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Date: AUG 05 2010
Refer To: EP2010-0304

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Subject: Submittal of the Completion Report for Regional Aquifer Well R-29

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the Completion Report for Regional Aquifer Well R-29.

If you have any questions, please contact Ted Ball at (505) 665-3996 (tedball@lanl.gov) or Tom Whitacre at (505) 665-5042 (twhitacre@doeal.gov).

Sincerely,

Bruce Schappell, Executive Director
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Everett Trollinger, Federal Project Director
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MG/GR/TB/ME:sm

Enclosures: Two hard copies with electronic files – Completion Report for Regional Aquifer Well R-29 (LA-UR-10-4505)

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LA-UR-10-4505
August 2010
EP2010-0304

Completion Report for Regional Aquifer Well R-29

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

Los Alamos National Laboratory, operated by Los Alamos National Security, LLC, for the U.S. Department of Energy under Contract No. DE-AC52-06NA25396, has prepared this document pursuant to the Compliance Order on Consent, signed March 1, 2005. The Compliance Order on Consent contains requirements for the investigation and cleanup, including corrective action, of contamination at Los Alamos National Laboratory. The U.S. government has rights to use, reproduce, and distribute this document. The public may copy and use this document without charge, provided that this notice and any statement of authorship are reproduced on all copies.

LA-UR-10-4505
EP2010-0304

Completion Report for Regional Aquifer Well R-29

August 2010

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EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, and aquifer testing of regional groundwater monitoring well R-29, located north of Ancho Canyon, within Los Alamos National Laboratory Technical Area 49 (TA-49). This report was written in accordance with the requirements in Section IV.A.3.e.iv of the Compliance Order on Consent.

Well R-29 was installed at the direction of the New Mexico Environment Department (NMED) to provide a regional aquifer monitoring well downgradient of TA-49, establish water levels in the regional aquifer in this area, determine whether zones of perched-intermediate groundwater occur under Material Disposal Area AB, and resolve uncertainty about whether the lavas described during installation of earlier deep test wells are Tschicoma dacite or Cerros del Rio volcanic rocks.

The R-29 borehole was successfully completed to a total depth of 1248.0 ft below ground surface (bgs) using dual-rotary, fluid-assisted, and standard air-rotary drilling methods. Fluid additives used included potable water and foam. No drilling fluids, other than air and small amounts of potable water, were used below 1047.0 ft bgs, roughly 100 ft above the regional aquifer.

Geologic units penetrated included the Tshirege Member of the Bandelier Tuff, the Cerro Toledo interval, the Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed, and the Puye Formation. Neither Tschicoma dacite nor Cerros del Rio volcanic rocks were encountered at R-29. No perched groundwater was detected during drilling.

The R-29 monitoring well was completed with a 10.0-ft-long single screen from 1170.0 to 1180.0 ft bgs to evaluate water quality and measure water levels in the regional aquifer within the Puye Formation. The water level after well completion was measured at 1152.5 ft bgs. The well was completed in accordance with the NMED-approved well design. Well development and aquifer testing activities indicate the well will perform effectively to meet the planned objectives. A dedicated sampling system and water-level transducer were installed, and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

CONTENTS

1.0 INTRODUCTION 1

2.0 PRELIMINARY ACTIVITIES 1
2.1 Administrative Preparation 1
2.2 Site Preparation 2

3.0 DRILLING ACTIVITIES 2
3.1 Drilling Approach 2
3.2 Chronological Drilling Activities 2

4.0 SAMPLING ACTIVITIES 3
4.1 Cuttings Sampling 3
4.2 Water Sampling 4

5.0 GEOLOGY AND HYDROGEOLOGY 4
5.1 Stratigraphy 4
5.2 Groundwater 6

6.0 BOREHOLE LOGGING 6
6.1 Video Logging 6
6.2 Geophysical Logging 6

7.0 WELL INSTALLATION 7
7.1 Well Design 7
7.2 Well Construction 7

8.0 POSTINSTALLATION ACTIVITIES 8
8.1 Well Development 8
8.1.1 Well Development Field Parameters 8
8.2 Aquifer Testing 9
8.3 Dedicated Sampling System Installation 9
8.4 Wellhead Completion 9
8.5 Geodetic Survey 9
8.6 Waste Management and Site Restoration 10

9.0 DEVIATIONS FROM PLANNED ACTIVITIES 10

10.0 ACKNOWLEDGMENTS 10

11.0 REFERENCES AND MAP DATA SOURCES 11
11.1 References 11
11.2 Map Data Sources 11

Figures

Figure 1.0-1 Location of monitoring well R-29 13
Figure 5.1-1 Monitoring well R-29 borehole stratigraphy 14
Figure 7.2-1 Monitoring well R-29 as-built well construction diagram 15
Figure 8.3-1a As-built schematic for monitoring well R-29 17
Figure 8.3-1b As-built technical notes for monitoring well R-29 18

