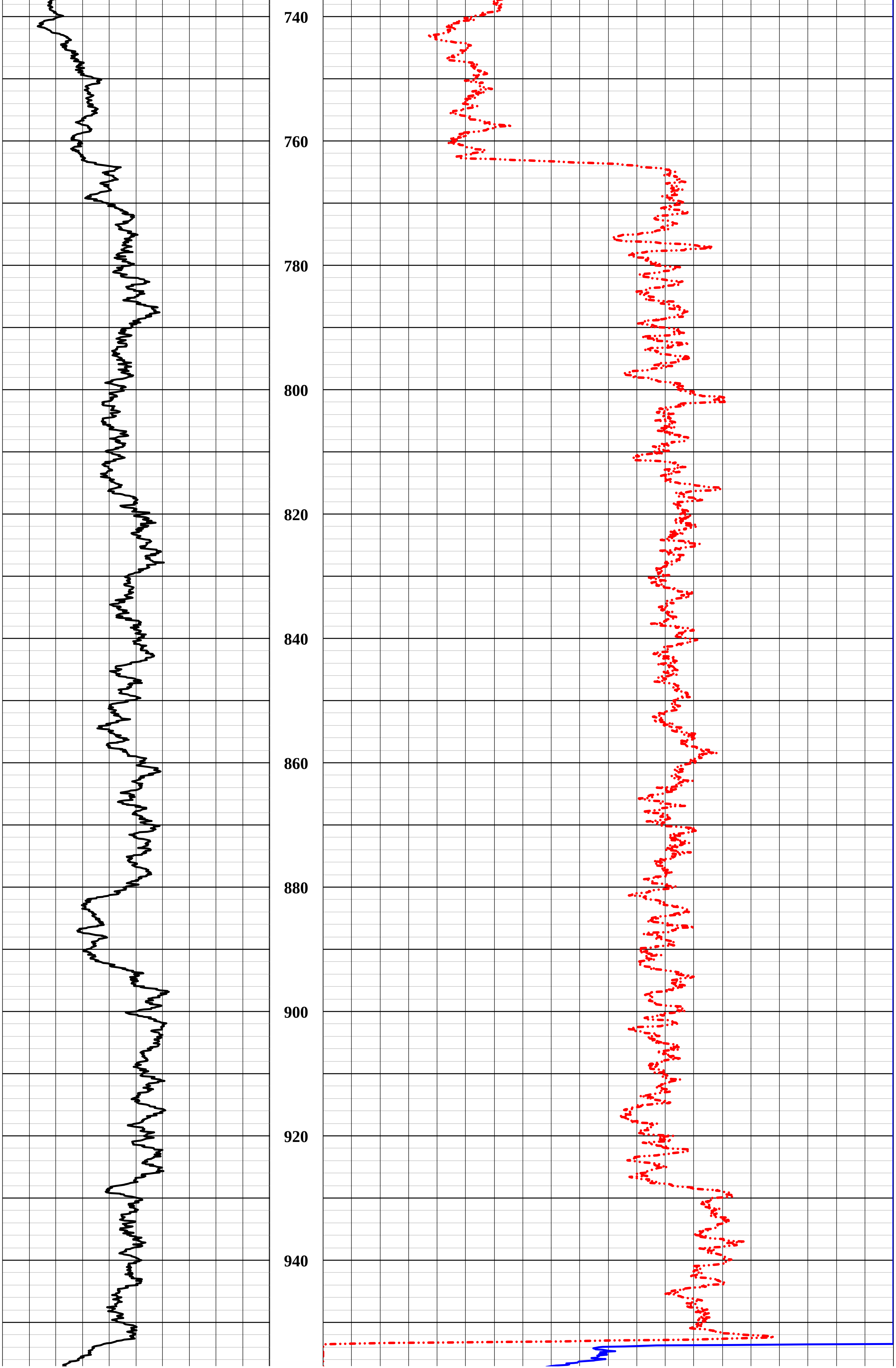
660
680
700
720


740
760
780
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820
840
860
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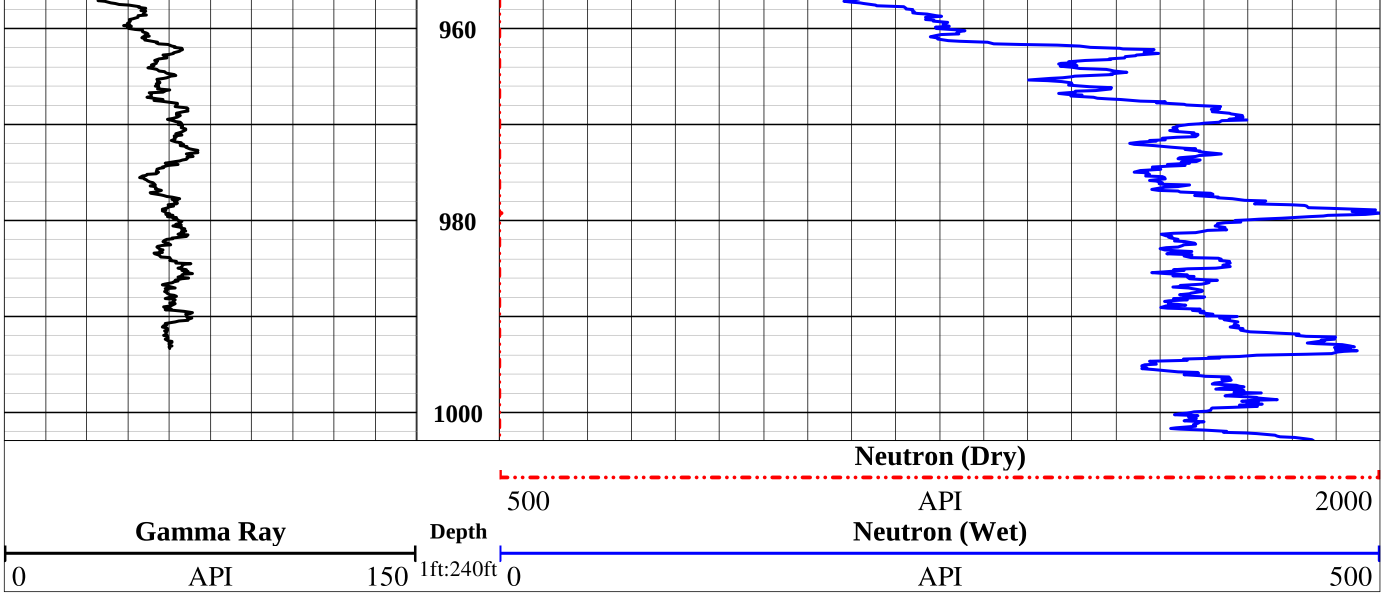
900
920
940


960
980
1000
Neutron (Dry)
500
API
2000
Gamma Ray
Depth
Neutron (Wet)
0
API
150
1ft:240ft
0
API
500

**JET WEST GEOPHYSICAL SERVICES, LLC.**

State Plane 1927

Northing:

Easting:

| | |
|---|---|
| COMPANY | Las Alamos National Labs |
| WELL ID | Crin No.4 |
| FIELD | LANL (Los Alamos National Labs) |
| COUNTY | Los Alamos |
| STATE | New Mexico |

**TYPE OF LOG: Gamma Ray, Neutron Log**

OTHER SERVICES
None

LOCATION

SEC TWP RGE

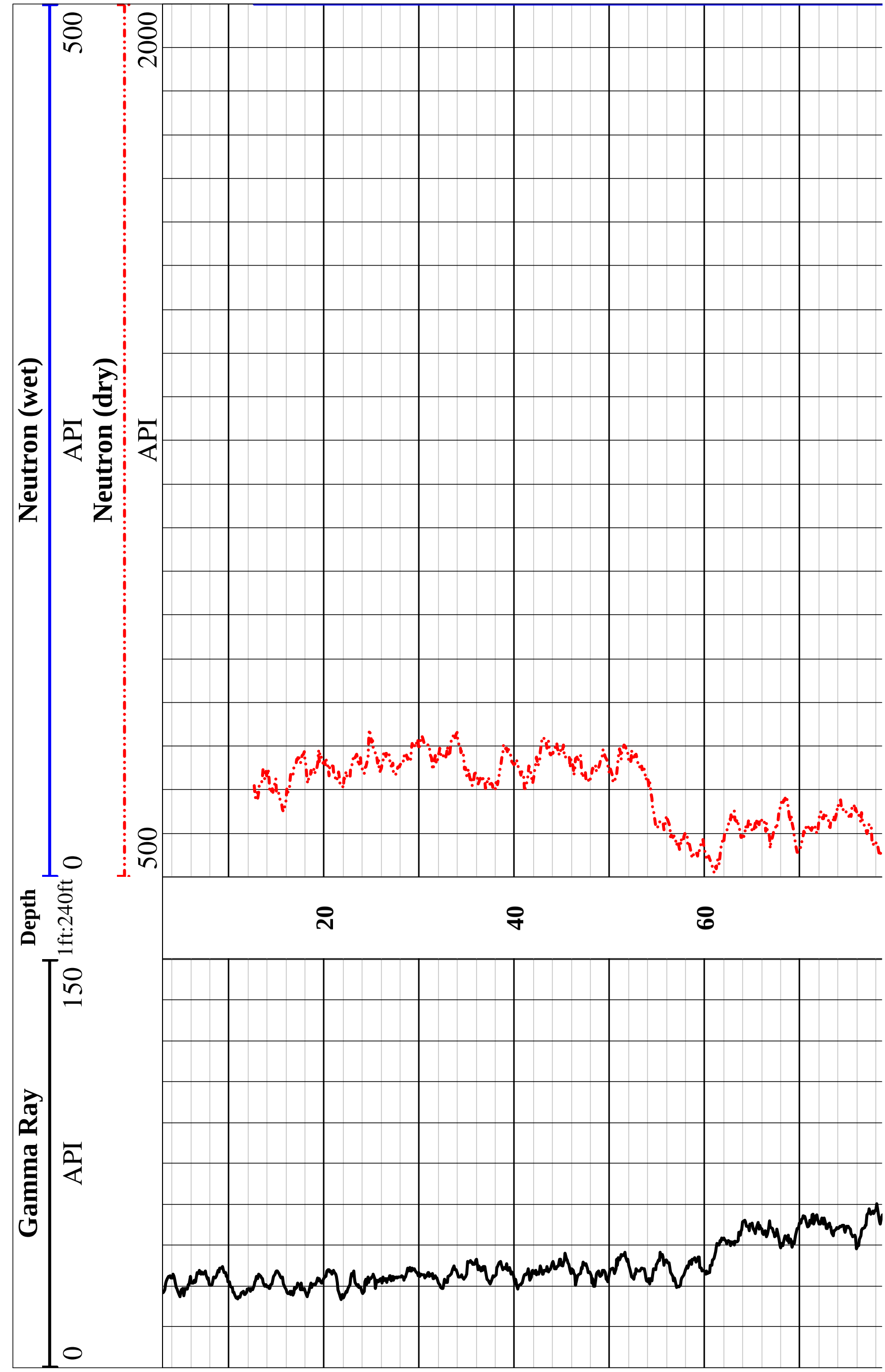
API No.

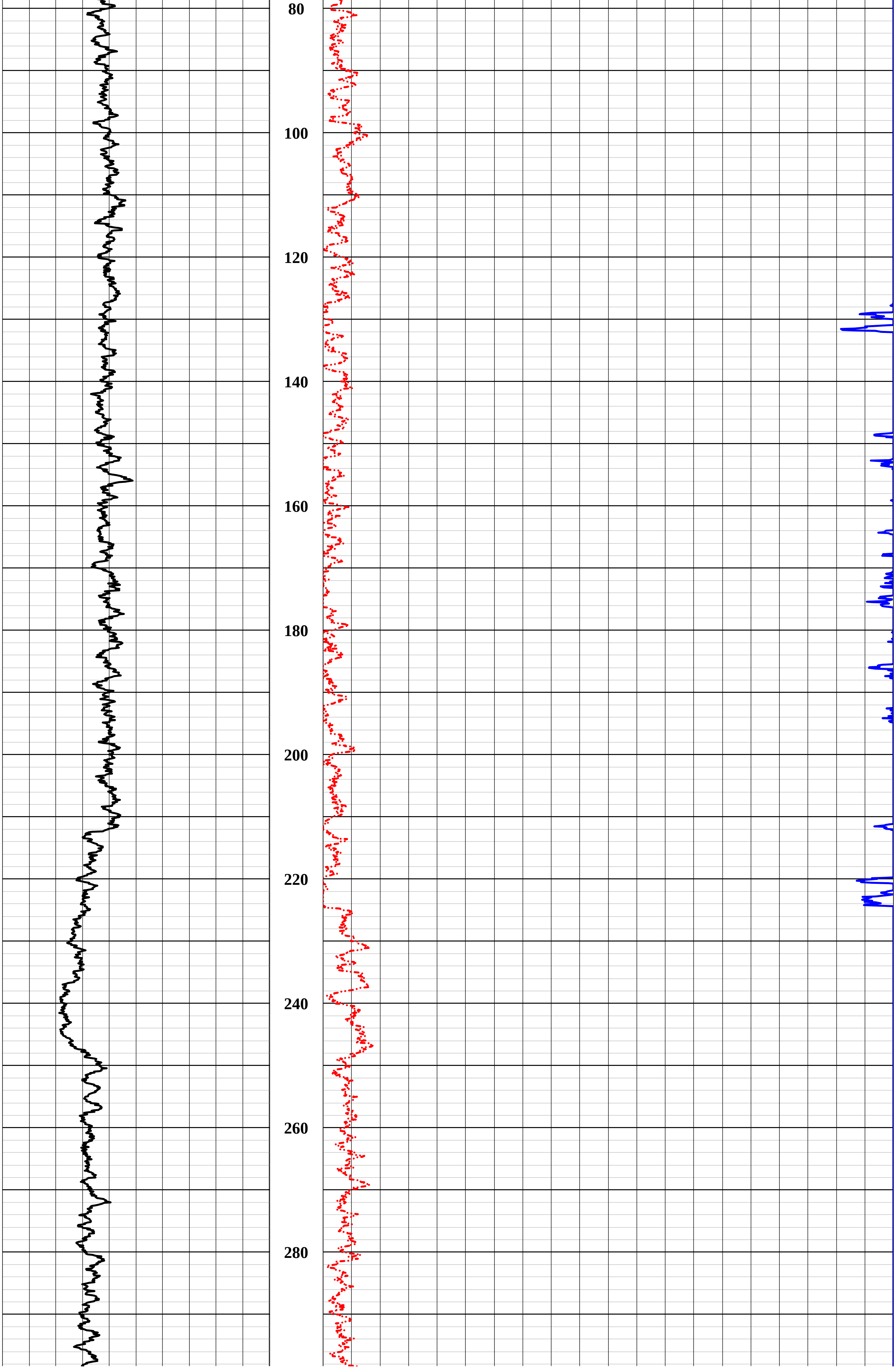
| | | | | |
|---|---|---|---|---|
| PERMANENT DATUM | Ground Level | ELEVATION | | K.B. |
| LOG MEAS. FROM | Ground Level | ABOVE PERM. DATUM | | T.O.C |
| DRILLING MEAS. FROM | Ground Level | | | G.L. |

| | | | |
|---|---|---|---|
| DATE | 05-11-2016 | TYPE FLUID IN HOLE | Air/water |
| RUN No. | one | SALINITY | |
| TYPE LOG | QL-NB696 | DENSITY | |
| DEPTH-DRILLER | 1202 ft. | LEVEL | 1076 ft. |
| DEPTH-LOGGER | 1193.6 ft. | MAX. REG. TEMP | |
| BTM LOGGED INTERVAL | 1193 ft. | DIGITIZE INTERVAL | 0.1 ft. |
| TOP LOGGED INTERVAL | Surface | | |
| OPERATING RIG TIME | | | |
| RECORDED BY | A.Henderson | | |
| WITNESSED BY | Holt Services | | |

| RUN | BOREHOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | WGT. | FROM | TO |
| 1 | | | | 20 inch | steel | 0 ft. | 61.25 ft. |
| 2 | | | | 18 inch | steel | 0 ft. | 595.28 ft. |
| 3 | | | | 16 inch | steel | 0 ft. | 821.76 ft. |
| | | | | 14 inch | steel | 0 ft. | 1202 ft. |

REMARKS: Well is 11° angle from vertical.