Tables

Table 3.1-1 Fluid Quantities Used during R-29 Drilling and Well Construction 19
Table 4.2-1 Summary of Groundwater Screening Samples Collected during Drilling and Well Development of Well R-29 20
Table 6.0-1 R-29 Video and Geophysical Logging Runs 20
Table 7.2-1 R-29 Monitoring Well Annular Fill Materials 21
Table 8.5-1 R-29 Survey Coordinates 21
Table 8.6-1 Summary of Waste Samples Collected during Drilling and Development of R-29 21

Appendixes

Appendix A Borehole R-29 Lithologic Log
Appendix B Groundwater Analytical Results
Appendix C Aquifer Testing Report
Appendix D Borehole Video Logging (on DVD included with this document)
Appendix E Geophysical Logging Report (on CD included with this document)
Appendix F Geodetic Survey

Acronyms and Abbreviations

amsl	above mean sea level
APS	Accelerator Porosity Sonde
ASTM	American Society for Testing and Materials
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
ECS	Elemental Capture Spectroscopy
EES-14	Earth and Environmental Sciences Group 14
Eh	oxidation-reduction potential
EP	Environmental Programs
EPA	Environmental Protection Agency (U.S.)
gpd	gallons per day
gpm	gallons per minute
HE	high explosives
HNGS	Hostile Natural Gamma Spectroscopy
hp	horsepower

ICPMS	inductively coupled plasma mass spectrometry
ICPOES	Inductively coupled plasma optical emission spectroscopy
I.D.	inside diameter
LANL	Los Alamos National Laboratory
µS/cm	microsiemens per centimeter
mV	millivolt
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
pH	potential of hydrogen
PVC	polyvinyl chloride
Qal	alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
Qbt 1g	Unit 1g of Tshirege Member of the Bandelier Tuff
Qbt 1v	Unit 1v of Tshirege Member of the Bandelier Tuff
Qbt 2	Unit 2 of Tshirege Member of the Bandelier Tuff
Qbt 3	Unit 3 of Tshirege Member of the Bandelier Tuff
Qbt 4	Unit 4 of Tshirege Member of the Bandelier Tuff
Qct	Cerro Toledo interval
RCRA	Resource Conservation and Recovery Act
RPF	Records Processing Facility
SOP	standard operating procedure
SU	standard unit
TA	technical area
TD	total depth
TDL	Triple Detector Lithodensity
TOC	total organic carbon
Tpf	Puye Formation
VOC	volatile organic compound
WES-EDA	Environmental Services Division–Environmental Data and Analysis
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes site preparation, borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for regional groundwater monitoring well R-29. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the Compliance Order on Consent (the Consent Order). The R-29 monitoring well borehole was drilled and installed from February 12 to March 12, 2010, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

The R-29 project site is located north of Ancho Canyon, within the Laboratory's Technical Area 49 (TA-49) (Figure 1.0-1). Well R-29 was drilled at the direction of NMED to provide a regional aquifer monitoring well downgradient of TA-49 and to help define the nature and extent of contamination in the area. Other objectives were to establish the water level in the regional aquifer in this area, determine whether zones of perched-intermediate groundwater occur under Material Disposal Area AB, and resolve uncertainty about whether the lavas described during installation of earlier deep test wells are Tschicoma dacite or Cerros del Rio volcanic rocks.

The R-29 borehole was drilled to a total depth (TD) of 1248.0 ft below ground surface (bgs). A monitoring well was then installed with one 10-ft screen between 1170.0 and 1180.0 ft bgs. The depth to water before well installation was measured at 1151.5 ft bgs on February 27, 2010, and 1152.5 ft bgs after well installation before aquifer testing on March 21, 2010. During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD.

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

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendixes completed to date associated with the R-29 project.

2.0 PRELIMINARY ACTIVITIES

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

2.1 Administrative Preparation

The following documents helped guide the implementation of the scope of work for well R-29:

- "Well R-29 Drill Plan—Final, Installation of Well R-29, TA-49, Los Alamos National Laboratory, Revision 1" (North Wind Inc. 2010, 109456)
- "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling" (LANL 2007, 100972)
- "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan" (LANL 2006, 092600)

- "Waste Characterization Strategy Form for South Canyon Wells R-29 and R-30 (TA-49, MDA-AB) Regional Groundwater Well Installation and Corehole Drilling" (LANL 2009, 107444)

2.2 Site Preparation

The drill pad was constructed by Laboratory personnel before the rig was mobilized. Between February 8 and 10, 2010, activities included moving the dual-rotary drill rig, air compressors, trailers, and support vehicles to the drill site and staging alternative drilling tools and construction materials at the Pajarito Road laydown yard.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and approach and provides a chronological summary of field activities conducted at well R-29.