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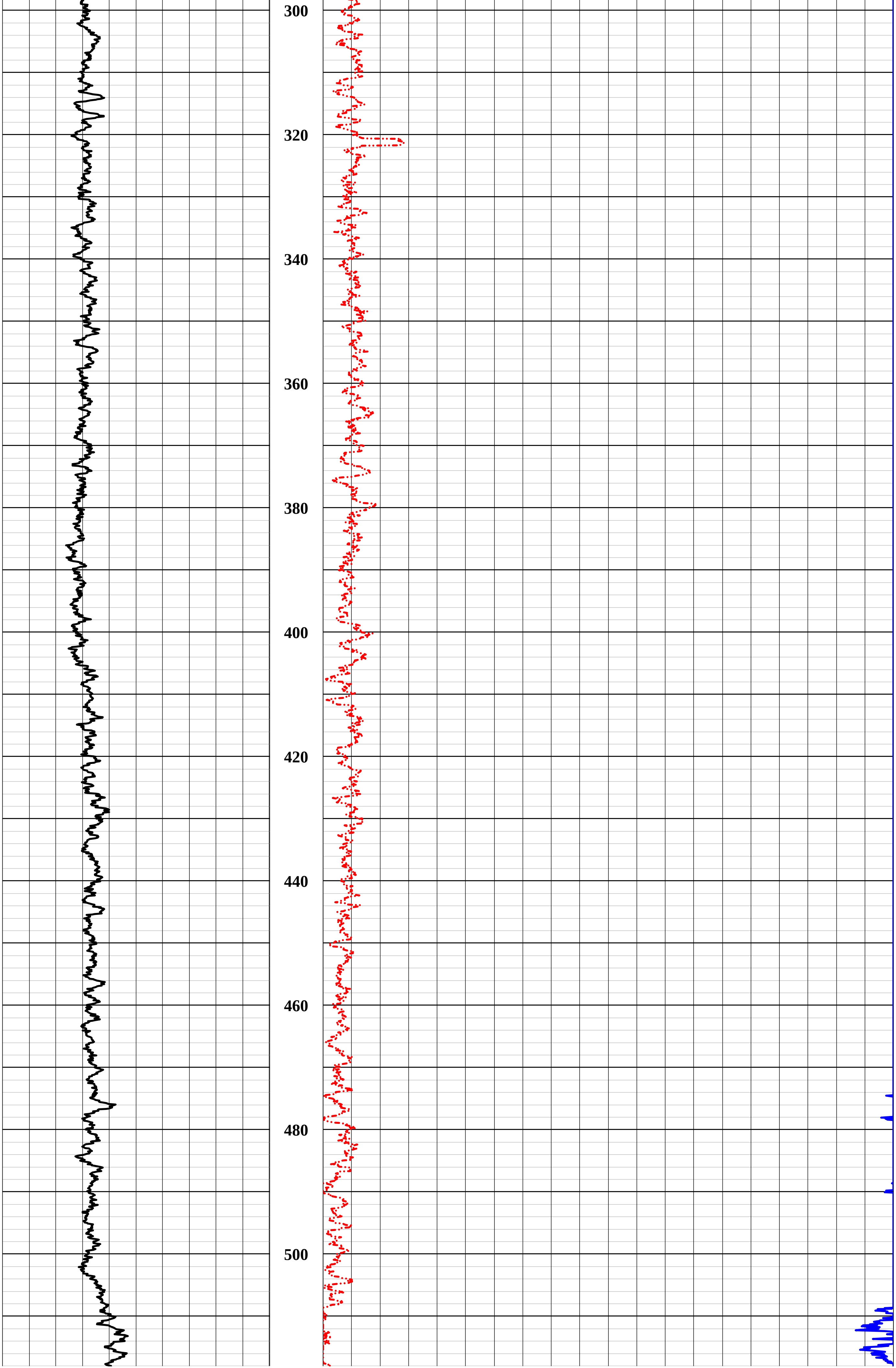
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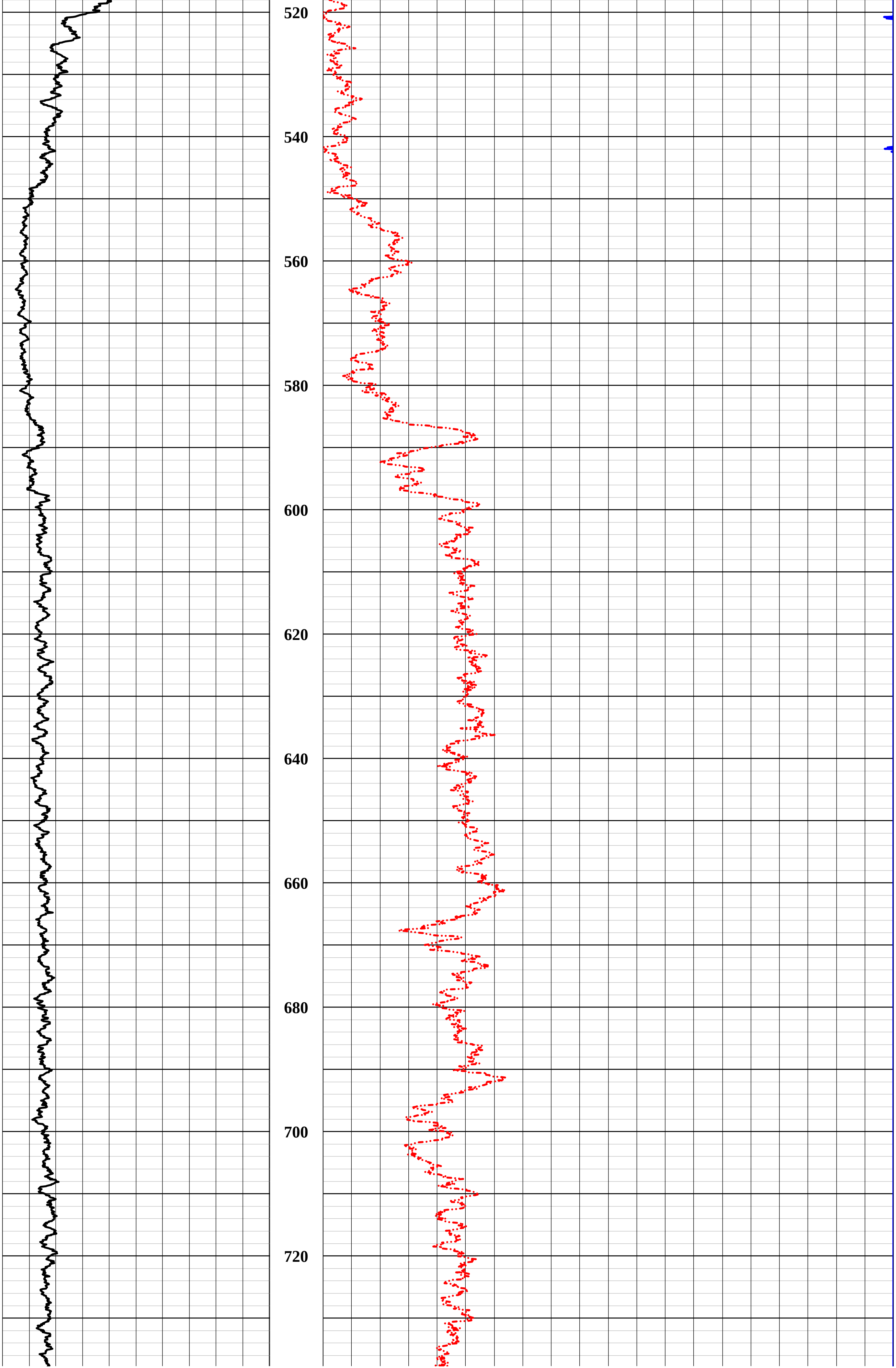
480
500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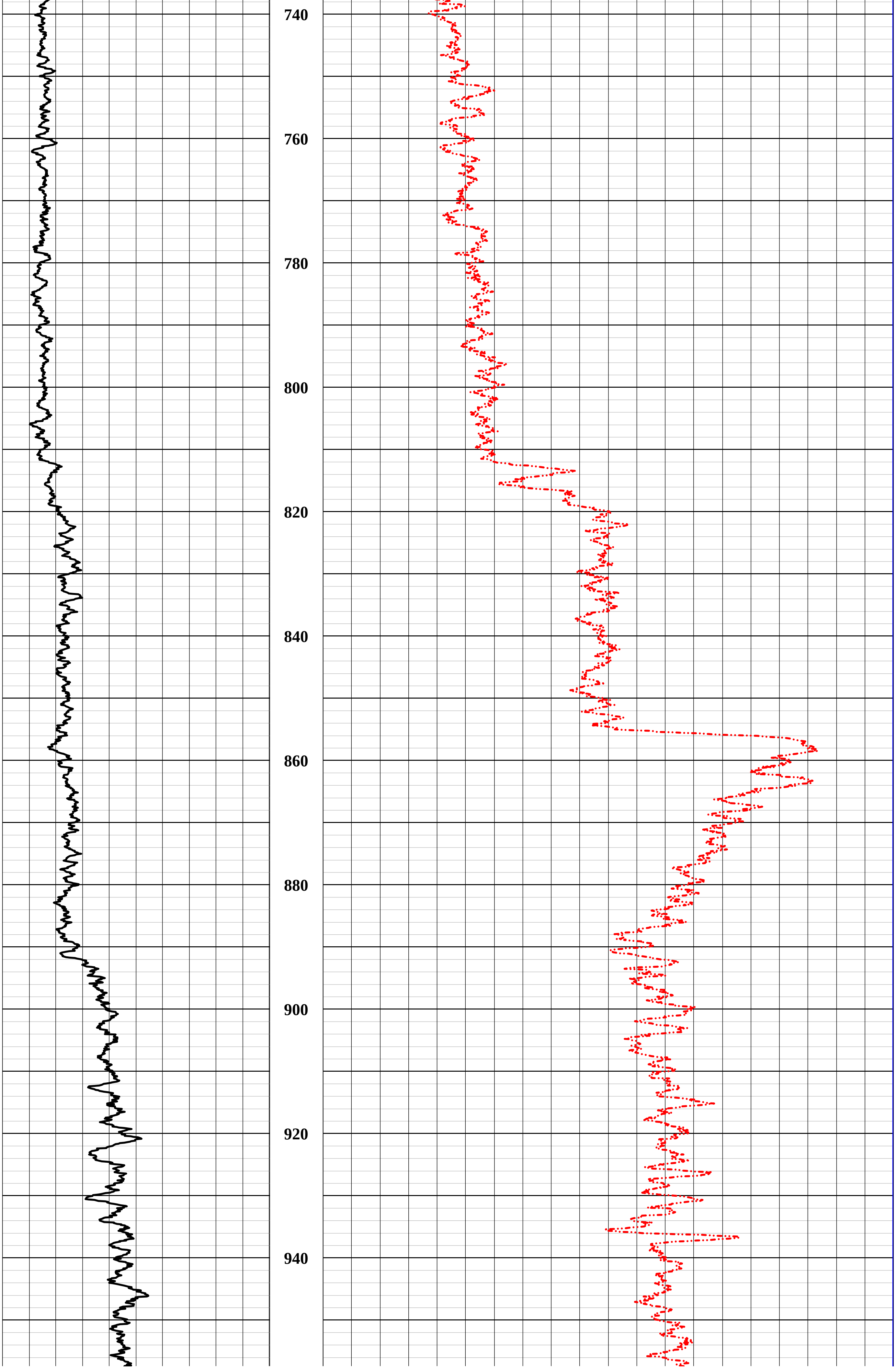
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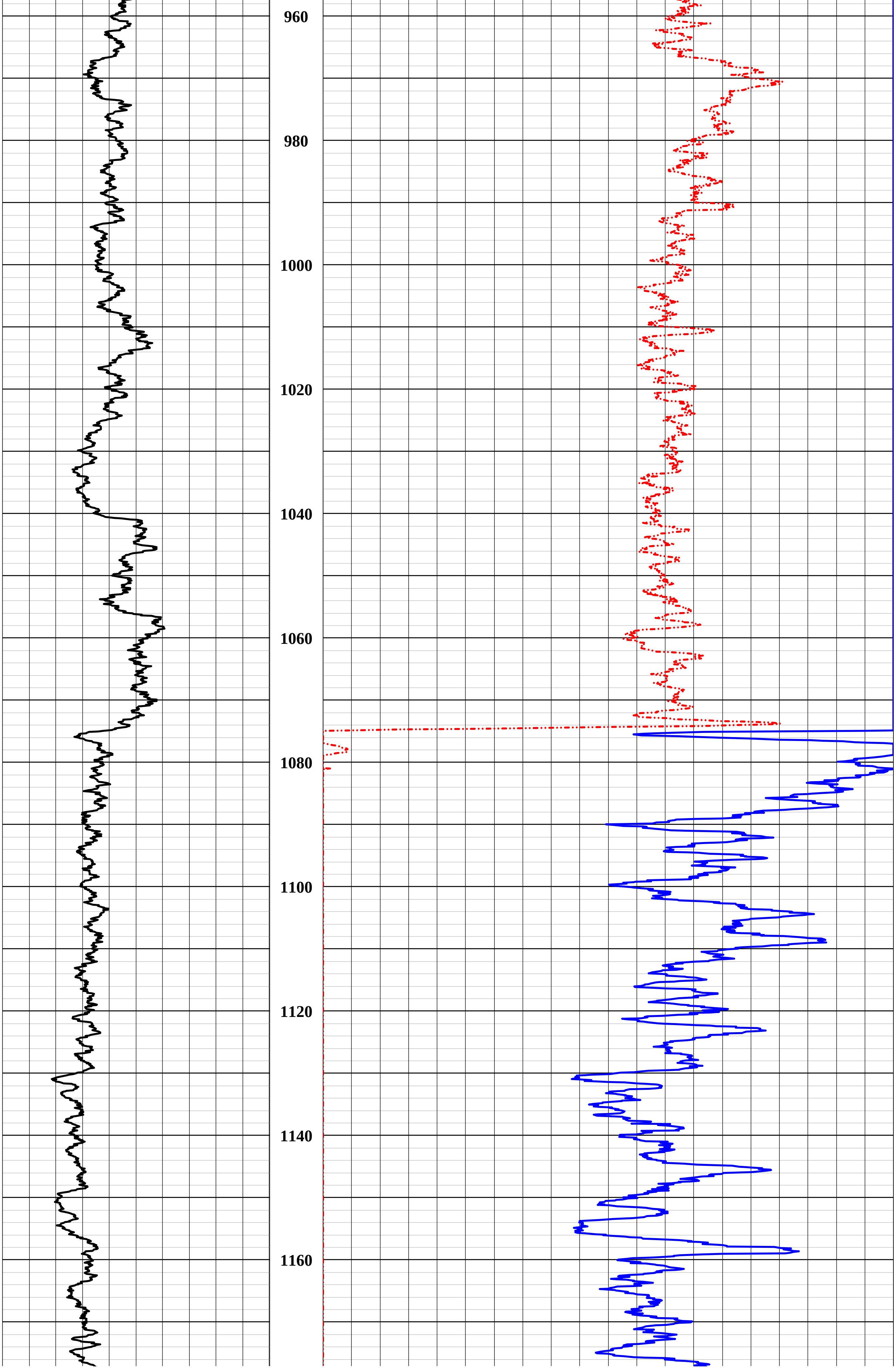
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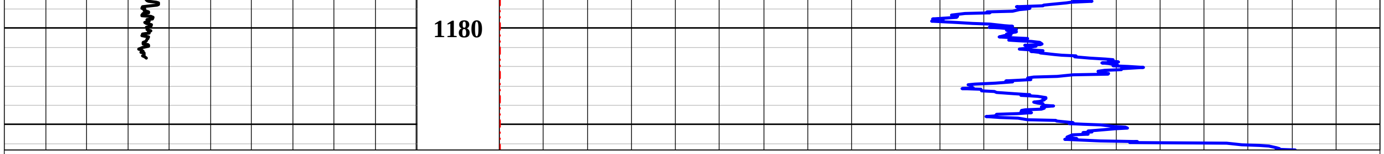
980
1000
1020
1040
1060
1080
1100
1120
1140
1160




| | Neutron (dry) | | |
|---|---|---|---|
| | 500 | API | 2000 |
| Gamma Ray | Depth | Neutron (wet) | |
| 0 API 150 | 1ft:240ft | 0 API 500 | |

**JET WEST GEOPHYSICAL SERVICES, LLC.**

| | | | |
|---|---|---|---|
| State Plane 1927 | COMPANY | Las Alamos National Labs | |
| Northing: | WELL ID | Crin No.5 | |
| Easting: | FIELD | LANL (Los Alamos National Labs) | |
| | COUNTY | Los Alamos | STATE New Mexico |

**TYPE OF LOG: Gamma Ray, Neutron Log**

OTHER SERVICES
None

LOCATION

SEC TWP RGE

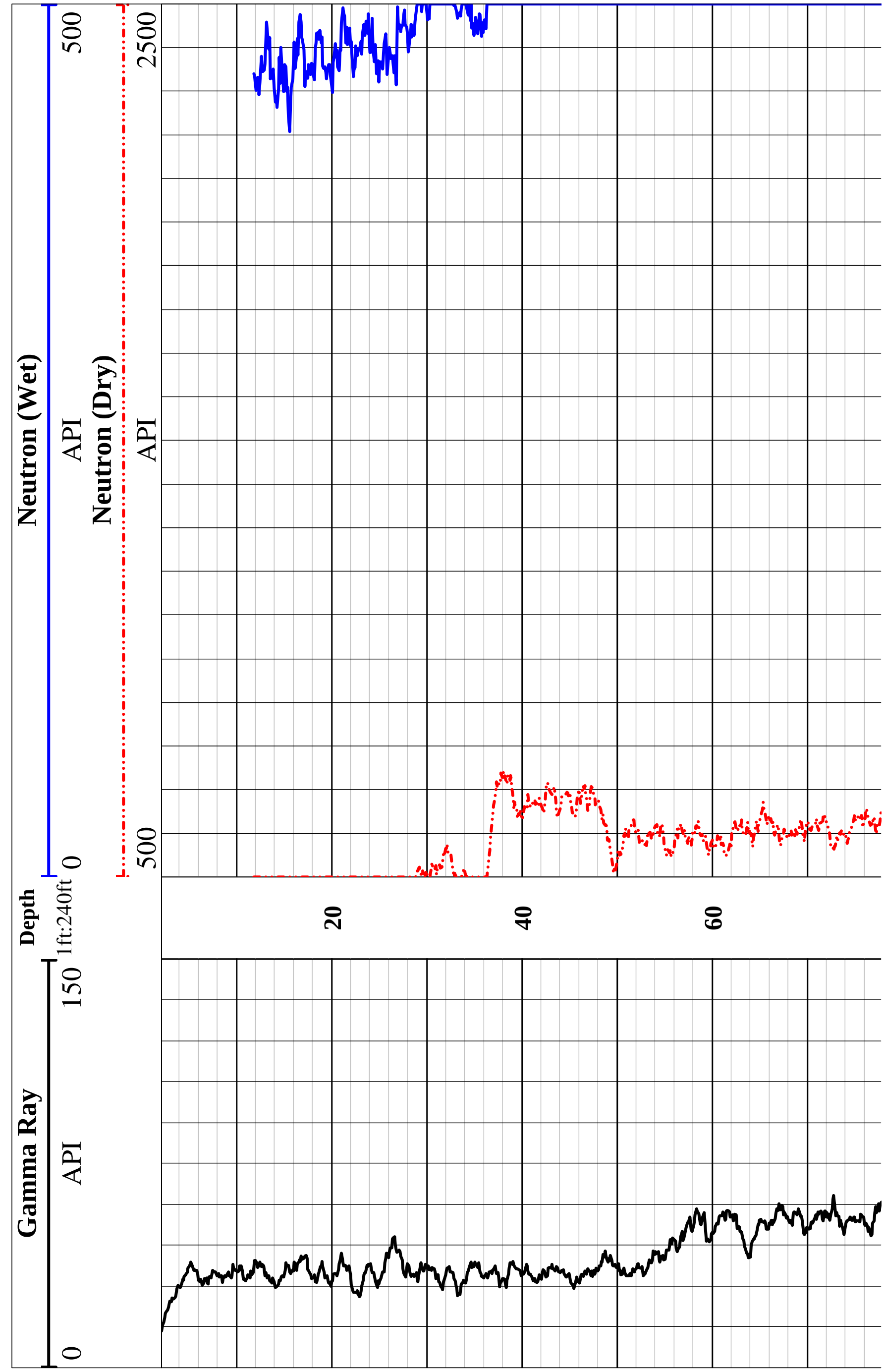
API No.

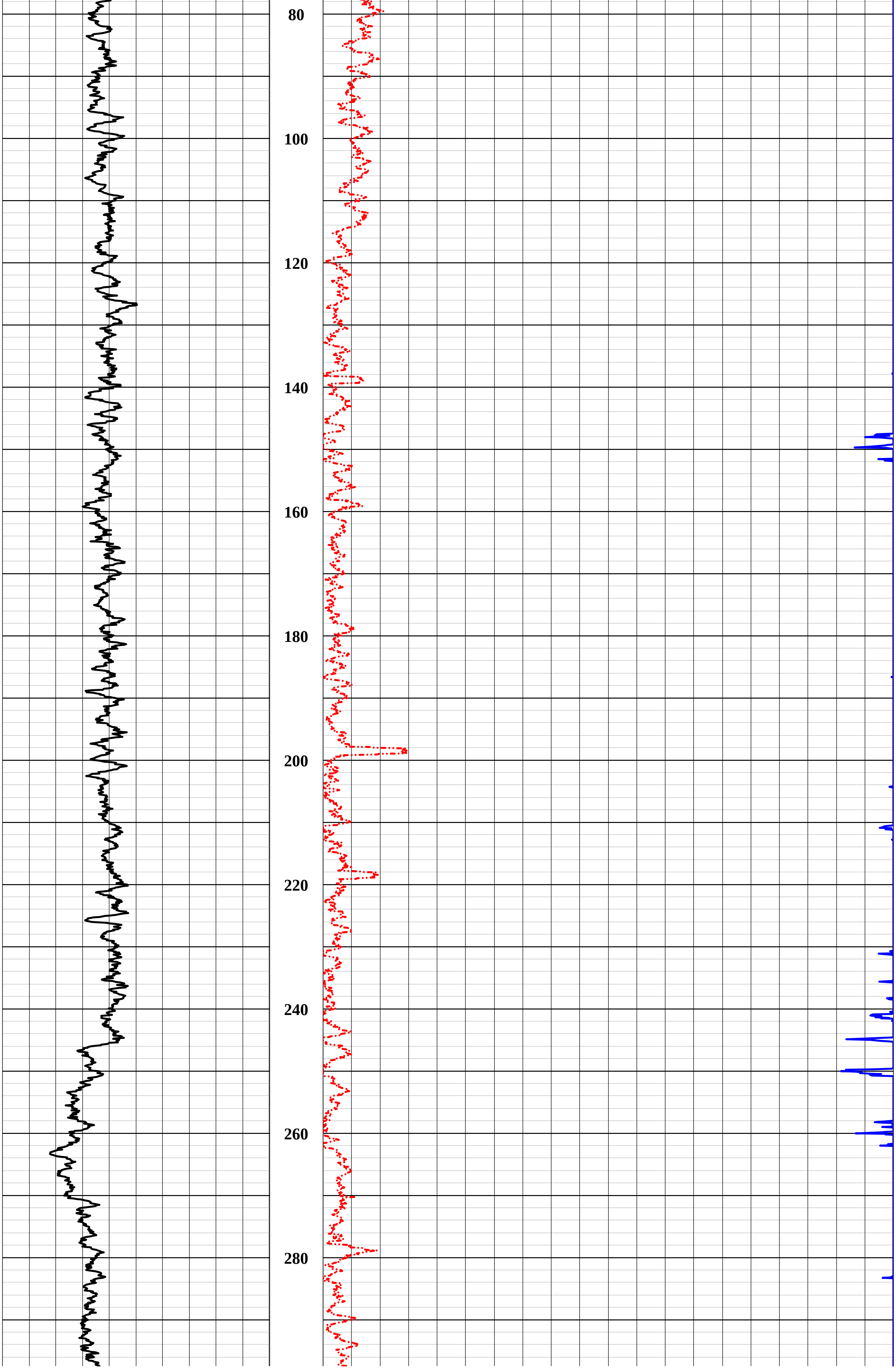
| | | | |
|---|---|---|---|
| PERMANENT DATUM | Ground Level | ELEVATION | K.B. |
| LOG MEAS. FROM | Ground Level | ABOVE PERM. DATUM | T.O.C |
| DRILLING MEAS. FROM | Ground Level | | G.L. |

| | | | |
|---|---|---|---|
| DATE | 07-01-2016 | TYPE FLUID IN HOLE | Air/water |
| RUN No. | one | SALINITY | |
| TYPE LOG | QL-NB696 | DENSITY | |
| DEPTH-DRILLER | 1290 ft. | LEVEL | 1156 ft. |
| DEPTH-LOGGER | 1282 ft. | MAX. REG. TEMP | |
| BTM LOGGED INTERVAL | 1281 ft. | DIGITIZE INTERVAL | 0.1 ft. |
| TOP LOGGED INTERVAL | Surface | | |
| OPERATING RIG TIME | | | |
| RECORDED BY | A.Henderson | | |
| WITNESSED BY | Holt Services | | |

| RUN | BOREHOLE RECORD | | | CASING RECORD | | | |
|---|---|---|---|---|---|---|---|
| NO. | BIT | FROM | TO | SIZE | WGT. | FROM | TO |
| 1 | | | | 20 inch | steel | 0 ft. | 55.77 ft. |
| 2 | | | | 18 inch | steel | 0 ft. | 594.41 ft. |
| 3 | | | | 16 inch | steel | 0 ft. | 914.11 ft. |
| | | | | 14 inch | steel | 0 ft. | 1290.00 ft. |

REMARKS: Well is 26° angle from vertical.

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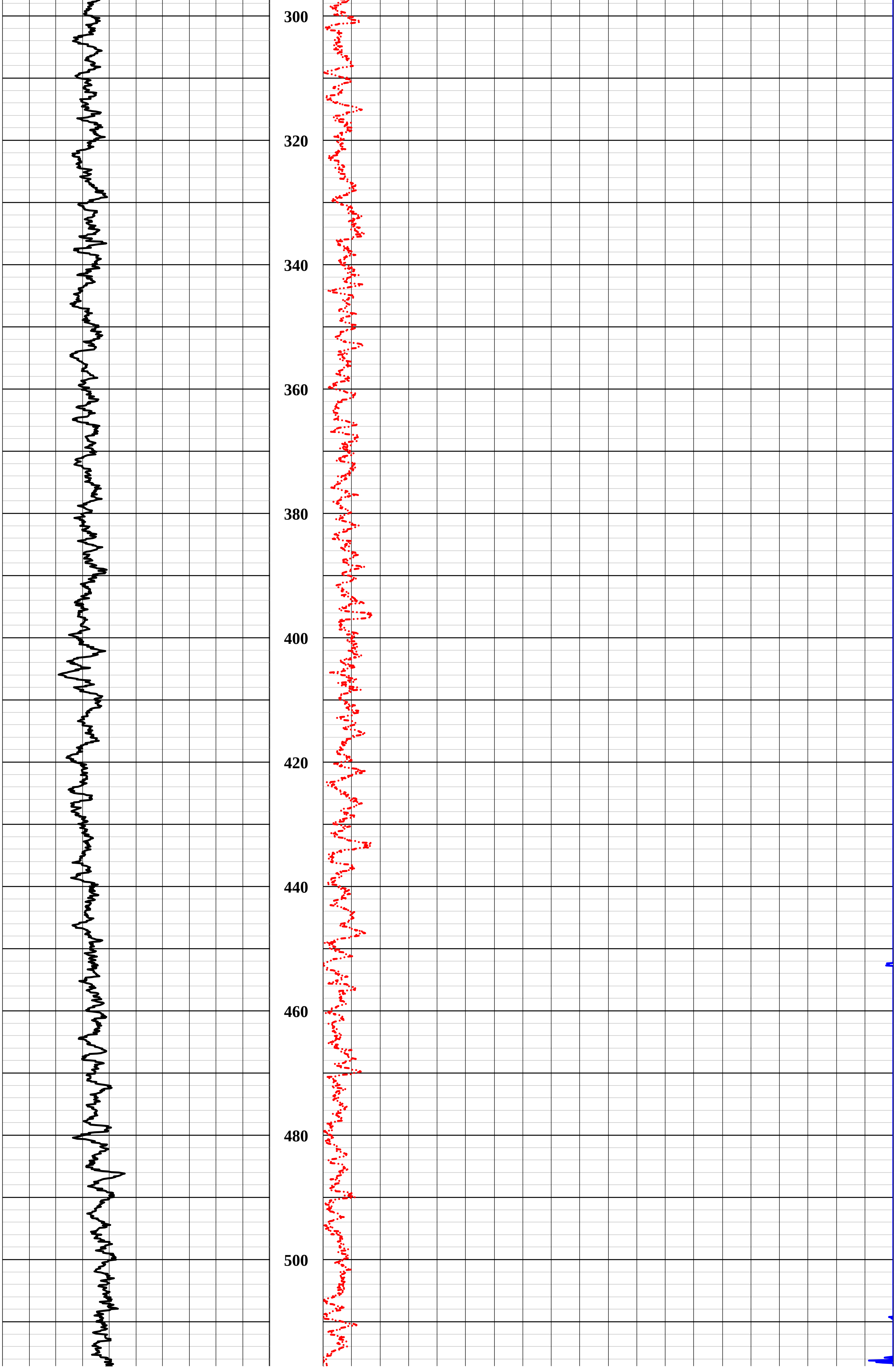
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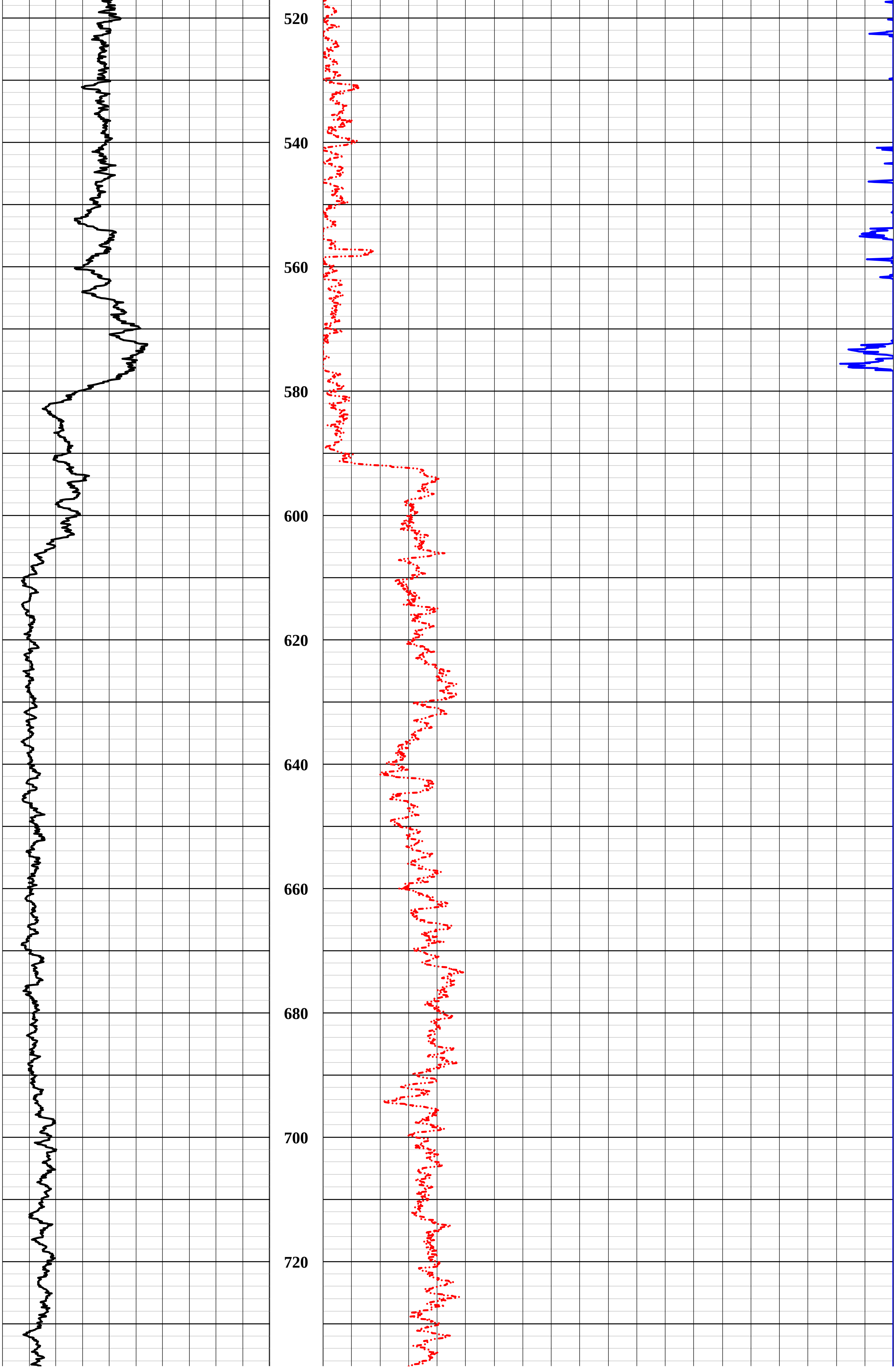
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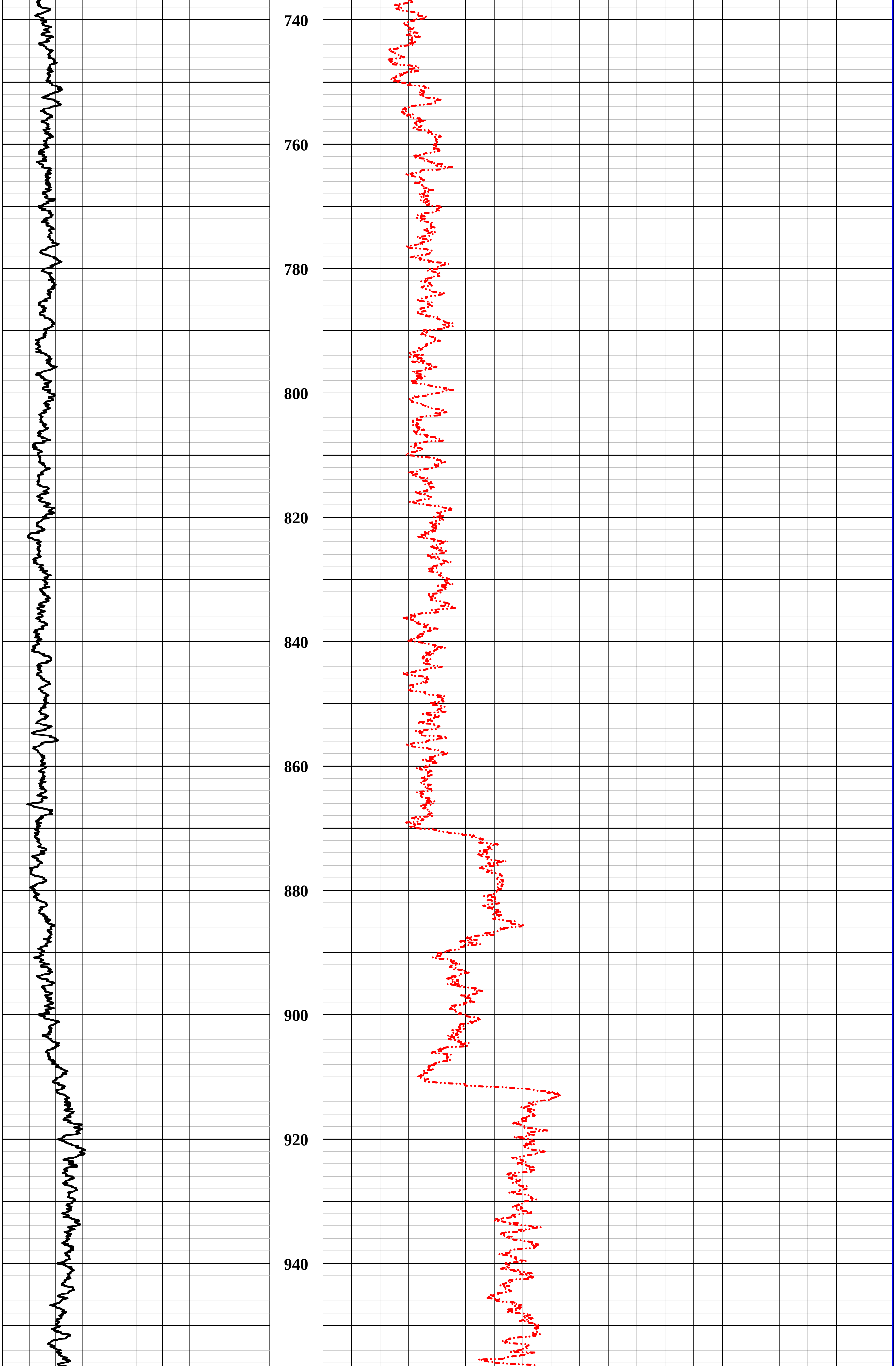
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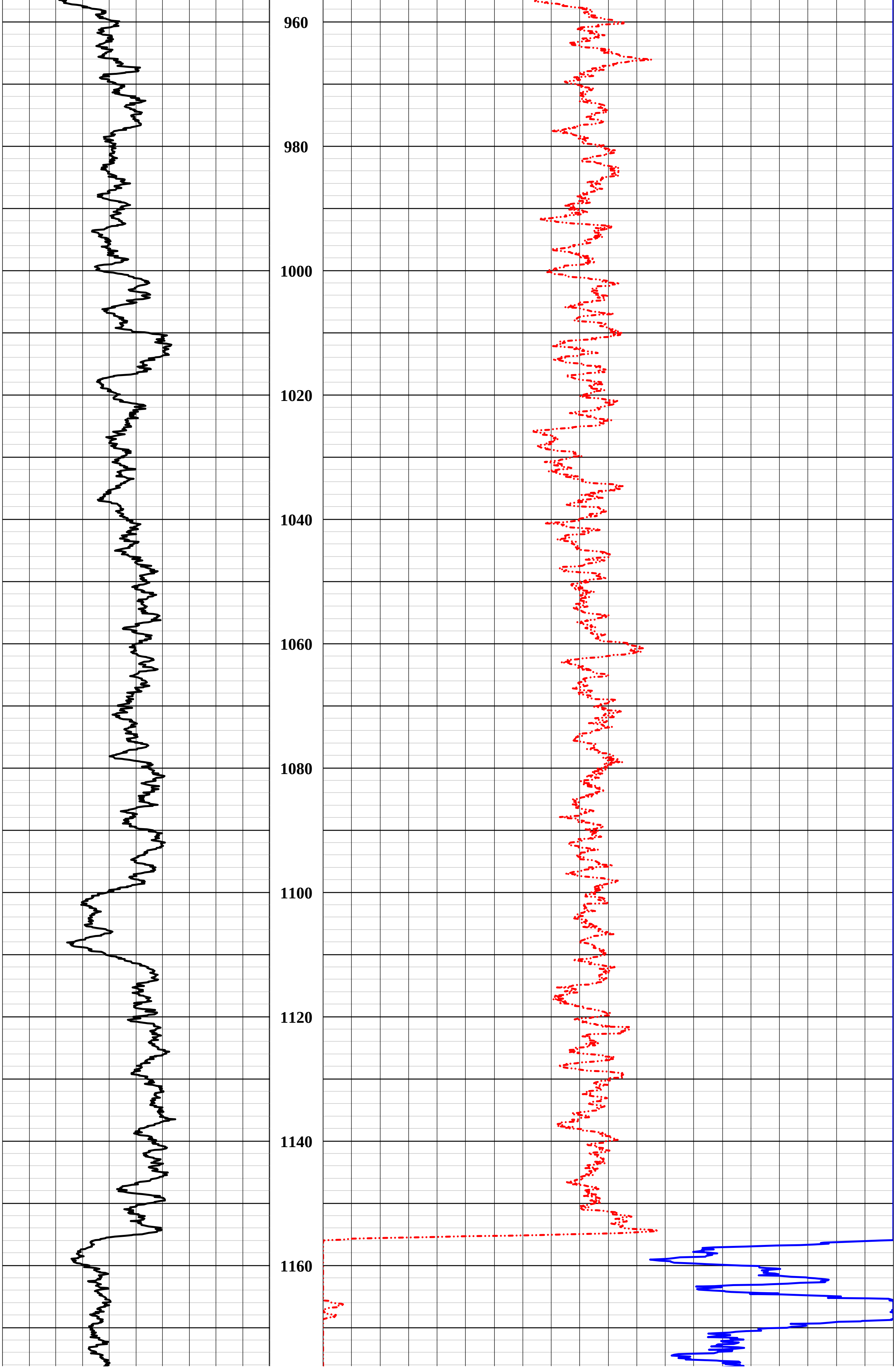
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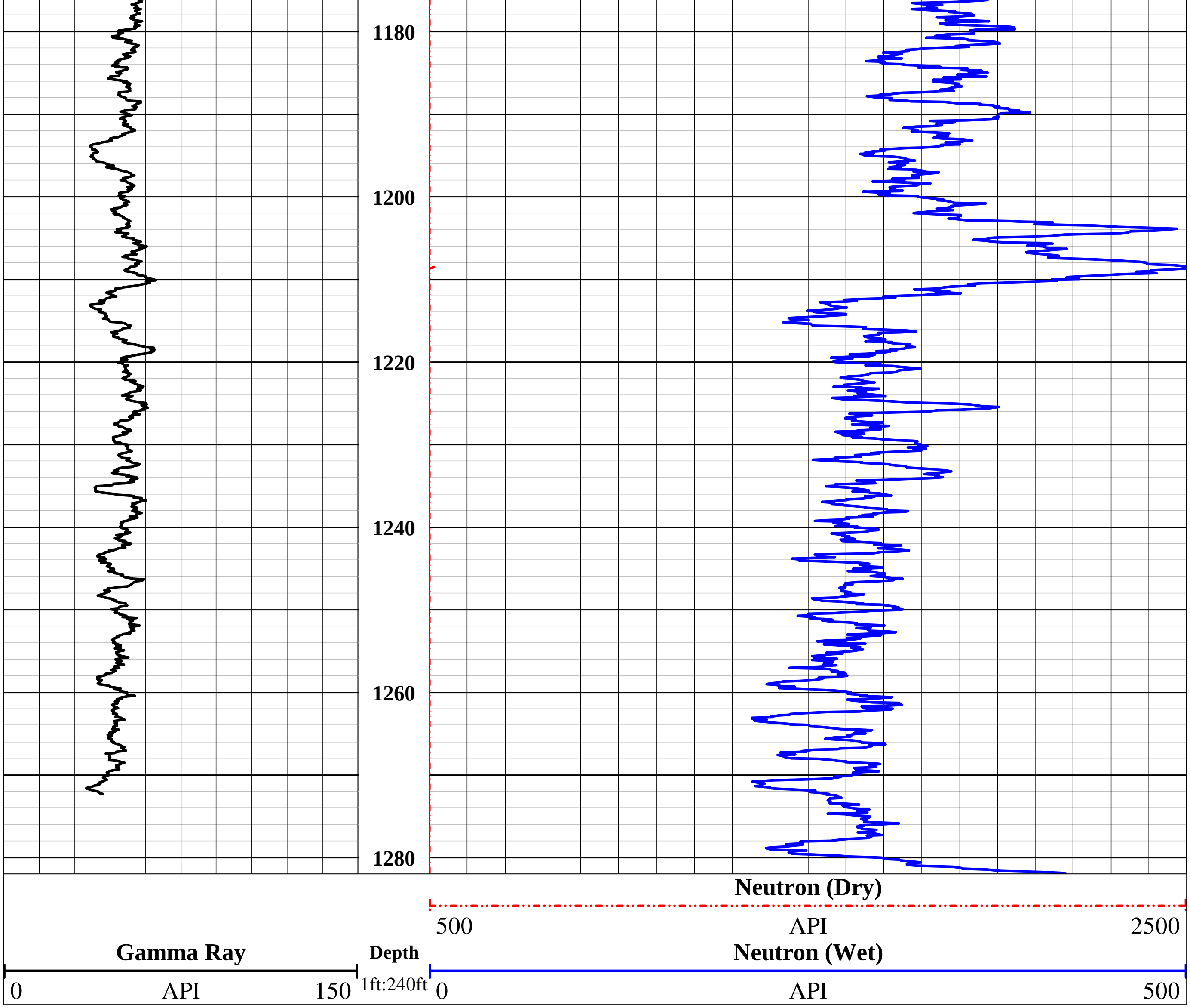
980
1000
1020
1040
1060
1080
1100
1120
1140
1160



1180
1200
1220
1240
1260
1280
Neutron (Dry)
500
API
2500
Gamma Ray
Depth
Neutron (Wet)
0
API
150
1ft:240ft
0
API
500

# Appendix C

*Final Well Design and*
*New Mexico Environment Department Approval*

| | |
|---|---|
| **From:** | Dale, Michael, NMENV |
| **To:** | White, Stephen Spalding |
| **Cc:** | Wear, Benjamin, NMENV; Dhawan, Neelam, NMENV; Cobrain, Dave, NMENV; Swickley, Stephani Fuller; Ball, Ted; Katzman, Danny; Longmire, Patrick; Granzow, Kim P; Yanicak, Stephen M |
| **Subject:** | Re: CrIN-1 well design |
| **Date:** | Wednesday, June 22, 2016 11:09:18 AM |

Steve,

New Mexico Environment Department (NMED) has reviewed the proposed well design plan (Plan) for injection well CrIN-1 that was received through e-mail correspondence on June 21, 2016 at 5:05 pm as shown below, and hereby issues this approval. Note that this approval is based on the information available to NMED at time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, the step-drawdown test, and constant-rate aquifer testing at CrIN-1. Please call if you have any questions concerning this approval.

Thank you,


Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078


---

**From:** White, Stephen Spalding <ssw@lanl.gov>
**Sent:** Tuesday, June 21, 2016 5:05 PM
**To:** Dale, Michael, NMENV; Katzman, Danny
**Cc:** Wear, Benjamin, NMENV; Dhawan, Neelam, NMENV; Cobrain, Dave, NMENV; Swickley, Stephani Fuller; Ball, Ted
**Subject:** RE: CrIN-1 well design

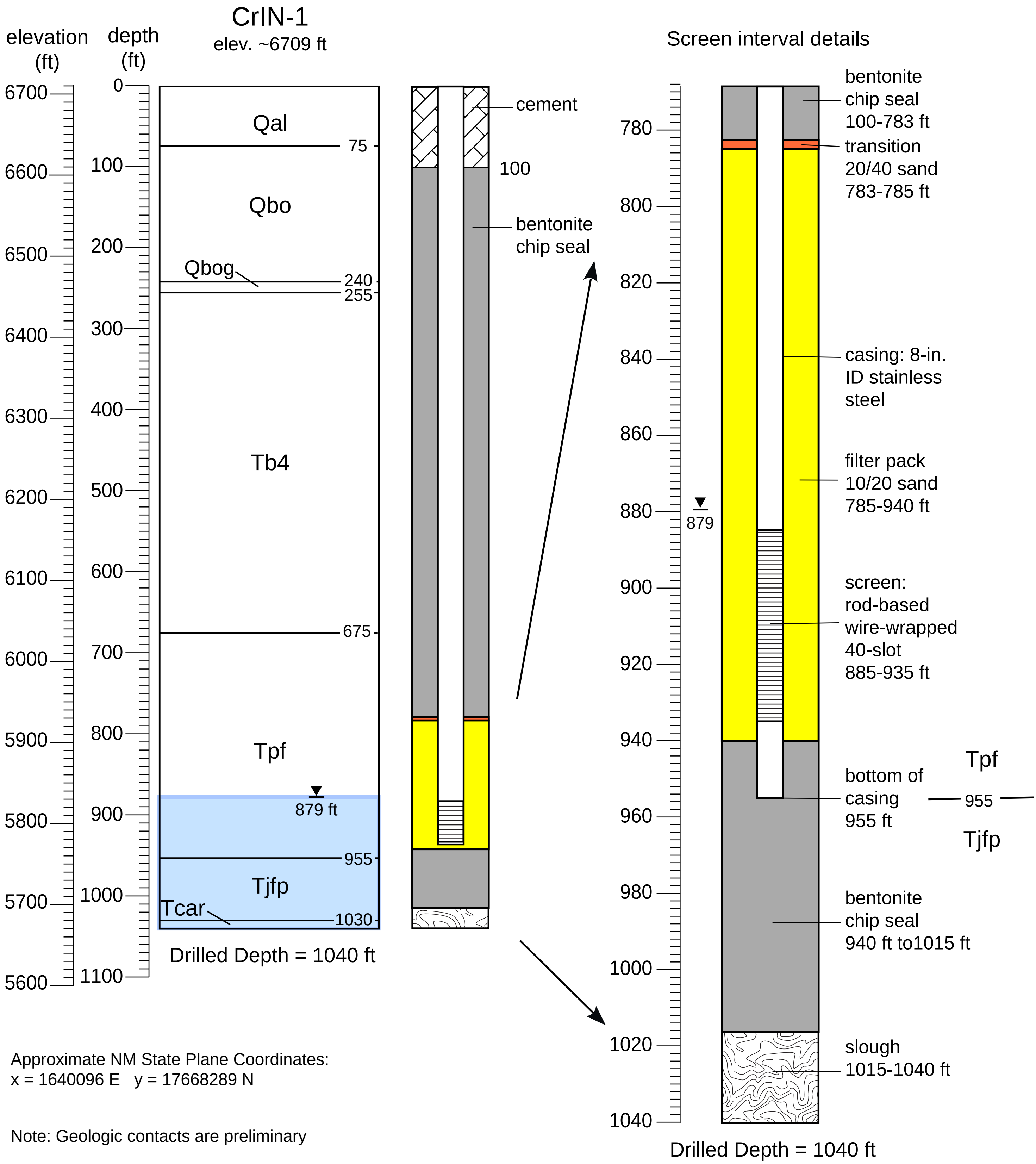
Michael,

Please find attached our well design proposal for CrIN-1.