3.1 Drilling Approach

The R-29 borehole was drilled using a Schramm Inc. T130XD Rotadrill dual-rotary drilling rig with casing rotator. The dual-rotary system allows for advancement of casing with the casing rotator while drilling with conventional air/mist/foam methods with the drill string. Other drilling equipment included tricone bits, downhole hammer bits, and 5.5-in. dual-wall drill pipe. Auxiliary equipment included three Ingersoll Rand 1070 ft^3/min trailer-mounted air compressors and two Sullair 1150 ft^3/min trailer-mounted air compressors. Casing sizes used included 24-in., 18-in., and 12-in. The dual-rotary technique used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole. In addition, the casing sizes selected ensured that the required 2-in.-minimum annular thickness of the filter pack around a 5.563-in.-outside diameter (O.D.) well, as required by the Consent Order (Section X.C.3), would be met.

Drilling additives were used as needed, along with potable water and air, between ground surface and 1047.0 ft bgs (approximately 100 ft above the anticipated top of the regional aquifer). The fluids and additives were used to cool the bit and help lift cuttings from the borehole. Only potable water and air were used below 1047.0 ft bgs. Potable water was also used during borehole jetting and cleaning activities before the regional well was constructed. Total amounts of drilling fluids and additives introduced into the borehole and those recovered are presented in Table 3.1-1.

3.2 Chronological Drilling Activities

The necessary drilling equipment and supplies were mobilized to the R-29 site between February 8 and 10, 2010. Notice to proceed was received from the Laboratory on February 10. Decontamination of tools and equipment continued through February 11, and drilling began on February 12 at 0800.

Between February 12 and 14, a 24-in. steel casing was advanced using dual-rotary techniques and a 24-in. tricone bit to 52.4 ft bgs. An 18-in. casing was landed at the same depth and set in a bentonite plug, and a 17.5-in. open borehole was advanced from 52.4 to 196.4 ft bgs using a 17-in. tricone bit. On February 14, drilling was temporarily halted to allow for minor repositioning of the rig over the borehole.

The borehole was advanced to 938.7 ft bgs on February 16, when drilling activities were temporarily paused to monitor for perched water. After a recovery period of approximately 35 min, water was tagged multiple times in a 2-h period, but the water-level measurements were inconsistent and fluctuated between 910.8 and 916.7 ft bgs. After a failed attempt to airlift a groundwater sample, the decision was made to continue drilling. The 17.5-in. borehole was advanced to 1060.0 ft bgs between February 14 and 16. The use of foam was discontinued at 1047.0 ft bgs.

The Laboratory video camera and natural gamma/induction tools were run in the borehole on February 17 with a borehole depth of 1060.0 ft bgs. Standing water, believed to be drilling water, was present at 972.0 ft bgs. The video camera showed no water entering along the borehole wall in the expected zone of perched saturation. It also showed large washouts from 566.0 to 580.0 ft bgs and at about 893 ft bgs. The natural gamma and induction tools tagged the borehole bottom at 1031.0 ft bgs, indicating that roughly 29.0 ft of slough was present.

Between February 18 and 24, 12-in. casing-advance drilling continued through the slough to 1195.0 ft bgs using an 11 7/8-in. hammer bit with a 14 1/4-in. under-reamer during which time regional aquifer saturation was first detected at 1175.0 ft bgs.

On February 25 at 1415 h, open-hole drilling was completed to TD of 1248.0 ft bgs using an 11 7/8-in. tricone bit. A water sample was air-lifted from this depth, as required in the drilling work plan. Discharge was estimated at 25 to 30 gallons per minute (gpm). Groundwater was tagged at 1151.5 ft bgs over a 4-h period on February 26 before the well was installed.

During drilling, 24-h operations were conducted, consisting of two 12-h shifts, 7 d/wk. Other than some sloughing of formational material during drilling, borehole instability issues were not encountered that noticeably impeded progress. Minor slowdowns occurred while the cyclone, coupling, and casing-rotator shoe were repaired, as well as during the repositioning of the drill rig.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-29. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-29 borehole at 5-ft intervals from ground surface to the TD of 1248.0 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected by the site geologist from a discharge cyclone, placed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected from ground surface to TD and placed in chip trays, along with unsieved (whole rock) cuttings. Recovery of the samples was good; total recovery was essentially 100% of the borehole. The only interval without recovery was from 780.0 to 785.0 ft bgs. The core boxes and chip trays were delivered to the Laboratory's archive at the conclusion of drilling activities. All screening measurements were within the range of background values.