Thanks,

SW


Steve White
LANL ER-ES
505-257-8299 (cell)
505-667-9005 (desk)




Approximate NM State Plane Coordinates:
x = 1640096 E   y = 17668289 N

Note: Geologic contacts are preliminary

| | |
|---|---|
| **From:** | Dale, Michael, NMENV |
| **To:** | Katzman, Danny |
| **Cc:** | Swickley, Stephani Fuller; White, Stephen Spalding; Everett, Mark Capen; Rodriguez, Cheryl L; Wear, Benjamin, NMENV; Cobrain, Dave, NMENV; Kulis, Jerzy, NMENV; Fellenz, David Richard; Green, Megan, NMENV; Longmire, Patrick; Granzow, Kim P; mayer.richard@epa.gov |
| **Subject:** | RE: CrIN-2 Well Design Plan |
| **Date:** | Wednesday, May 11, 2016 9:46:26 AM |

Danny,

New Mexico Environment Department (NMED) has reviewed the proposed well design plan (Plan) for injection well CrIN-2 that was received through e-mail correspondence on May 10, 2016 at 1:37 pm as shown below, and hereby issues this approval. As a result of the review, NMED recommends that LANL evaluate the potential use of larger filter-pack grain size(s) along the screened interval and above the regional water table within the vadose zone. An overall larger grain size and/or grading of grain sizes may optimize injection rates and long-term efficiency of the well with respect to reducing biofouling and formation of inorganic scale. Note that this approval is based on the information available to NMED at time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, the step-drawdown test, and constant-rate aquifer testing at CrIN-2. Please call if you have any questions concerning this approval.

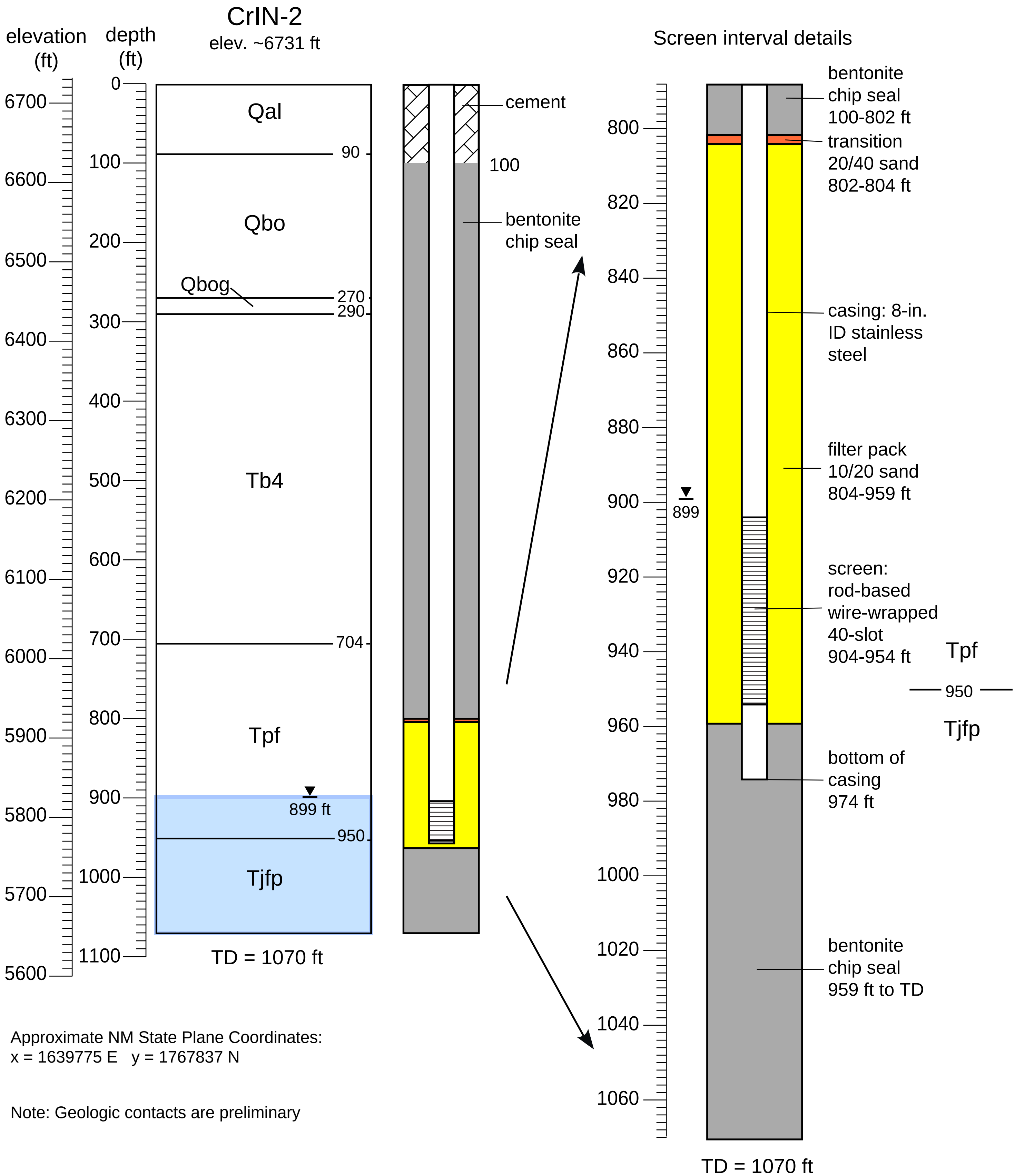
Thank you,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

---

**From:** Katzman, Danny [mailto:katzman@lanl.gov]
**Sent:** Tuesday, May 10, 2016 1:37 PM
**To:** Dale, Michael, NMENV
**Cc:** Swickley, Stephani Fuller; White, Stephen Spalding; Everett, Mark Capen; Rodriguez, Cheryl L
**Subject:** CrIN-2 Well Design Plan

Michael- attached is our proposal for the CrIN-2 well design. Please review at your earliest convenience. We are hoping to begin construction on Wed.
Thanks.
Danny




Approximate NM State Plane Coordinates:
x = 1639775 E y = 1767837 N

Note: Geologic contacts are preliminary

| | |
|---|---|
| **From:** | Dale, Michael, NMENV |
| **To:** | White, Stephen Spalding |
| **Cc:** | Katzman, Danny; Swickley, Stephani Fuller; Ball, Ted; Rodriguez, Cheryl L; Shen, Hai; Wear, Benjamin, NMENV; Cobrain, Dave, NMENV; Dhawan, Neelam, NMENV; Huddleson, Steven, NMENV; Longmire, Patrick; Fellenz, David Richard; Granzow, Kim P; Green, Megan; Yanicak, Stephen M |
| **Subject:** | RE: CrIN3 sell design proposal |
| **Date:** | Wednesday, August 17, 2016 2:15:07 PM |

Steve,

New Mexico Environment Department (NMED) has reviewed the proposed well design plan (Plan) for injection well CrIN-3 that was received today, August 17, 2016 at 11:24 am, and hereby issues this approval. Note that this approval is based on the information available to NMED at time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, the step-drawdown test, and constant-rate aquifer testing at CrIN-3. Please call if you have any questions concerning this approval.

Thank you,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

---

**From:** White, Stephen Spalding [mailto:ssw@lanl.gov]
**Sent:** Wednesday, August 17, 2016 11:24 AM
**To:** Dale, Michael, NMENV
**Cc:** Katzman, Danny; Swickley, Stephani Fuller; Ball, Ted; Rodriguez, Cheryl L; Shen, Hai
**Subject:** CrIN3 sell design proposal

Michael,

Please find attached our well design proposal for Chromium Injection Well #3 (CrIN-3).

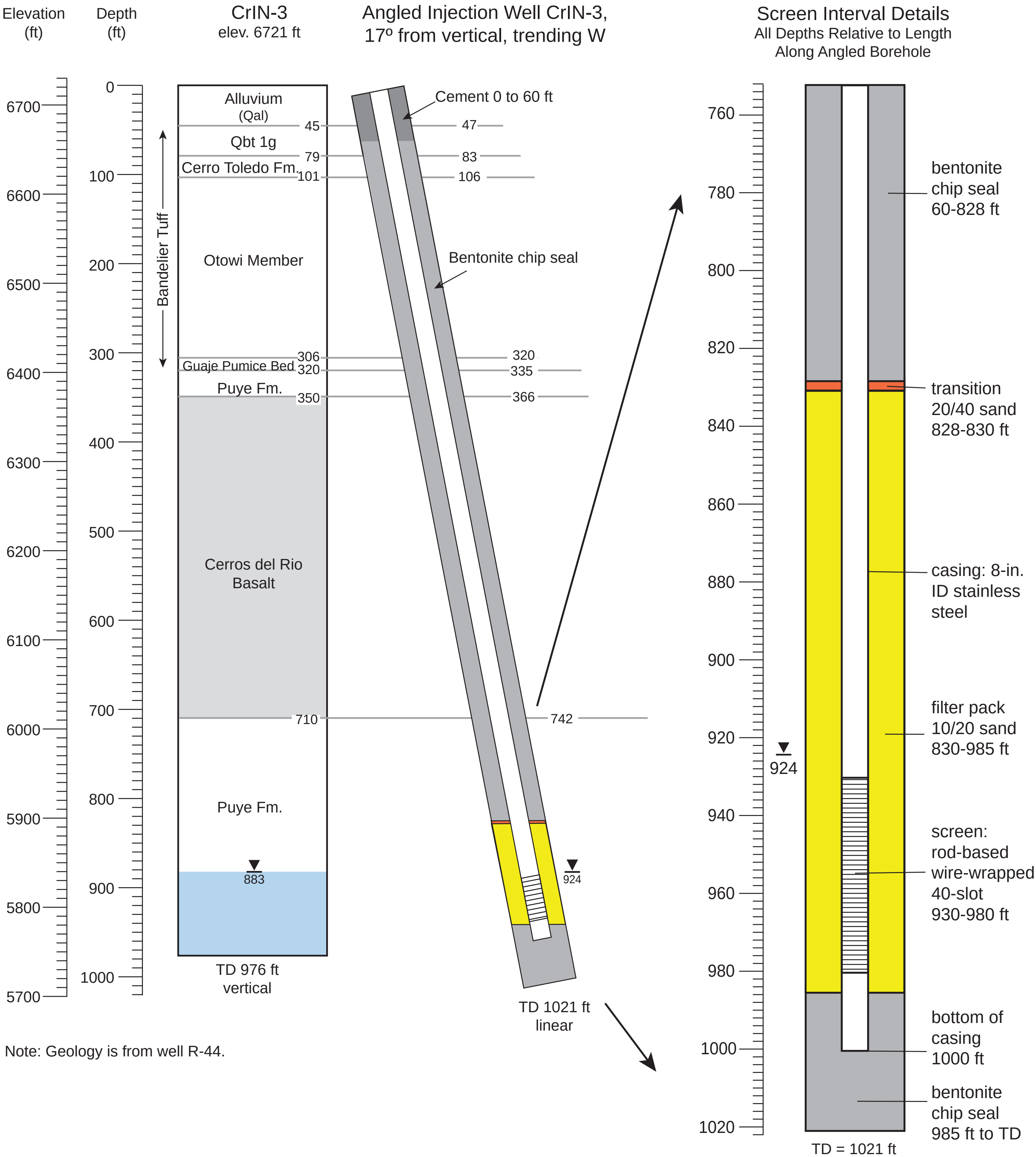
We had to coax some material out of the bottom of the drill casing and wait a bit for the water level to find static, but we're in good shape now; nothing in the drill casing and a SWL at 924 ft.

Let us know what you think.

Thanks,

SW

Steve White
LANL ER-ES
505-257-8299 (cell)
505-667-9005 (desk)




Note: Geology is from well R-44.

**From:** Dale, Michael, NMENV
**To:** White, Stephen Spalding
**Cc:** Wear, Benjamin, NMENV; Kulis, Jerzy, NMENV; Katzman, Danny; Rodriguez, Cheryl L; Everett, Mark Capen; Fellenz, David Richard; Green, Megan; Granzow, Kim P; Yanicak, Stephen M
**Subject:** RE: Email Policy Violation
**Date:** Thursday, May 12, 2016 4:53:48 PM

---

Steve,

New Mexico Environment Department (NMED) has reviewed the proposed well design plan for injection well CrIN-4 that was received today, May 12, 2016 at 1:28 pm as attached in your e-mail below, and hereby issues this approval. Note that this approval is based on the information available to NMED at time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, the step-drawdown test, and constant-rate aquifer testing at CrIN-4. Please call if you have any questions concerning this approval.

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

________________________________________
From: White, Stephen Spalding [ssw@lanl.gov]
Sent: Thursday, May 12, 2016 1:28 PM
To: Dale, Michael, NMENV
Cc: Katzman, Danny; Wear, Benjamin, NMENV
Subject: RE: Email Policy Violation

No problem. It's a site map that's causing the trouble.

SW

Steve White
LANL ER-ES
505-257-8299 (cell)
505-667-9005 (desk)

-----Original Message-----
From: Dale, Michael, NMENV [mailto:Michael.Dale@state.nm.us]
Sent: Thursday, May 12, 2016 1:04 PM
To: White, Stephen Spalding <ssw@lanl.gov>
Cc: Katzman, Danny <katzman@lanl.gov>; Wear, Benjamin, NMENV <Benjamin.Wear@state.nm.us>
Subject: FW: Email Policy Violation

Steve,

The e-mail, the CrIN-4 proposed well design, I suspect, that you tried sending was too large for the State system. Maybe try reducing the file size?

Thanks,

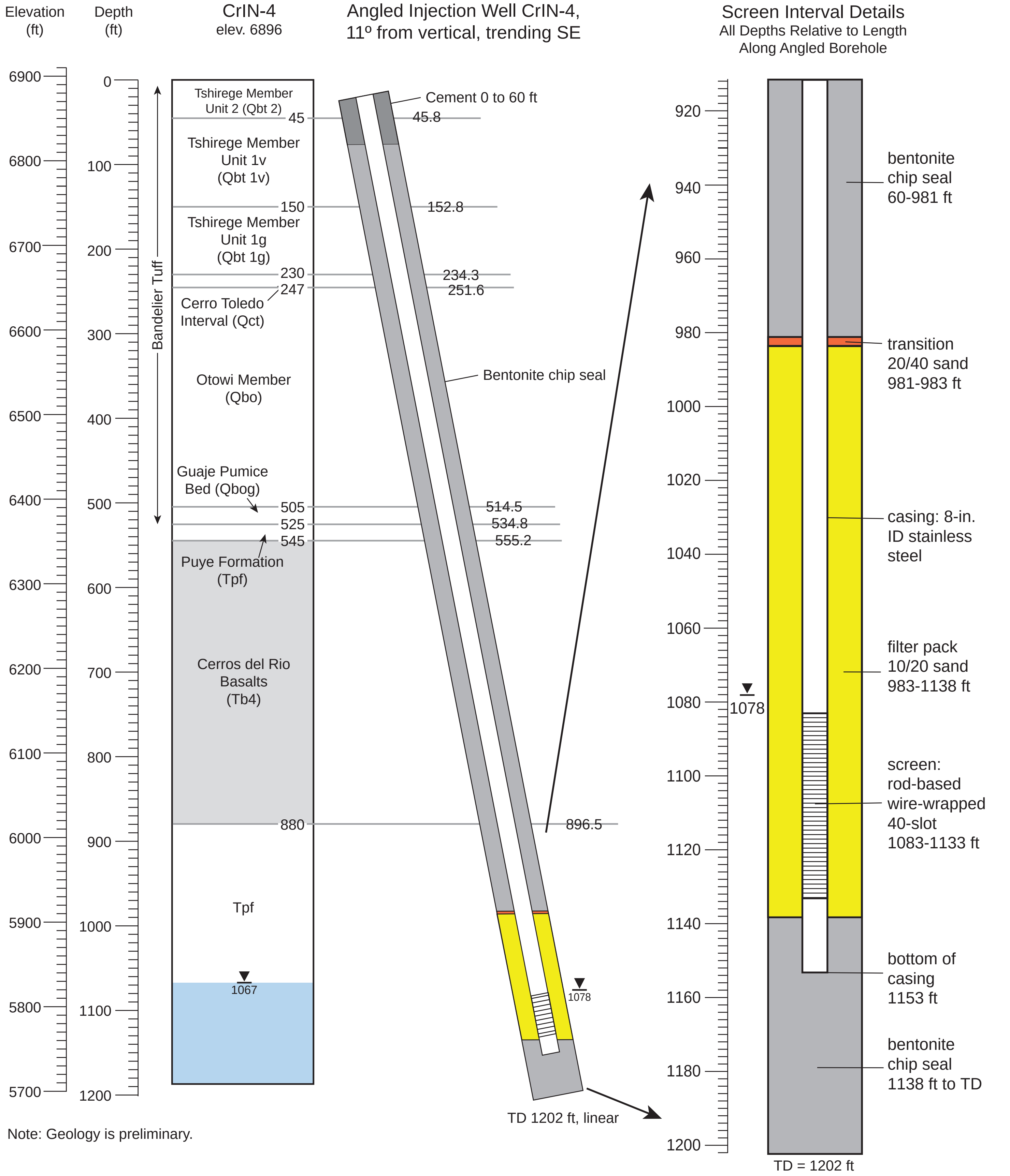
Michael

-----Original Message-----
From: enterpriseemailadministrators@state.nm.us [mailto:enterpriseemailadministrators@state.nm.us]
Sent: Thursday, May 12, 2016 12:25 PM
Subject: Email Policy Violation

Email Security service has detected content matching a policy in place for your organization, in the following email that was sent to you:

Sender: ssw@lanl.gov
Date: Thu, 12 May 2016 18:23:26 +0000
Subject: CrIN-4 well design
Please contact your IT Helpdesk or System Administrator for further assistance.

Matching Policy: Message Exceeds the Maximum Allowed Size




Note: Geology is preliminary.

| | |
|---|---|
| **From:** | Dale, Michael, NMENV |
| **To:** | White, Stephen Spalding |
| **Cc:** | Katzman, Danny; Swickley, Stephani Fuller; Rodriguez, Cheryl L; Shen, Hai; Wear, Benjamin, NMENV; Cobrain, Dave, NMENV; Fellenz, David Richard; Green, Megan; Granzow, Kim P; Yanicak, Stephen M; LucasKamat, Susan, NMENV; Trujillo, Antonio Geronimo; longmire@cybermesa.com |
| **Subject:** | RE: CrIN5 well design proposal |
| **Date:** | Saturday, July 02, 2016 10:28:31 AM |

Steve,

New Mexico Environment Department (NMED) has reviewed the proposed well design plan (Plan) for injection well CrIN-5 that was received through e-mail correspondence today, July 2, 2016 at 9:14 am as shown below, and hereby issues this approval. Note that this approval is based on the information available to NMED at time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of CrIN-5 as soon as such data or information become available. In addition, please provide NMED reasonable-time (e.g., 1 -2 days) notification prior to the initiation of well development, the step-drawdown test, and constant-rate aquifer testing at CrIN-5. Please call if you have any questions concerning this approval.

Thank you,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

---

**From:** White, Stephen Spalding [mailto:ssw@lanl.gov]
**Sent:** Saturday, July 02, 2016 9:14 AM
**To:** Dale, Michael, NMENV
**Cc:** Katzman, Danny; Swickley, Stephani Fuller; Rodriguez, Cheryl L; Shen, Hai
**Subject:** CrIN5 well design proposal

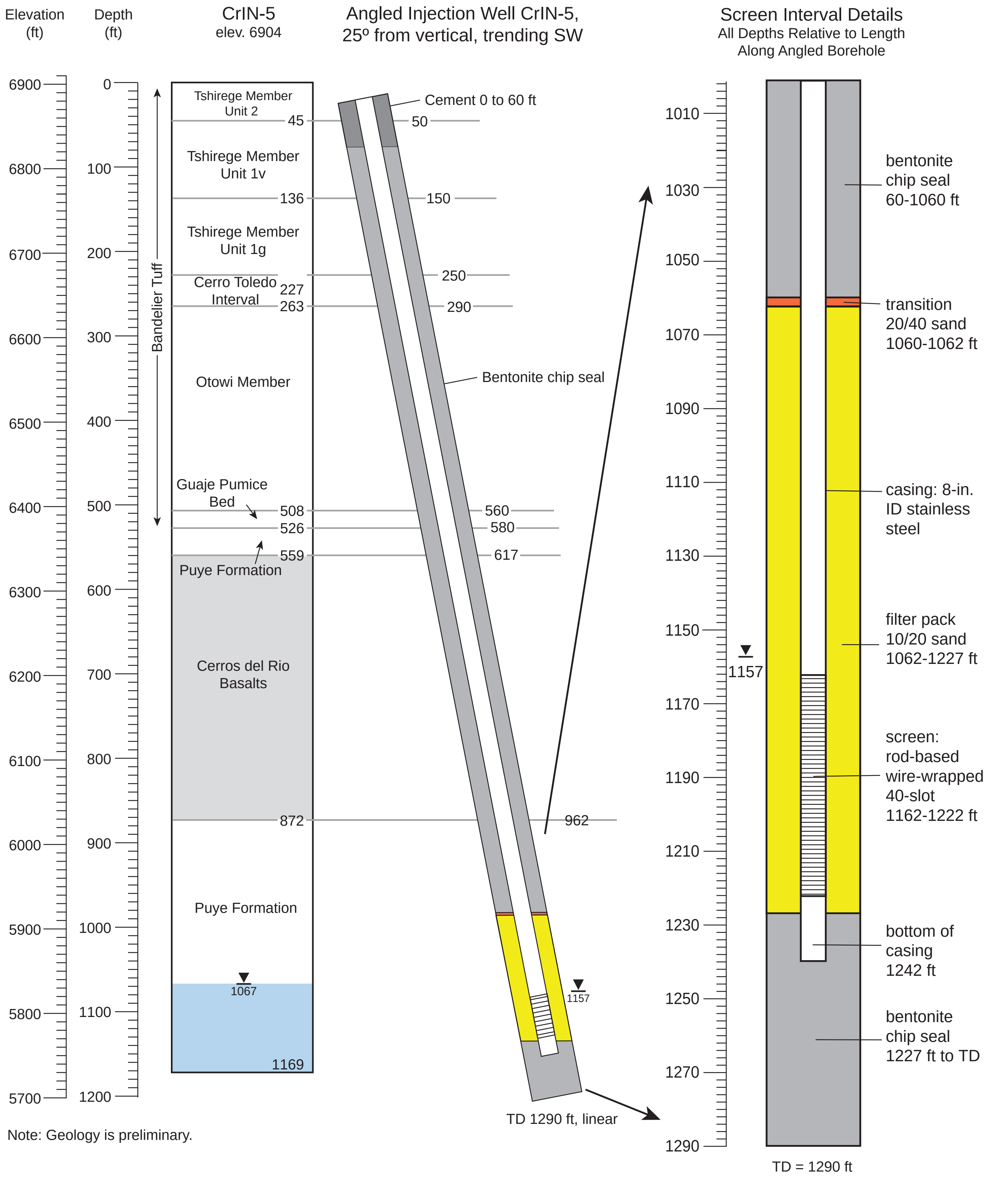
Hi Michael,

Please find attached our well design proposal for CrIN-5. Let me know if you have any questions.

Thanks,

SW

Steve White
LANL ER-ES
505-257-8299 (cell)
505-667-9005 (desk)




Note: Geology is preliminary.

# Appendix D

*Analysis of CrIN Pumping Test Data*

## D-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of the five pumping tests conducted from May 31 to September 11, 2016, at chromium injection (CrIN) wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 to characterize the regional aquifer at the Los Alamos National Laboratory (LANL or the Laboratory). The wells are screened in the Puye Formation. The test data are applied to estimate aquifer (hydraulic) parameters. It is assumed that the pumping tests are conducted in a partially penetrated aquifer with limited thickness, which is homogeneous and anisotropic. The aquifer is assumed to have a uniform thickness (without boundary effects). The software AQTESOLV (Duffield 2007, 601723) is used to interpret the pumping test data. Two theoretical models built in the software AQTESOLV, Theis (1934-1935, 098241), and Neuman (1974, 085421) are applied for estimate aquifer parameters. The Theis model is representative for confined aquifer conditions; however, the Theis model was applied with a correction for unconfined effects. The Neuman model is representative of unconfined aquifer conditions. The analyses allow transmissivity, hydraulic conductivity, storage coefficient, specific yield, and anisotropic factor to be estimated.

It is important to note that in the Theis analyses presented below, the storage coefficient estimates are not expected to be realistic. Typically, single-well pumping tests do not provide reasonable storage coefficient estimates. Good estimates for storage coefficient are typically obtained using cross-well pumping tests.

Determining hydraulic conductivity of the aquifer materials based on the estimated aquifer transmissivity is challenging because the effective aquifer thickness is impacted during the pumping tests and it is unknown. The total aquifer thickness of the regional aquifer extends more than 1000 ft. However, during the pumping tests conducted near the regional water table, only a small vertical portion of the regional aquifer is affected by the pumping tests. The effective aquifer thickness depends on the length of the well screen (and filter pack) and the hydraulic properties of the aquifer (especially the vertical anisotropy). The saturated thickness is also impacted by pumping because it causes a decline in the regional water table. Based on previous analyses, aquifer thickness of 30 m (100 ft) is assumed and is considered to be representative for the chromium site wells at the Laboratory.

**Theis model:** Theis model (Theis 1934-1935, 098241) was derived for simulating the transient flow to a fully penetrating well in a confined aquifer with uniform thickness and hydraulic properties. The solution assumes a line source for the pumped well and neglects wellbore storage:

$$\boldsymbol{s = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-y}}{y}\,dy = \frac{Q}{4\pi T}W(u)}$$ **Equation D-1**

$$\boldsymbol{u = \frac{r^2\mu}{4Tt}}$$ **Equation D-2**

where, *s* is drawdown (L); *Q* is pumping rate [$L^3/T$]; *T* is transmissivity [$L^2/T$]; *r* is radial distance [L]; $\mu$ is storativity [dimensionless]; and *t* is time [T]; and *W*(*u*) is the Theis well function. The Theis solution is derived for confined aquifers. However, Jacob's correction for partial dewatering of water-table (unconfined) aquifers allows the use of the Theis solution for unconfined aquifers as well. Jacob's correction was applied as implemented in the software AQTESOLV (Duffield 2007, 601723) in the Theis analyses presented below.

Hantush (Hantush 1961, 098237; Hantush 1961, 106003) modified the Theis model for simulating the effects of partial penetration in an aquifer with uniform thickness. For a piezometer, the partial penetration correction is computed as follows:

$$s = \frac{Q}{4\pi T}\left\{W(u) + \frac{2b}{\pi(l-d)}\sum_{n=1}^{\infty}\frac{1}{n}\left[\sin\left(\frac{n\pi l}{b}\right) - \sin\left(\frac{n\pi d}{b}\right)\right]\cos\left(\frac{n\pi z}{b}\right)W(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b})\right\} \quad \textbf{Equation D-3}$$

where, $b$ is aquifer thickness [L]; $d$ is depth to top of pumping well screen [L]; $l$ is depth to bottom of pumping well screen [L]; $Kz/Kr$ is vertical to horizontal hydraulic conductivity anisotropy [dimensionless]; $W(u,\beta)$ is the Hantush-Jacob well function; and $z$ is depth to piezometer opening [L].

**Neuman model:** The Neuman model was developed to address the delayed gravity response of the unconfined aquifer (Neuman 1974, 085421). The "delayed yield" represents the gravitational drainage (infiltration) from the vadose zone into aquifer from pumping. Therefore, the pumping test analyses using Neuman model also provide information about the properties of the vadose zone in addition to the regional aquifer properties. An analytical solution was derived for simulating the transient flow to a fully or partially penetrating well in a homogeneous, anisotropic unconfined aquifer with delayed gravity response. The Neuman model assumes instantaneous drainage at the water table. The solution also assumes a line source for the pumped well and neglects wellbore storage.

$$s = \frac{Q}{4\pi T}\int_0^{\infty} 4yJ_0(y\sqrt{\beta})\{u_0(y) + \sum_{n=1}^{\infty} u_n(y)\}dy \quad \textbf{Equation D-4}$$

$$\beta = \frac{r^2K_z}{b^2K_r} \quad \textbf{Equation D-5}$$

where, $J_0$ is Bessel function of first kind and zero order; $u_0$ and $u_n$ are functions for computing drawdowns in a piezometer or in a partially penetrating observation well (Neuman 1974, 085421). The drawdown in a piezometer is calculated using the following two equations:

$$u_0(y) = \frac{\left[1-\exp\left(-t_s\beta(y^2-\gamma_0^2)\right)\right]\cosh(\gamma_0 Z_D)}{[y^2+(1+\sigma)\gamma_0^2-\frac{\left(y^2-\gamma_0^2\right)^2}{\sigma}]\cosh(\gamma_0)}\cdot\frac{\sinh(\gamma_0(1-d_D))-\sinh(\gamma_0(1-l_D))}{(l_D-d_D)\sinh(\gamma_0)} \quad \textbf{Equation D-6}$$

$$u_n(y) = \frac{\left[1-\exp\left(-t_s\beta(y^2-\gamma_0^2)\right)\right]\cos(\gamma_0 Z_D)}{[y^2+(1+\sigma)\gamma_0^2-\frac{\left(y^2-\gamma_0^2\right)^2}{\sigma}]\cos(\gamma_0)}\cdot\frac{\sin(\gamma_0(1-d_D))-\sin(\gamma_0(1-l_D))}{(l_D-d_D)\sin(\gamma_0)} \quad \textbf{Equation D-7}$$

where $d_D$ is dimensionless depth to top of pumping well screen (d/b); $l_D$ is dimensionless depth to bottom of pumping well screen (1/b); $Z_D$ is dimensionless elevation of piezometer opening above the base of aquifer (z/b); and the gamma terms are computed numerically. Neuman model is built in the software AQTESOLV for simulating water flow in unconfined aquifers. By using the principle of superposition in time, AQTESOLV also accounts for transient pumping rates.

The analyses presented below are performed using the Theis and Neuman solutions coded into the software AQTESOLV (Duffield 2007, 601723). AQTESOLV uses the principle of superposition to account for the transient in the pumping rate. The solutions are applied to account for unconfined aquifer conditions.

The following sections will discuss the interpretations of the pumping test data collected from wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5.

## D-2.0 CRIN-1

The pumping test at CrIN-1 was conducted from July 18 to July 21, 2016, and the pump was run at multiple steps with various constant pumping rates (Figure D-1). The observation of the well pressure transients started from 13:01 on July 18. At 13:58, a constant pumping rate of 30 gallons per minute (gpm) was initiated for about 1 h, then increased to 50 gpm for about another hour, and then increased to 70 gpm for an additional 1 h. After 3 h and three-step pumping, the pump was stopped for a 16-h recovery, and the water levels were monitored until 8:58 on July 19. At 8:58, the pump was restarted with a constant rate of 70 gpm for 24 h, after which the pump was stopped for another 16-h recovery period (see Figure D-1).

The observed water depths were converted to corrected displacements or drawdowns (in feet) by using the mean water depth before the pumping as the initial water depth (Figure D-2). First, the Theis model was used to fit the drawdown data of multistep pumping test and recovery data. The well structure and pumping test parameters are shown in Tables D-1 and D-2. The estimated hydraulic conductivity is 5.64 m/d, and the storage coefficient is very small ($10^{-6}$). The computed drawdowns from the Theis model cannot fit the observations, especially during the 1-d constant pumping period (Figure D-3). Although the weighting coefficients of the drawdown observations were adjusted to be very small for the late-time data during this 1-d pumping period, the data points could not be made to fit well. The drawdowns during this period decreased with time, which may be the result of some additional recharge resources from boundaries and caused by the pumping test. The Theis model used no-flow boundaries for the top and bottom boundaries and could not simulate any additional recharge sources.

The Neuman model was also used to fit the observed drawdown and recovery data. A new parameter, “specific yield,” was added to address the delayed gravity response of the unconfined aquifer, the computed drawdowns from the Neuman model can fit the data better than the Theis model. The estimated parameters are listed in Table D-3: conductivity is 2.27 m/d, storage coefficient is 0.000799, and specific yield is 0.32, which is close to the expected total (water-filled) porosity of the Puye Formation. The parameter β is a coefficient to describe the hydraulic conductivity anisotropic ratio ($\frac{r^2}{b^2}\frac{K_z}{K_r}$), where $r$ is radial distance, $b$ is aquifer thickness, $K_z$ is vertical conductivity, and $K_r$ is horizontal conductivity. In this case, the parameter β is 0.001488, and the anisotropic ratio of $\frac{K_z}{K_r}$ is equal to 0.23. The curve fitting is shown in Figure D-4. The objective function (sum of squares) was reduced to 29.4 from 366.3 obtained from the Theis model. However, the computed drawdowns from the Neuman model still do fit the late-time observations during the 1-d constant-pumping period very well.

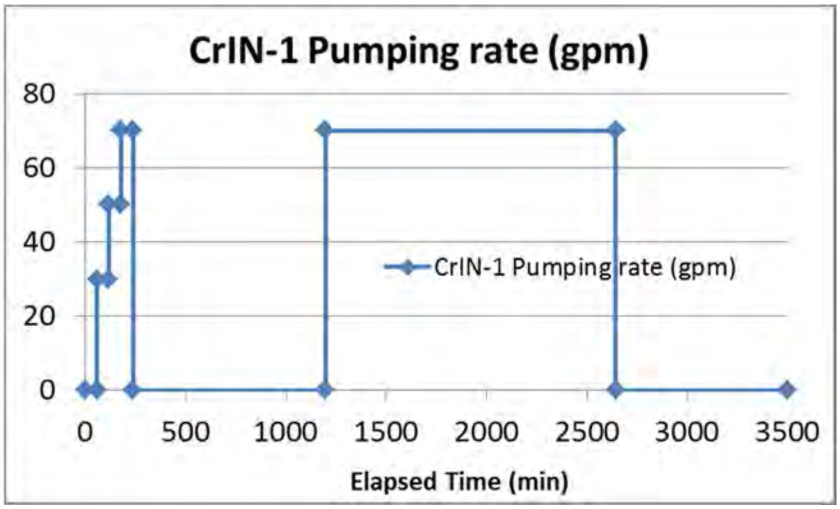



**Figure D-1** **Variable pumping rates for the test at well CrIN-1**

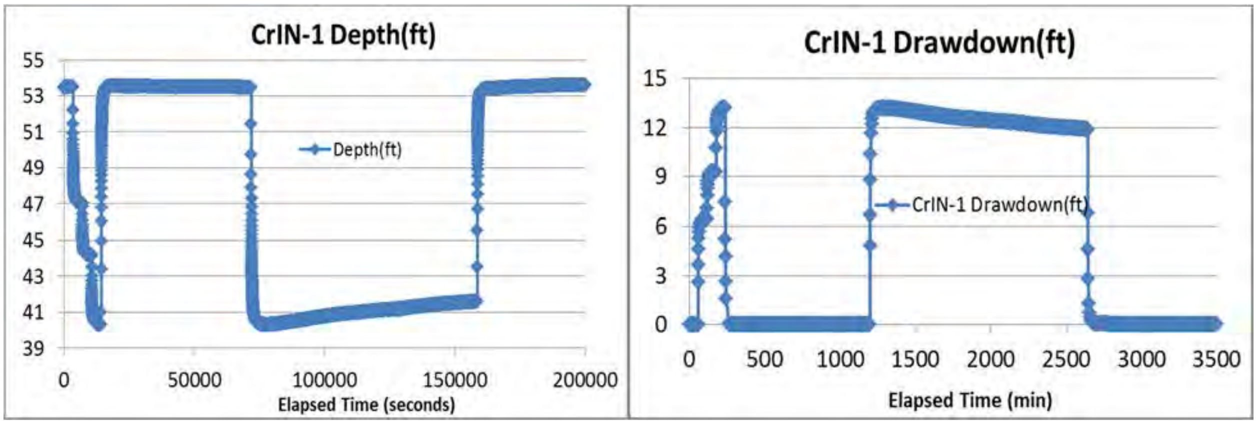



**Figure D-2** **Measured water depth (left) and drawdown (right) from the pumping test of well CrIN-1**

**Table D-1**
**CrIN-1 Well Structure and Pumping Test Data Applied in the Pumping Test Analyses**

Data Set: E:\EP2016\AquiferTest\CrIN\CrIN-1-Theis2.aqt
Title: CrIN-1 pumping test
Date: 09/23/16
Time: 16:29:51

PROJECT INFORMATION

Company: LANL
Client: zd
Project: ep
Location: Puye
Test Date: 2016
Test Well: CrIN-1

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.01

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: CrIN-1

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 8.625 ft
Well Radius: 8. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 86. ft

No. of pumping periods: 14

Pumping Period Data

| Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) |
|---|---|---|---|---|---|
| 0. | 1.0E-6 | 177.3 | 50. | 1197.3 | 70. |
| 57.3 | 0. | 177.3 | 70. | 2643.1 | 70. |
| 57.33 | 30. | 237.1 | 70. | 2643.2 | 0. |
| 116.8 | 30. | 237.2 | 0. | 3500. | 0. |
| 116.9 | 50. | 1197.3 | 0. | | |

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: CrIN-1

X Location: 0. ft
Y Location: 0. ft

Radial distance from CrIN-1: 0. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 86. ft

**Table D-2**
**Estimated Parameters Using the Theis Model for CrIN-1**

SOLUTION

Pumping Test
Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| T | 171.8 | $m^2$/day |
| S | 1.0E-6 | |
| Kz/Kr | 0.01 | |
| b | 100. | ft |

K = T/b = 5.637 m/day (0.006524 cm/sec)
Ss = S/b = 1.0E-8 1/ft

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 171.8 | 7.664 | +/- 15.05 | 22.42 | $m^2$/day |
| S | 1.0E-6 | 2.176E-6 | +/- 4.273E-6 | 0.4596 | |
| Kz/Kr | 0.01 | 0.02402 | +/- 0.04718 | 0.4163 | |
| b | 100. | not estimated | | | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 5.637 m/day (0.006524 cm/sec)
Ss = S/b = 1.0E-8 1/ft

Parameter Correlations

| | T | S | Kz/Kr |
|---|---|---|---|
| T | 1.00 | -0.03 | -0.35 |
| S | -0.03 | 1.00 | -0.93 |
| Kz/Kr | -0.35 | -0.93 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 366.3 $ft^2$
Variance . . . . . . . . . . . 0.6553 $ft^2$
Std. Deviation. . . . . . . 0.8095 ft
Mean . . . . . . . . . . . . . . -0.4083 ft
No. of Residuals . . . . 562
No. of Estimates . . . . 3

**Table D-3**
**Estimated Parameters Using the Neuman Model for CrIN-1**

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| T | 69.22 | $m^2$/day |
| S | 0.0007993 | |
| Sy | 0.32 | |
| ß | 0.001488 | |

K = T/b = 2.271 m/day (0.002629 cm/sec)
Ss = S/b = 7.993E-6 1/ft

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 69.22 | 2.438 | +/- 4.789 | 28.39 | $m^2$/day |
| S | 0.0007993 | 6.06E-5 | +/- 0.000119 | 13.19 | |
| Sy | 0.32 | 0.06129 | +/- 0.1204 | 5.221 | |
| ß | 0.001488 | 0.0002617 | +/- 0.0005139 | 5.687 | |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 2.271 m/day (0.002629 cm/sec)
Ss = S/b = 7.993E-6 1/ft

Parameter Correlations

| | T | S | Sy | ß |
|---|---|---|---|---|
| T | 1.00 | -0.93 | -0.86 | -1.00 |
| S | -0.93 | 1.00 | 0.83 | 0.93 |
| Sy | -0.86 | 0.83 | 1.00 | 0.86 |
| ß | -1.00 | 0.93 | 0.86 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 29.39 $ft^2$
Variance . . . . . . . . . . . 0.04898 $ft^2$
Std. Deviation. . . . . . . 0.2213 ft
Mean . . . . . . . . . . . . . . -0.06275 ft
No. of Residuals . . . . 604
No. of Estimates . . . . 4

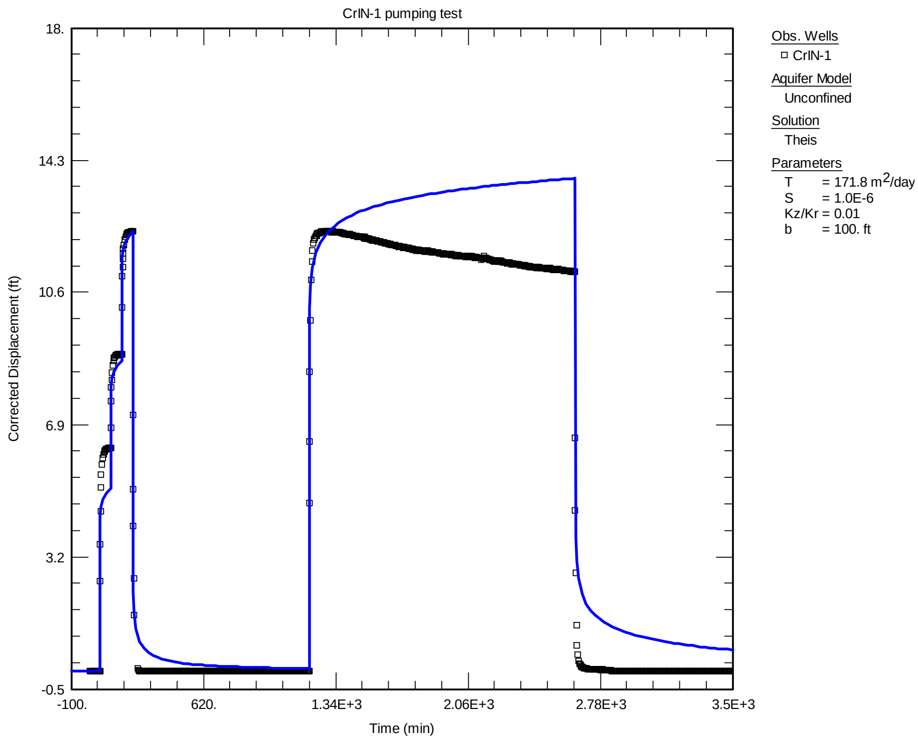



**Figure D-3 Matching observed drawdowns (black dots) during the four-step CrIN-1 test using the Theis model (blue line)**

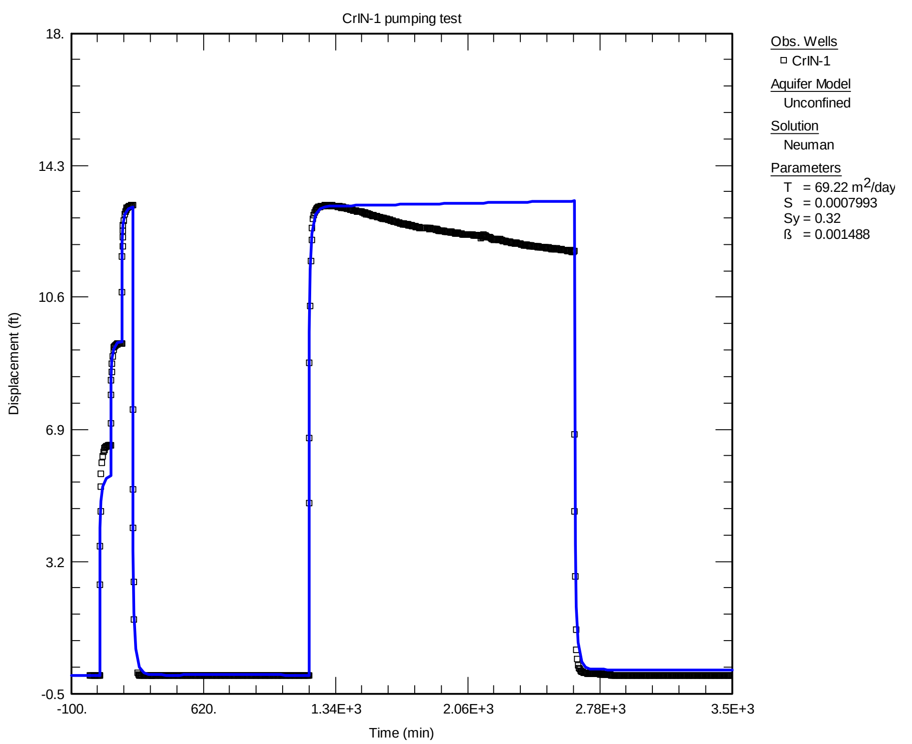



**Figure D-4 Matching observed drawdowns (black dots) during the four-step CrIN-1 test using the Neuman model (blue line)**

## D-3.0 CRIN-2

The pumping test at CrIN-2 was conducted from May 31 to June 3, 2016, and the pump was run at multiple steps with various constant pumping rates (Figure D-5). The pump was started at 12:01 on May 31 at a rate of 30 gpm for 1 h. At 13:00, the pump was stopped for about 1 h of recovery, after which it was restarted at a rate of 50 gpm for an additional 1 h. The pump was then stopped for about 1.5 h to observe the water-level recovery. During the third step, the pump was restarted with a rate of 70 gpm for 1 h. After 3 h of three-step pumping, the pump was stopped for a 16.5-h recovery period, and the water levels were monitored until 10:00 on June 1. The pump was restarted with a constant rate of 58 gpm for 24 h and then stopped for a 25-h recovery period (see Figure D-5).

Figure D-6 (left) shows some spikes in the observed water-level-depth data at the pump starting stages that are not representative of the actual pumping test drawdowns. When the spikes were manually located and removed, the data look clean and reasonable (Figure D-6, right). Additional details can be found in Rasmussen and Crawford (1997, 094014) and Spane (2002, 602105). The observed multistep water depths were converted to corrected displacements or drawdowns (in feet) and then used for parameter estimation (Figure D-7).

First, the variable-rate Theis model was used to fit the multistep observation data. The multistep variable pumping rates and parameter estimation results are shown in Tables D-4 and D-5. The estimated hydraulic conductivity is 8.55 m/d, and the storage coefficient is $10^{-6}$. The computed drawdowns during the first three steps and recovery time do not fit the observation data well (Figure D-8).

Next, the variable-rate Neuman model was used to fit the observation data. By considering the delayed gravity response of the unconfined aquifer, the Neuman model can simulate well the multistep pumping test processes and the computed drawdowns fit the observation data better. The estimated parameters are listed in Table D-6: conductivity is 3.26 m/d, storage coefficient is 0.00116, and specific yield is 0.32 (specific yield is during the parameter estimation process is limited to the expected maximum porosity of the Puye Formation, which is equal to 0.32). The parameter β coefficient is 0.003434, and in this model, the ratio of $\frac{K_z}{K_r}$ is equal to 0.536. The objective function (or sum of squares) is reduced from 227.2, which was obtained from the Theis model, to 79.2.

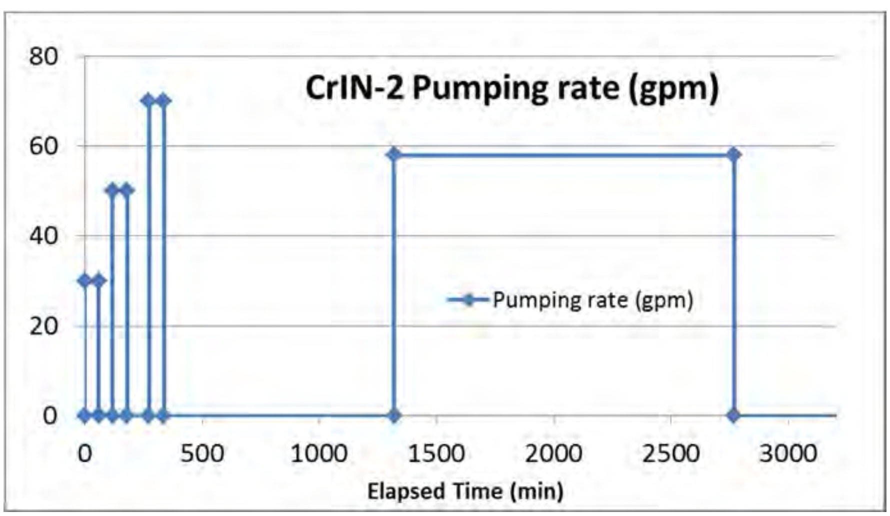



**Figure D-5 Variable pumping rates for the test at well CrIN-2**

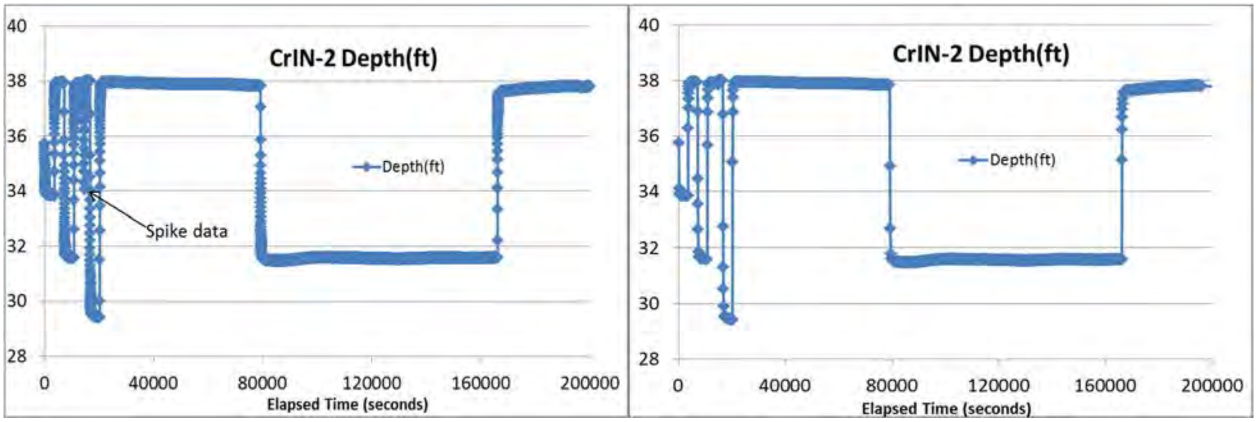



**Figure D-6** Measured water-depth data with spikes (left) and corrected water-depth data (right) from the pumping test of well CrIN-2

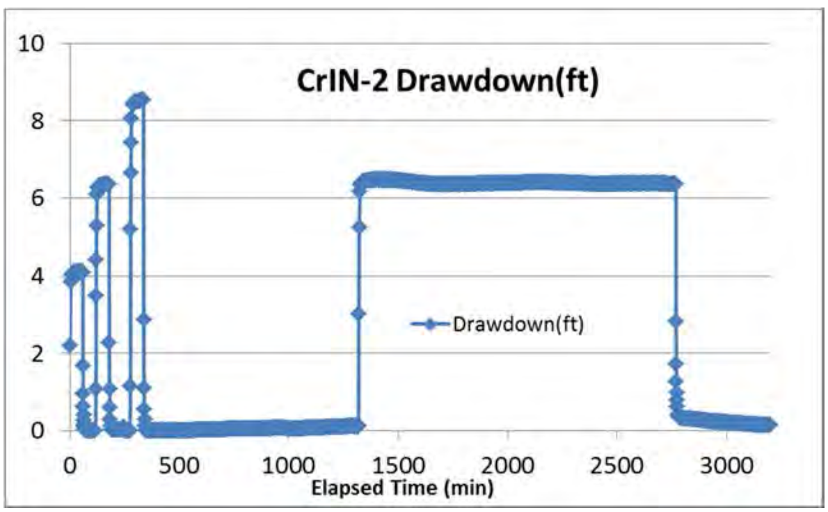



**Figure D-7** Corrected drawdown data from the pumping test of well CrIN-2

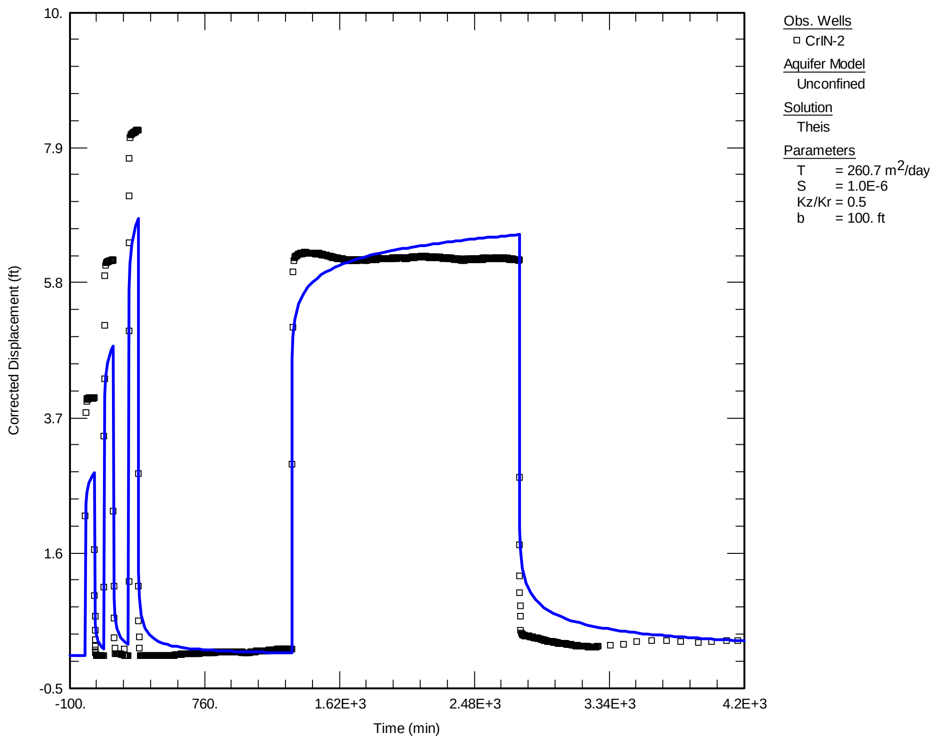



**Figure D-8** **Matching observed drawdowns (black dots) during the four-step CrIN-2 test using the Theis model (blue line)**

**Table D-4**
**CrIN-2 Well Structure and Pumping Test Data Applied in the Pumping Test Analyses**

Data Set: E:\EP2016\AquiferTest\CrIN\CrIN-2-Theis1.aqt
Date: 09/14/16
Time: 18:04:07

PROJECT INFORMATION

Company: LANL
Client: zd
Project: ep
Location: Puye
Test Date: 2016
Test Well: CrIN-2

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.5

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: CrIN-2

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 8.625 ft
Well Radius: 8. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 86. ft

No. of pumping periods: 9

Pumping Period Data

| Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) |
|---|---|---|---|---|---|
| 0. | 30. | 179.2 | 0. | 1318. | 58. |
| 59.17 | 0. | 274. | 70. | 2768.3 | 0. |
| 119.3 | 50. | 336.2 | 0. | 4271. | 0. |

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: CrIN-2

X Location: 0. ft
Y Location: 0. ft

Radial distance from CrIN-2: 0. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft

**Table D-5**
**Estimated Parameters Using the Theis Model for CrIN-2**

Aquifer Model: Unconfined
Solution Method: Theis

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 260.7 | 9.26 | +/- 18.18 | 28.15 | $m^2$/day |
| S | 1.0E-6 | 3.266E-6 | +/- 6.412E-6 | 0.3062 | |
| Kz/Kr | 0.5 | 2.16 | +/- 4.241 | 0.2314 | |
| b | 100. | not estimated | | | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 8.552 m/day (0.009898 cm/sec)
Ss = S/b = 1.0E-8 1/ft

Parameter Correlations

| | T | S | Kz/Kr |
|---|---|---|---|
| T | 1.00 | 0.15 | -0.33 |
| S | 0.15 | 1.00 | -0.98 |
| Kz/Kr | -0.33 | -0.98 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 227.2 $ft^2$
Variance . . . . . . . . . . . 0.2744 $ft^2$
Std. Deviation. . . . . . . 0.5238 ft
Mean . . . . . . . . . . . . . . -0.06096 ft
No. of Residuals . . . . 831
No. of Estimates . . . . 3

**Table D-6**
**Estimated Parameters Using the Neuman Model for CrIN-2**

Aquifer Model: Unconfined
Solution Method: Neuman

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 99.28 | 14.05 | +/- 27.57 | 7.069 | $m^2$/day |
| S | 0.00116 | 0.0003273 | +/- 0.0006425 | 3.544 | |
| Sy | 0.32 | 0.2009 | +/- 0.3943 | 1.593 | |
| ß | 0.003434 | 0.002067 | +/- 0.004058 | 1.661 | |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 3.257 m/day (0.00377 cm/sec)
Ss = S/b = 1.16E-5 1/ft

Parameter Correlations

| | T | S | Sy | ß |
|---|---|---|---|---|
| T | 1.00 | -0.97 | -0.99 | -1.00 |
| S | -0.97 | 1.00 | 0.97 | 0.97 |
| Sy | -0.99 | 0.97 | 1.00 | 0.99 |
| ß | -1.00 | 0.97 | 0.99 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares .... 79.19 $ft^2$
Variance ........... 0.09576 $ft^2$
Std. Deviation....... 0.3094 ft
Mean .............. -0.01445 ft
No. of Residuals .... 831
No. of Estimates .... 4

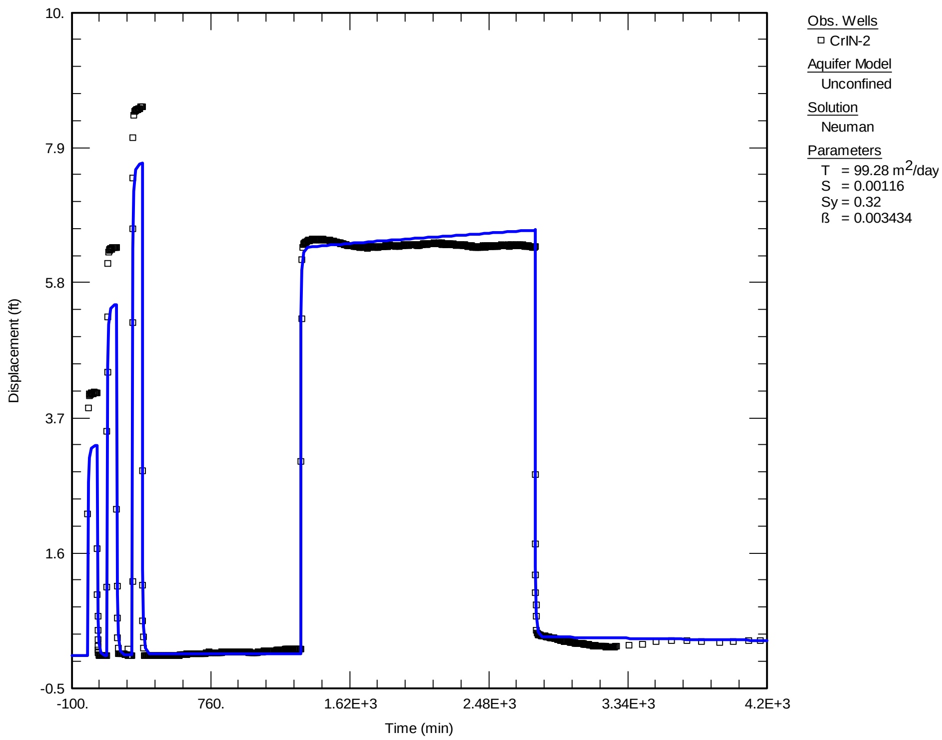



**Figure D-9** **Matching of the observed drawdowns (black dots) during the four-step CrIN-2 test using the Neuman model (blue line)**

## D-4.0 CRIN-3

The pumping test at CrIN-3 was conducted from September 8 to 11, 2016 (the latest test in a series of five pumping tests), and the pump was run at multiple steps with various constant pumping rates. This well was drilled with an angle of 17 degrees vertically. The contact depths for the stratigraphy and screen are in linear feet along borehole length (the actual depths can be estimated by accounting for the well angle). During the test, detailed pumping rate observations were recorded with a about 5-min frequency (Figure D-10). The pump was started from 7:43 on September 8 at rates varying from 46 to 55 gpm for about 1 h (step 1); at 8:46, the rate increased to about 55–64 gpm for about 1 h (step 2), and then at 9:46, the pumping went to step 3. The rates increased continuously to about 71–82 gpm for another hour. At 10:46, the pump was stopped for about 4 h of recovery and was restarted with a nearly constant rate of 81 gpm for 24 h. Finally, the pump was stopped for about 1.5 d of recovery (Figure D-10).

Figure D-11 (left) shows some artificial spikes in the observation data at the pump starting stage. The spikes were located and removed and the cleaned-up water-level data are shown in Figure D-11 (right). The observed multistep water depths were converted to corrected displacements or drawdowns (in feet) and used to estimate the parameter (Figure D-12).

First, the variable-rate Theis model was used to fit the multistep observation data. The multistep variable pumping rates and parameter estimation results are shown in Tables D-7 and D-8. The estimated hydraulic conductivity is 31.56 m/d and the storage coefficient is $10^{-6}$. The computed drawdowns during the first three pumping steps and the recovery period are shown in Figure D-13.

Next, the variable-rate Neuman model was used to estimate the parameter based on the observation data (Figure D-14). By considering the delayed gravity response of the unconfined aquifer, the Neuman model can simulate well the multistep pumping test processes, and the computed drawdowns fit the observation data slightly better. The estimated parameters are listed in Table D-9: conductivity is 14.87 m/d, storage coefficient is 0.0102, and specific yield is p (specific yield is during the parameter estimation process is limited to the expected maximum porosity of the Puye Formation, which is equal to 0.32). The parameter β coefficient is 0.00064, and in this model, the ratio of $\frac{K_z}{K_r}$ is equal to 0.1. The objective function (or sum of squares) is reduced from 29.56, which was obtained from the Theis model, to 24.92.

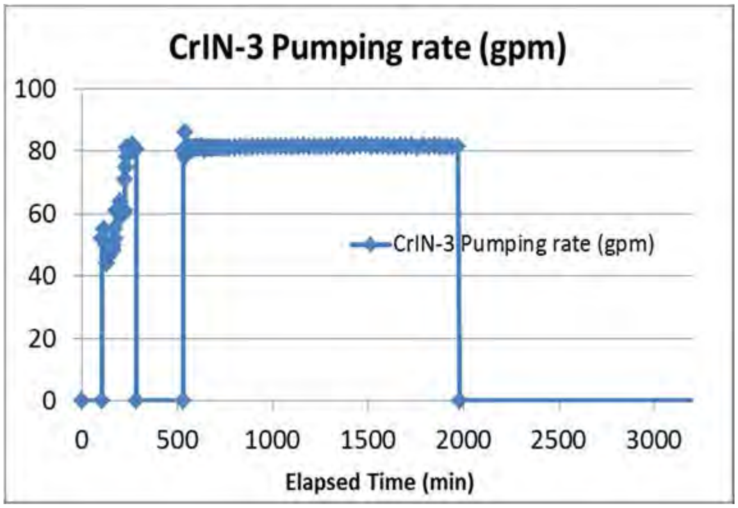



**Figure D-10 Variable pumping rates for the test at well CrIN-3**

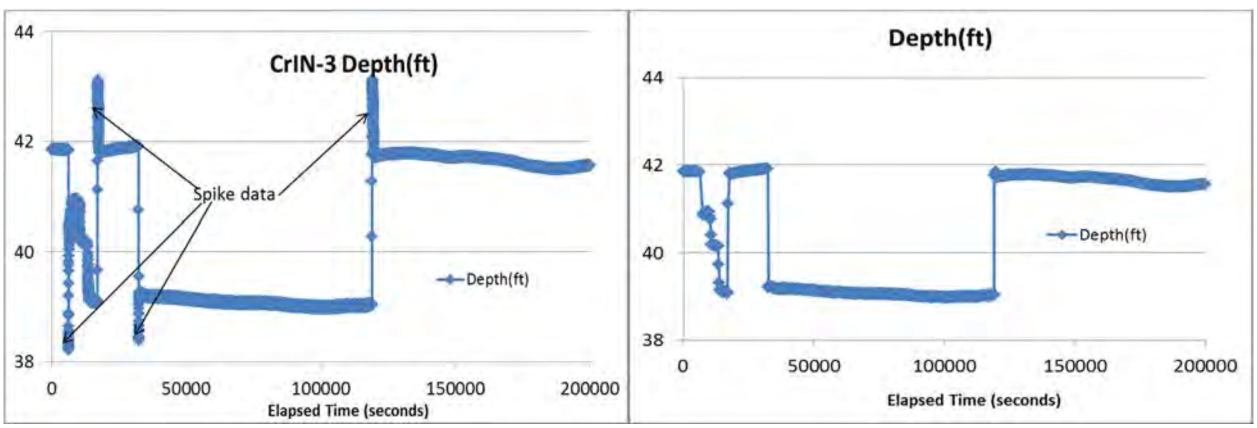



**Figure D-11 Measured water-depth data with spikes (left) and corrected water-depth data (right) from the pumping test of well CrIN-3**

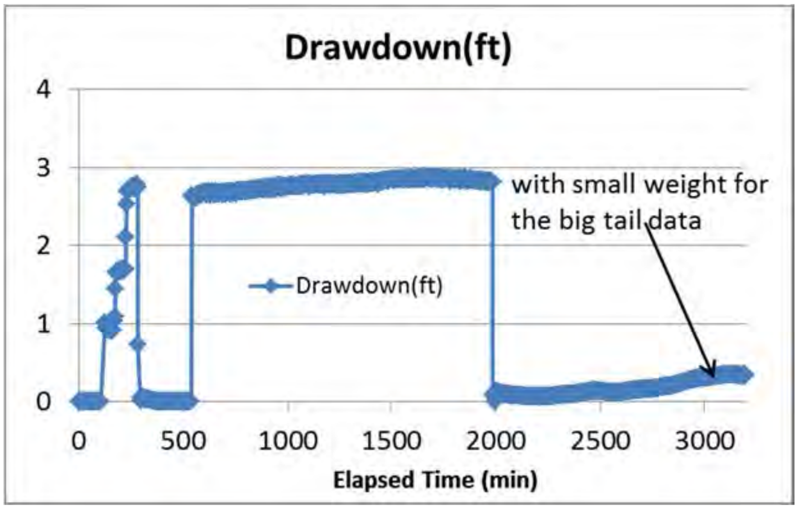



**Figure D-12 Corrected drawdown data from the pumping test of well CrIN-3**

**Table D-7**
**CrIN-3 Well Structure and Pumping Test Data Applied in the Pumping Test Analyses**

Data Set: E:\EP2016\AquiferTest\CrIN\CrIN-3-Theis1.aqt
Title: CrIN-3 Pumping Test
Date: 11/01/16
Time: 14:29:14

PROJECT INFORMATION

Company: LANL
Client: zd
Project: ep
Location: Puye
Test Date: 2016
Test Well: CrIN-3

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.1

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: CrIN-3

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 8.625 ft
Well Radius: 8. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 86. ft

No. of pumping periods: 142

Pumping Period Data

| Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) |
|---|---|---|---|---|---|
| 0. | 1.0E-8 | 283.1 | 0. | 725. | 81.2 |
| 0. | 1.0E-9 | 527.9 | 0. | 740. | 81.1 |
| 103. | 1.0E-9 | 528. | 80. | 755. | 81.1 |
| 103. | 0. | 530. | 80. | 770. | 81.1 |
| 105. | 0. | 531. | 80. | 800. | 81.2 |
| 108. | 52. | 532.5 | 80. | 830. | 81.3 |
| 116. | 55. | 533. | 80. | 860. | 81.2 |
| 122. | 50. | 534. | 80. | 890. | 81.4 |
| 128. | 44. | 535. | 80. | 920. | 81.3 |
| 135. | 47. | 536. | 80. | 950. | 81.3 |
| 140. | 46. | 537. | 80. | 980. | 81.5 |
| 145. | 47. | 538. | 80. | 1010. | 81.5 |
| 150. | 48. | 539. | 86. | 1040. | 81.4 |
| 155. | 48. | 540. | 78. | 1070. | 81.6 |
| 160. | 49. | 541. | 80. | 1100. | 81.4 |
| 165. | 48. | 542. | 80. | 1130. | 81.6 |
| 166. | 50. | 543. | 80. | 1160. | 81.7 |
| 167. | 55. | 544. | 81. | 1190. | 81.6 |
| 168. | 55. | 545. | 81. | 1220. | 81.6 |
| 171. | 55. | 547. | 80.5 | 1250. | 81.5 |
| 175. | 52. | 549. | 81. | 1280. | 81.6 |
| 176. | 52. | 551. | 80.5 | 1310. | 81.7 |
| 178. | 61. | 553. | 80. | 1340. | 81.4 |

**Table D-8**
**Estimated Parameters Using the Theis Model for CrIN-3**

Aquifer Model: Unconfined
Solution Method: Theis

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 961.8 | 45.16 | +/- 88.65 | 21.3 | $m^2$/day |
| S | 1.0E-6 | 0.05029 | +/- 0.09872 | 1.989E-5 | |
| Kz/Kr | 0.1 | 5570.7 | +/- 1.094E+4 | 1.795E-5 | |
| b | 100. | not estimated | | | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 31.56 m/day (0.03652 cm/sec)
Ss = S/b = 1.0E-8 1/ft

Parameter Correlations

| | T | S | Kz/Kr |
|---|---|---|---|
| T | 1.00 | -0.24 | 0.24 |
| S | -0.24 | 1.00 | -1.00 |
| Kz/Kr | 0.24 | -1.00 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 29.56 $ft^2$
Variance . . . . . . . . . . . 0.03863 $ft^2$
Std. Deviation. . . . . . . 0.1966 ft
Mean . . . . . . . . . . . . . . -0.04677 ft
No. of Residuals . . . . 768
No. of Estimates . . . . 3

**Table D-9**
**Estimated Parameters Using the Neuman Model for CrIN-3**

Aquifer Model: Unconfined
Solution Method: Neuman

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 453.3 | 2.237 | +/- 4.392 | 202.6 | $m^2$/day |
| S | 0.01019 | 0.001035 | +/- 0.002033 | 9.84 | |
| Sy | 0.32 | 0.07128 | +/- 0.1399 | 4.489 | |
| ß | 0.00064 | not estimated | | | |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 14.87 m/day (0.01721 cm/sec)
Ss = S/b = 0.0001019 1/ft

Parameter Correlations

| | T | S | Sy |
|---|---|---|---|
| T | 1.00 | -0.50 | -0.68 |
| S | -0.50 | 1.00 | 0.45 |
| Sy | -0.68 | 0.45 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares .... 24.92 $ft^2$
Variance ........... 0.03258 $ft^2$
Std. Deviation....... 0.1805 ft
Mean .............. -0.03723 ft
No. of Residuals .... 768
No. of Estimates .... 3

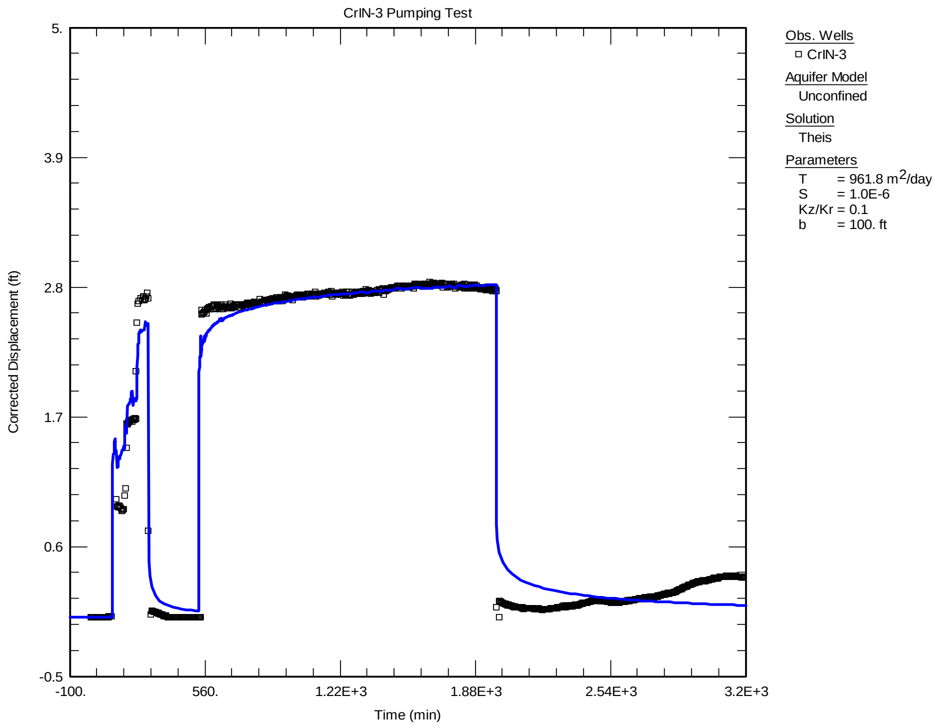



**Figure D-13 Matching observed drawdowns (black dots) during the four-step CrIN-3 test using the Theis model (blue line)**

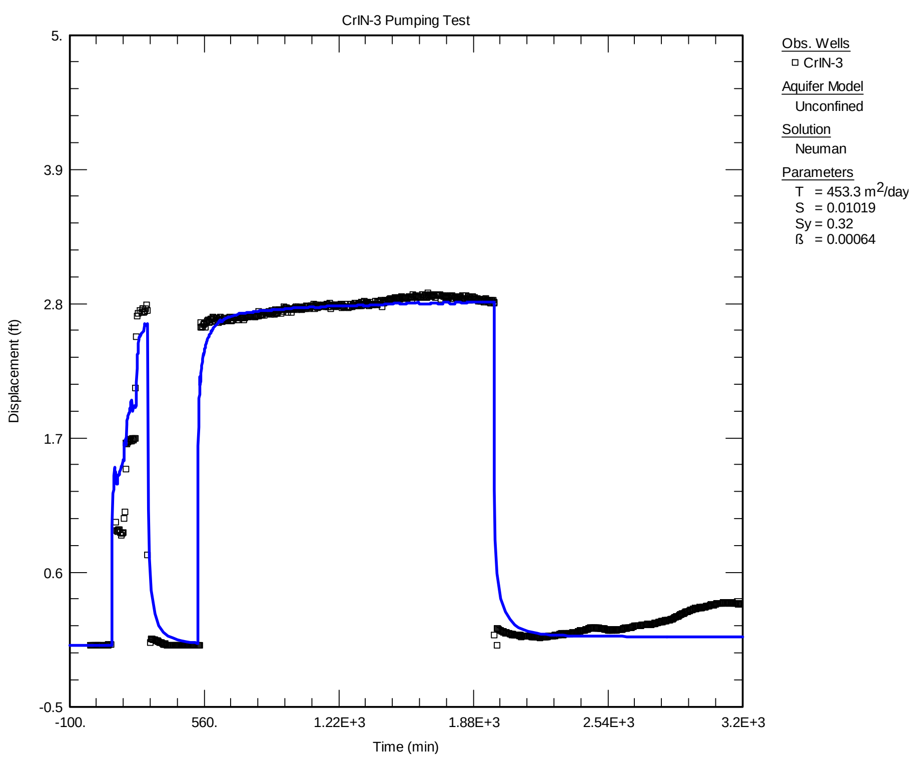



**Figure D-14 Matching observed drawdowns (black dots) during the four-step CrIN-3 test using the Neuman model (blue line)**

### D-5.0 CRIN-4

The observation at CrIN-4 occurred from June 21 to 23, 2016, and multistep pumping was started at 9:58 am on June 21 with a pumping rate of 38 gpm for about 1 h, after which the rate was increased to 60 gpm for another hour and to 75 gpm for another hour. The pump was then stopped for a recovery of 2 h. The pump was restarted with a constant rate of 62 gpm for 24 h. Finally, the pump was stopped for a recovery of about 1 d until 14:58 on June 23. The pumping and recovery processes are shown in Figure D-15.

Figure D-16 (left) shows some artificial spikes in the observation data at the pump starting and stopping stages. The spikes were located and removed, and the corrected water-depth data are shown in Figure D-16 (right). The corrected water depths were converted to displacements or drawdowns (in feet) and were used for parameter estimation (Figure D-17).

It should be noted that this well was drilled with an angle of 11 degrees vertically. The contact depths for the stratigraphy and screen are in linear feet along borehole length. The screen was designed from depth 1083 ft to 1133 ft bgs with a length of 50 ft. When the well angle is taken into account, the depths below ground surface can be used to compute the actual vertical depths below the ground surface.

The variable-rate Theis model was used to simulate the multistep pumping test. The multistep variable pumping rates and parameter estimation results are shown in Tables D-10 and D-11. The estimated hydraulic conductivity is 15.61 m/d and the storage coefficient is $10^{-6}$. The computed drawdowns during the first three steps and the recovery time do not fit the observation data very well (with an objective function value or sum of squares of 128.1) (Figure D-18).

The variable-rate Neuman model was used to fit the observation data (Figure D-19). By considering the delayed gravity response of the unconfined aquifer, the Neuman model can simulate well the multistep pumping test processes and the computed drawdowns fit the observation data better. The estimated parameters are listed in Table D-12, in which the conductivity is 5.84 m/d, storage coefficient is 0.00656, and specific yield is 0.32 (specific yield is during the parameter estimation process is limited to the expected maximum porosity of the Puye Formation, which is equal to 0.32). The parameter β coefficient is 0.002449, and in this model, the ratio of $\frac{K_z}{K_r}$ is equal to 0.383. The objective function is reduced from 128.1, which was obtained from the Theis model, to 75.2.

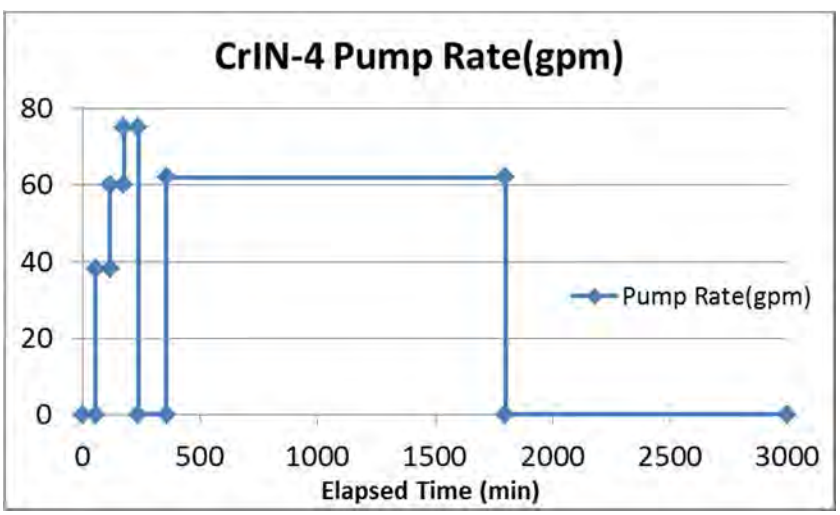



**Figure D-15 Variable pumping rates for the test at well CrIN-4**

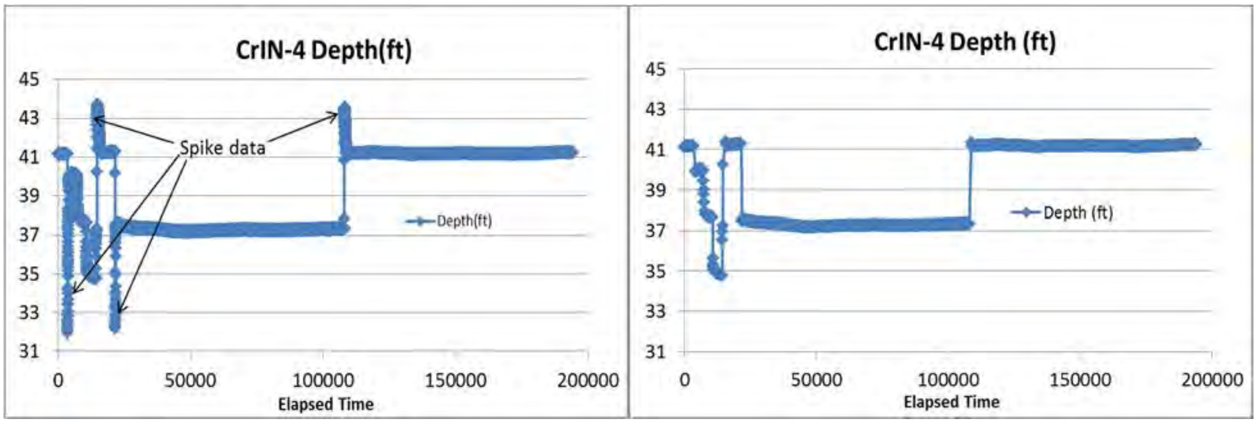



**Figure D-16 Measured water-depth data with spikes (left) and corrected water-depth data (right) from the pumping test of well CrIN-4 (elapsed time = seconds)**

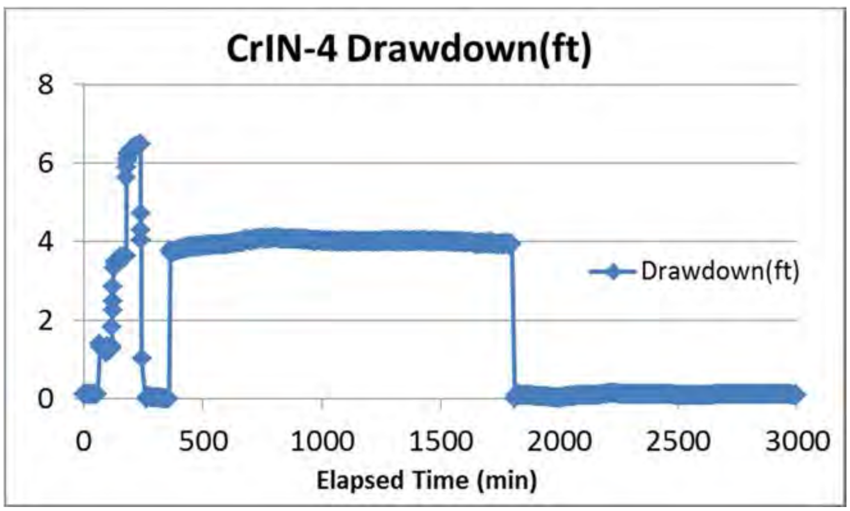



**Figure D-17 Corrected drawdown data from the pumping test of well CrIN-4**

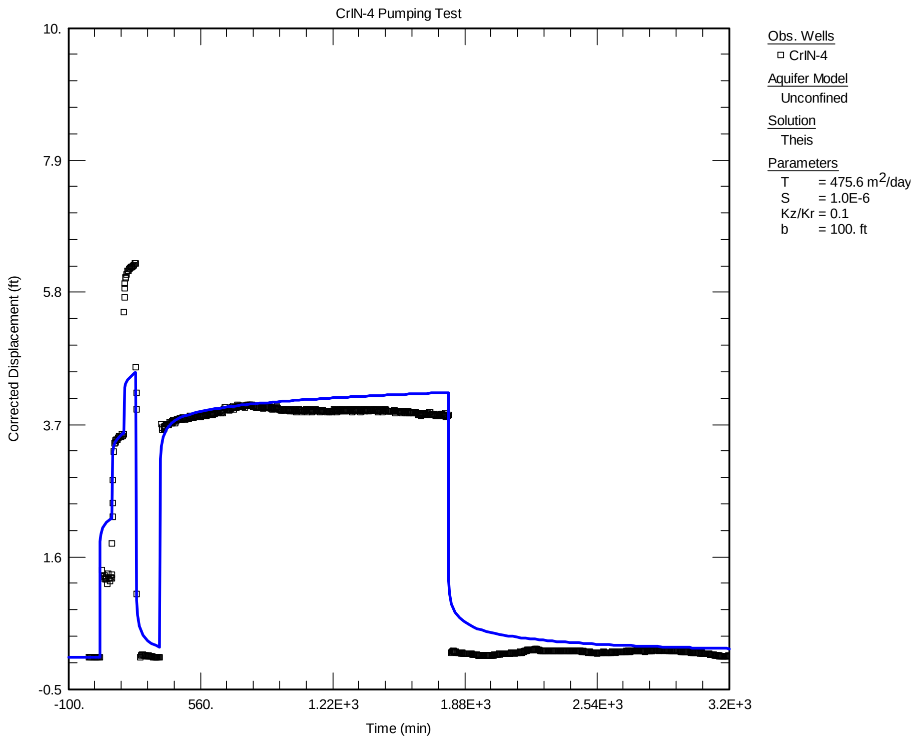



**Figure D-18 Matching of the observed drawdowns (black dots) during the four-step CrIN-4 test using the Theis model (blue line)**

**Table D-10**
**CrIN-4 Well Structure and Pumping Test Data Applied in the Pumping Test Analyses**

Data Set: E:\EP2016\AquiferTest\CrIN\CrIN-4-Theis1.aqt
Title: CrIN-4 Pumping Test
Date: 10/06/16
Time: 10:31:22

PROJECT INFORMATION

Company: LANL
Client: zd
Project: ep
Location: Puye
Test Date: 2016
Test Well: CrIN-4

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.1

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: CrIN-4

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 8.625 ft
Well Radius: 8. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 86. ft

No. of pumping periods: 13

Pumping Period Data

| Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) |
|---|---|---|---|---|---|
| 0. | 1.0E-8 | 177.7 | 60. | 357.5 | 62. |
| 57.4 | 0. | 177.7 | 75. | 1799.3 | 0. |
| 57.5 | 38. | 237.8 | 75. | 3000. | 0. |
| 118.2 | 38. | 237.8 | 0. | | |
| 118.2 | 60. | 357.4 | 0. | | |

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: CrIN-4

X Location: 0. ft
Y Location: 0. ft

Radial distance from CrIN-4: 0. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 86. ft

**Table D-11**
**Estimated Parameters Using the Theis Model for CrIN-4**

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| T | 474.3 | $m^2$/day |
| S | 1.0E-6 | |
| Kz/Kr | 0.1 | |
| b | 100. | ft |

K = T/b = 15.56 m/day (0.01801 cm/sec)
Ss = S/b = 1.0E-8 1/ft

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 475.6 | 32.2 | +/- 63.21 | 14.77 | $m^2$/day |
| S | 1.0E-6 | 0.2609 | +/- 0.5121 | 3.833E-6 | |
| Kz/Kr | 0.1 | 2.89E+4 | +/- 5.673E+4 | 3.46E-6 | |
| b | 100. | not estimated | | | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 15.61 m/day (0.01806 cm/sec)
Ss = S/b = 1.0E-8 1/ft

Parameter Correlations

| | T | S | Kz/Kr |
|---|---|---|---|
| T | 1.00 | -0.36 | 0.36 |
| S | -0.36 | 1.00 | -1.00 |
| Kz/Kr | 0.36 | -1.00 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 128.1 $ft^2$
Variance . . . . . . . . . . . 0.1924 $ft^2$
Std. Deviation. . . . . . . 0.4386 ft
Mean . . . . . . . . . . . . . . -0.09789 ft
No. of Residuals . . . . 669
No. of Estimates . . . . 3

**Table D-12**
**Estimated Parameters Using the Neuman Model for CrIN-4**

Aquifer Model: Unconfined
Solution Method: Neuman

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 178. | 23.36 | +/- 45.85 | 7.621 | $m^2$/day |
| S | 0.006561 | 0.0019 | +/- 0.00373 | 3.452 | |
| Sy | 0.32 | 0.2017 | +/- 0.396 | 1.586 | |
| ß | 0.002449 | 0.00147 | +/- 0.002886 | 1.666 | |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 5.839 m/day (0.006759 cm/sec)
Ss = S/b = 6.561E-5 1/ft

Parameter Correlations

| | T | S | Sy | ß |
|---|---|---|---|---|
| T | 1.00 | -0.92 | -0.98 | -1.00 |
| S | -0.92 | 1.00 | 0.91 | 0.91 |
| Sy | -0.98 | 0.91 | 1.00 | 0.98 |
| ß | -1.00 | 0.91 | 0.98 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares .... 75.23 $ft^2$
Variance ........... 0.1131 $ft^2$
Std. Deviation....... 0.3363 ft
Mean .............. -0.09209 ft
No. of Residuals .... 669
No. of Estimates .... 4

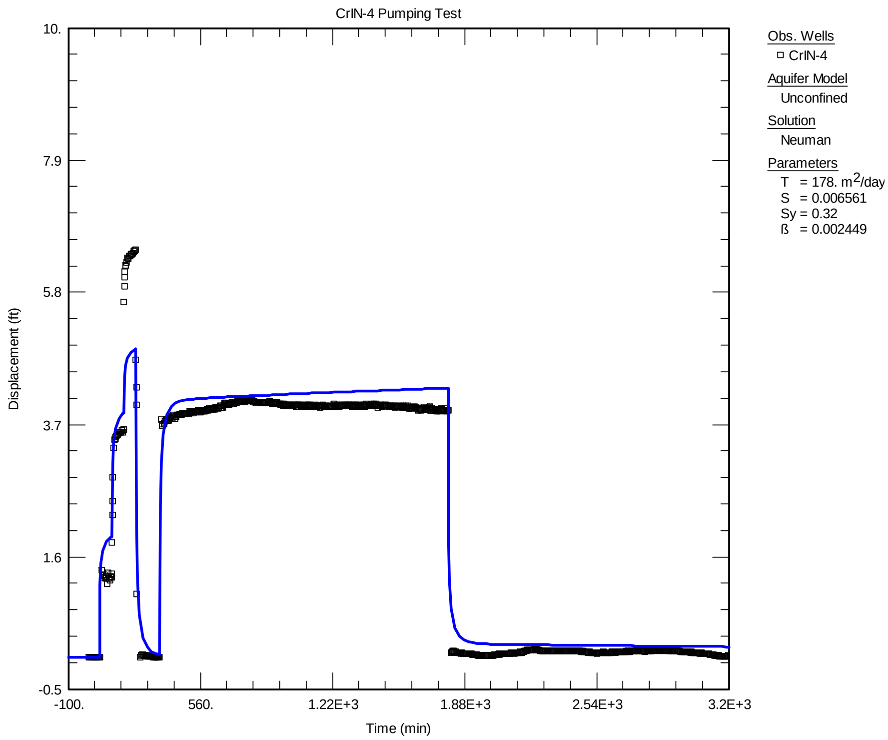



**Figure D-19 Matching observed drawdowns (black dots) during the four-step CrIN-4 test using the Neuman model (blue line)**

### D-6.0 CRIN-5

The well CrIN-5 was drilled with an angle of 25 degrees vertically. The screen was placed within the Puye Formation from 1162 to 1222 ft bgs with a length of 60 ft. Taking into account the well angle, the below ground surface depths can be applied to compute the actual vertical depths below the ground surface. The observation at CrIN-5 occurred from August 3 to 5, 2016, and the multistep pumping was started at 9:59 on August 3, with a pumping rate of 32 gpm for about 1 h, after which the rate increased to 50 gpm for another hour and 68 gpm for another hour. The pump was then stopped for a recovery of 2 h. The pump was restarted with a constant rate of 61 gpm for 24 h and was finally stopped for a recovery of about 1 d until 13:01 on August 5. The pumping and recovery processes are shown in Figure D-20.

Figure D-21 (left) shows some artificial spikes in the observation data at the pump starting and stopping stages. The spikes were located and removed, and the corrected data are presented in Figure D-21 (right). The observed water depths were converted to corrected displacements or drawdowns (in feet) and then used for parameter estimation (Figure D-22).

The variable-rate Theis model is used to simulate approximately the multistep pumping test. The multistep variable pumping rates and parameter estimation results are shown in Tables D-13 and D-14. The estimated hydraulic conductivity is 11.87 m/d and the storage coefficient is $10^{-6}$. The computed drawdowns during the first three steps and recovery time do not fit the observation data very well (with an objective function value or sum of squares of 166.7) (Figure D-23).

The variable-rate Neuman model was then used to estimate the hydraulic parameters and to fit the observation data (Figure D-24). By considering the delayed gravity response of the unconfined aquifer, the Neuman model can simulate well the multistep pumping test processes and the computed drawdowns match the observation data better. The estimated parameters are listed in Table D-15: conductivity is 5.97 m/d, storage coefficient is 0.000014, and specific yield is 0.23. The parameter β coefficient is 0.00034, and in this model, the ratio of $\frac{K_z}{K_r}$ is equal to 0.05. The objective function is reduced more than half from 166.7, which was obtained from the Theis model, to 76.3.

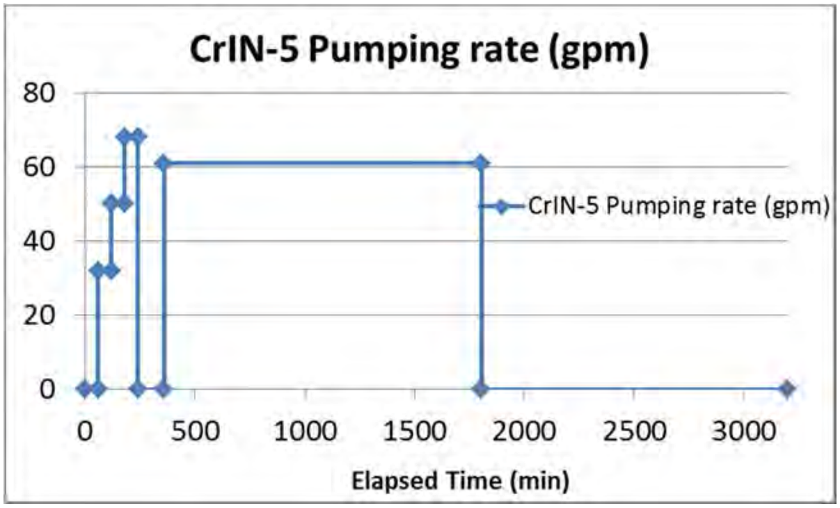



**Figure D-20 Variable pumping rates for the test at well CrIN-5**

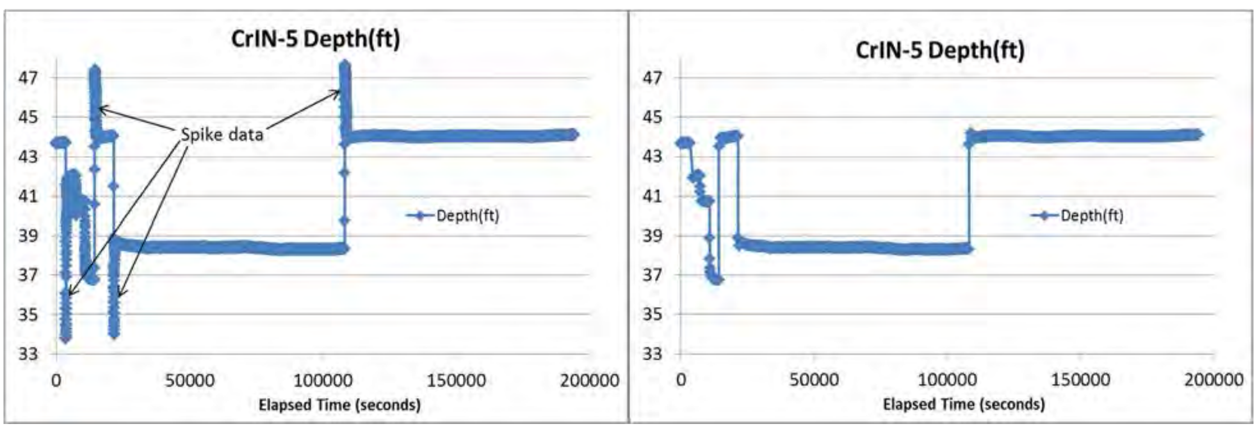



**Figure D-21 Measured water-depth data with spikes (left) and corrected water-depth data (right) from the pumping test of well CrIN-5**

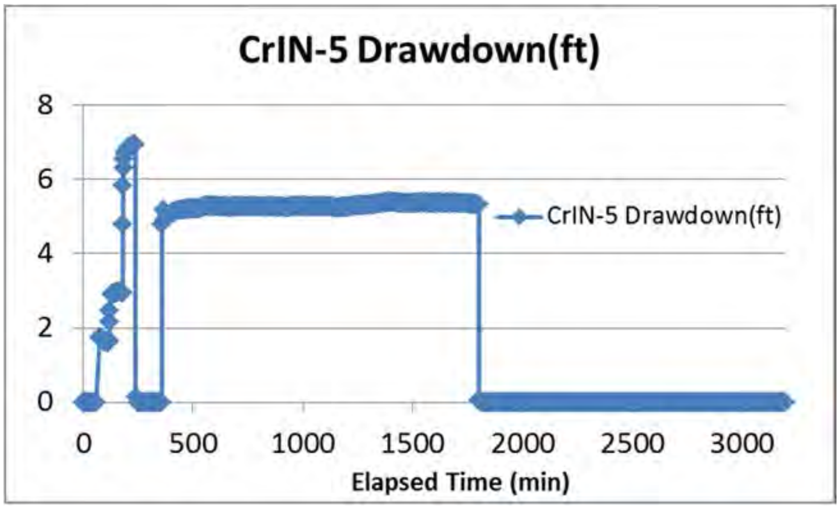



**Figure D-22 Corrected drawdown data from the pumping test of well CrIN-5**

**Table D-13**
**CrIN-5 Well Structure and Pumping Test Data Applied in the Pumping Test Analyses**

Data Set: E:\EP2016\AquiferTest\CrIN\CrIN-5-Theis1.aqt
Title: CrIN-5 Pumping Test
Date: 10/07/16
Time: 15:14:21

PROJECT INFORMATION

Company: LANL
Client: zd
Project: ep
Location: Puye
Test Date: 2016
Test Well: CrIN-4

AQUIFER DATA

Saturated Thickness: 100. ft
Anisotropy Ratio (Kz/Kr): 0.01

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: CrIN-5

X Location: 0. ft
Y Location: 0. ft

Casing Radius: 8.625 ft
Well Radius: 8. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 96. ft

No. of pumping periods: 14

Pumping Period Data

| Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) | Time (min) | Rate (gal/min) |
|---|---|---|---|---|---|
| 0. | 1.0E-8 | 180.3 | 50. | 358.8 | 61. |
| 58.8 | 0. | 180.3 | 68. | 1802.8 | 61. |
| 58.83 | 32. | 238.8 | 68. | 1802.8 | 0. |
| 120.1 | 32. | 238.8 | 0. | 3200. | 0. |
| 120.2 | 50. | 358.8 | 0. | | |

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: CrIN-5

X Location: 0. ft
Y Location: 0. ft

Radial distance from CrIN-5: 0. ft

Partially Penetrating Well
Depth to Top of Screen: 36. ft
Depth to Bottom of Screen: 96. ft

**Table D-14**
**Estimated Parameters with the Theis Model for CrIN-5**

Aquifer Model: Unconfined
Solution Method: Theis

VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| T | 355.1 | $m^2$/day |
| S | 1.0E-6 | |
| Kz/Kr | 0.01 | |
| b | 100. | ft |

K = T/b = 11.65 m/day (0.01349 cm/sec)
Ss = S/b = 1.0E-8 1/ft

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 361.7 | 13.08 | +/- 25.69 | 27.65 | $m^2$/day |
| S | 1.0E-6 | 3.652E-7 | +/- 7.172E-7 | 2.738 | |
| Kz/Kr | 0.01 | 0.005662 | +/- 0.01112 | 1.766 | |
| b | 100. | not estimated | | | ft |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 11.87 m/day (0.01374 cm/sec)
Ss = S/b = 1.0E-8 1/ft

Parameter Correlations

| | T | S | Kz/Kr |
|---|---|---|---|
| T | 1.00 | -1.00 | -1.00 |
| S | -1.00 | 1.00 | 1.00 |
| Kz/Kr | -1.00 | 1.00 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 166.7 $ft^2$
Variance . . . . . . . . . . . 0.258 $ft^2$
Std. Deviation. . . . . . . 0.5079 ft
Mean . . . . . . . . . . . . . . -0.2307 ft
No. of Residuals . . . . 649
No. of Estimates . . . . 3

**Table D-15**
**Estimated Parameters Using the Neuman Model for CrIN-5**

Aquifer Model: Unconfined
Solution Method: Neuman

VISUAL ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | |
|---|---|---|
| T | 361.7 | $m^2$/day |
| S | 1.0E-6 | |
| Sy | 0.2407 | |
| ß | 0.0003374 | |

K = T/b = 11.87 m/day (0.01374 cm/sec)
Ss = S/b = 1.0E-8 1/ft

AUTOMATIC ESTIMATION RESULTS

Estimated Parameters

| Parameter | Estimate | Std. Error | Approx. C.I. | t-Ratio | |
|---|---|---|---|---|---|
| T | 181.9 | 0.1375 | +/- 0.2701 | 1322.5 | $m^2$/day |
| S | 1.365E-5 | 2.165E-6 | +/- 4.252E-6 | 6.305 | |
| Sy | 0.2288 | 0.09752 | +/- 0.1915 | 2.346 | |
| ß | 0.0003398 | 1.848E-6 | +/- 3.63E-6 | 183.8 | |

C.I. is approximate 95% confidence interval for parameter
t-ratio = estimate/std. error
No estimation window

K = T/b = 5.967 m/day (0.006906 cm/sec)
Ss = S/b = 1.365E-7 1/ft

Parameter Correlations

| | T | S | Sy | ß |
|---|---|---|---|---|
| T | 1.00 | -0.03 | -0.55 | 1.00 |
| S | -0.03 | 1.00 | 0.02 | -0.09 |
| Sy | -0.55 | 0.02 | 1.00 | -0.59 |
| ß | 1.00 | -0.09 | -0.59 | 1.00 |

Residual Statistics

for weighted residuals

Sum of Squares . . . . 76.31 $ft^2$
Variance . . . . . . . . . . . 0.1183 $ft^2$
Std. Deviation. . . . . . . 0.344 ft
Mean . . . . . . . . . . . . . . -0.04854 ft
No. of Residuals . . . . 649
No. of Estimates . . . . 4

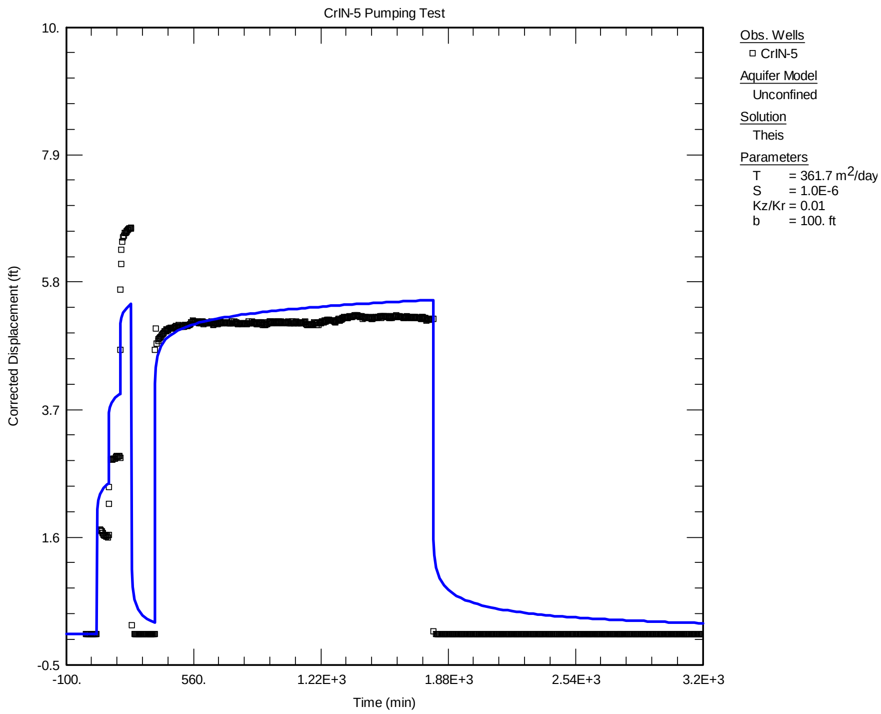



**Figure D-23 Matching observed drawdowns (black dots) during the four-step CrIN-5 test using the Theis model (blue line)**

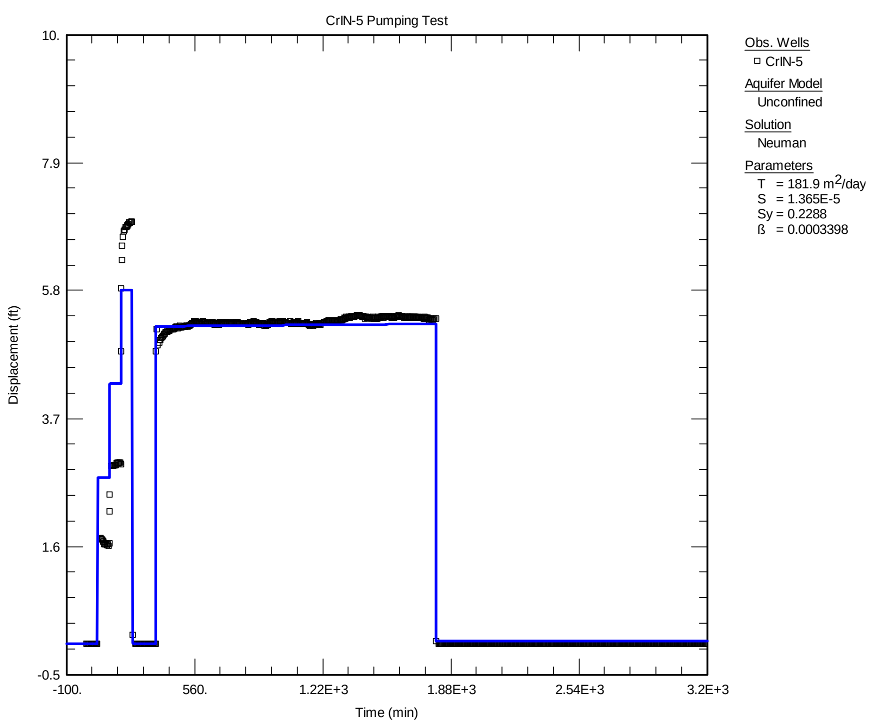



**Figure D-24 Matching of the observed drawdowns (black dots) during the four-step CrIN-5 test using the Neuman model (blue line)**

## D-7.0 SUMMARY

A series of pumping tests were conducted on wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 at the Laboratory's Chromium site to (1) characterize pumping/injection capabilities of these wells and (2) to gain an understanding of the hydraulic characteristics of the regional aquifer. All the wells are screened in the saturated portion of the Puye Formation. These five sets of pumping test data were used for parameter estimations with two analytical models: the Theis and the Neuman. The estimated parameters from the five tests are summarized in Table D-16.

The aquifer transmissivity estimated using the Theis model are more consistent with previous pumping tests conducted at the site. The aquifer transmissivity estimated using the Neuman model are lower than the Theis estimates primarily because the Neuman model accounts for delayed yield effect from the vadose zone, which causes some aquifer recharge during the pumping tests.

The estimated hydraulic conductivities derived from using the Theis model are consistently smaller than those from using the Neuman model. The estimated average hydraulic conductivities are 14.7 and 6.4 m/d for the Theis and Neuman models, respectively. However, determining hydraulic conductivity of the aquifer materials based on the estimated aquifer transmissivity is uncertain because the effective aquifer thickness during is not known.

The anisotropy factors estimated by both models are similar. The anisotropy factors for the Theis and Neuman models are 0.23 and 0.26, respectively.

The storage coefficients estimated with Theis model are very small ($10^{-6}$), and they are not considered to be realistic because they are based on single-well pumping test analyses.

The specific yield estimates obtained using the Neuman model are uncertain; this parameter was constrained not to exceed the expected maximum porosity of the Puye Formation, which is equal to 0.32; in most of the Neuman analyses the specific yield was close to this maximum value (Table D-16).

The storage coefficients estimated with Neuman model are reasonable (with an average of 0.0037).

Because the Neuman model considers the delayed gravity response of the unconfined aquifer, the computed drawdowns for the five tests match the observation data better than those computed from the Theis model.

The regional water levels reached almost complete recovery at all the CrIN wells after the 24-h pumping was terminated.

**Table D-16**
**Summary of the Estimated Parameters Using the Theis and Neuman Models**

| Model | Parameter | CrIN-1 | CrIN-2 | CrIN-3 | CrIN-4 | CrIN-5 | Average |
|---|---|---|---|---|---|---|---|
| | 24 h-pumping rate (gpm) | 70 | 58 | 81.5 | 62 | 61 | —* |
| | Drawdown (ft) | 13.2 | 6.4 | 2.8 | 4 | 5.3 | — |
| | Specific capacity (gpm/ft) | 5.3 | 9.1 | 29.1 | 15.5 | 11.5 | 14.1 |
| Theis (with unconfined correction) | Hydraulic conductivity (m/d) | 5.6 | 8.6 | 31.6 | 15.6 | 11.9 | 14.7 |
| | Transmissivity ($m^2$/d) | 172 | 261 | 962 | 476 | 362 | 446 |
| | Storage coefficient (−) | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ | $10^{-6}$ |
| | Anisotropy ratio Kz/Kr (−) | 0.20 | 0.50 | 0.1 | 0.30 | 0.05 | 0.23 |
| Neuman (unconfined) | Hydraulic conductivity (m/d) | 2.3 | 3.3 | 14.9 | 5.8 | 6.0 | 6.4 |
| | Transmissivity ($m^2$/d) | 69.2 | 99.3 | 453. | 178. | 182. | 196 |
| | Storage coefficient (−) | 0.0008 | 0.00116 | 0.0102 | 0.00656 | 0.000014 | 0.0037 |
| | Anisotropy ratio Kz/Kr (−) | 0.23 | 0.54 | 0.1 | 0.383 | 0.05 | 0.26 |
| | Specific yield (−) | 0.32 | 0.32 | 0.32 | 0.32 | 0.23 | 0.30 |

*— = Not calculated.

## D-8.0 REFERENCES

*The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ERID or ESHID. This information is also included in text citations. ERIDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESHIDs 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.*

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