Borehole stratigraphy at R-29 is summarized in section 5.1, and a detailed lithologic log is provided in Appendix A.

4.2 Water Sampling

Regional groundwater samples were collected from the top of the regional aquifer and at borehole TD during drilling. The sample from the upper regional aquifer was collected on February 21, 2010, by airlifting from a depth of 1175.0 ft bgs. The sample from the lower regional aquifer was collected on February 25 by airlifting from 1248 ft bgs. Samples were analyzed for metals, anions, (including perchlorate), cations, high explosive (HE) compounds, and volatile organic compounds (VOCs).

Three groundwater samples were collected during well development from the development pump's discharge line. All samples were analyzed for total organic carbon (TOC), and the final sample was also analyzed for metals and anions. Table 4.2-1 summarizes screening samples collected at R-29. Groundwater chemistry and field water-quality parameters are discussed in Appendix B.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for the full suite of constituents, including radioactive elements; anions/cations; general inorganic chemicals; volatile and semivolatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sample frequency at R-29 will be evaluated and presented in the annual "Interim Facility-Wide Groundwater Monitoring Plan."

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-29 is presented below. The Laboratory's geology task leader and site geologists examined cuttings to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, and water-level measurements were used to characterize groundwater occurrences.

5.1 Stratigraphy

The stratigraphy observed in the R-29 borehole is based on lithologic descriptions of cuttings samples collected from the discharge cyclone and borehole geophysical logs and described below in order of youngest to oldest geologic units. Figure 5.1-1 illustrates the stratigraphy encountered at R-29. A detailed lithologic log based on microscopic examination and analysis of drill cuttings is presented in Appendix A.

Alluvium (0–10 ft bgs)

Alluvial sediments were encountered at R-29 from ground surface to 10 ft bgs. These sediments consisted of fine to medium grained silts and sands with minor gravels, including intermediate composition volcanic lithic fragments and pumice fragments, minor quartz and sanidine crystals. Well pad construction gravel and abundant woody debris were also present in this interval.

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

Unit 4 of the Tshirege Member of the Bandelier Tuff occurred from 10 to 85 ft bgs. Unit 4 consisted of pale brown to light gray, weakly welded to nonwelded, and weathered ash-flow tuffs with crystal-poor pumice fragments, volcanic lithics, and quartz and sanidine phenocrysts (generally about 10% to 15% or less) in an ashy matrix. Pumices in this unit generally had a sugary appearance because of devitrification.

Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (85–185 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff occurred from 85 to 185 ft bgs. Unit 3 consisted of moderately to nonwelded, vapor-phase altered ash-flow tuffs white to light gray in color, slightly weathered. Present were crystal-rich pumice fragments, minor volcanic lithics, and quartz and sanidine phenocrysts in an ashy matrix.

Unit 2, Tshirege Member of the Bandelier Tuff, Qbt 2 (185–275 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff occurred from 185 to 275 ft bgs. Unit 2 consisted of light gray to gray and light brownish-gray, moderately to strongly welded, crystal-rich, devitrified ash-flow tuffs with porous pumices altered by vapor-phase crystallization. The tuffs included some volcanic lithics and abundant quartz and sanidine phenocrysts. Minor orange-brown iron-oxide staining was apparent on pumice and lithic fragments.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (275-375 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff occurred from 275 to 375 ft bgs. Unit 1v consisted of light gray, weakly to nonwelded, devitrified, crystal rich ash-flow tuffs. The tuffs contained white to light gray pumices that exhibited a more fibrous/porous structure downsection. The tuffs included some volcanic lithics and abundant quartz and sanidine phenocrysts. Some orange to orange-brown oxidation was apparent on pumice fragments.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (375–550 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff occurred from 375 to 550 ft bgs. Unit 1g consisted of white to light gray, nonwelded, vitric ash-flow tuffs. The tuffs included glassy pumices that exhibited a strong fibrous/porous structure, minor volcanic lithics, and abundant quartz and sanidine phenocrysts.

Cerro Toledo Interval, Qct (550–653 ft bgs)

Tephra and volcaniclastic rocks of the Cerro Toledo interval occurred from 550 to 653 ft bgs. This interval consisted of very pale brown to gray-light gray tuffaceous sedimentary deposits. These deposits consisted predominantly of moderately sorted fine to coarse sand and gravel (largely intermediate composition volcanic lithics, likely derived from Tschicoma dacites in the Jemez Mountains), reworked tuff/pumice fragments, and quartz and sanidine crystals. Orange-brown oxidation was apparent on most clasts.

Otowi Member of the Bandelier Tuff, Qbo (653–893 ft bgs)

The Otowi Member of the Bandelier Tuff occurred from 653 to 893 ft bgs. The Otowi Member consisted of white to light gray, gray and pinkish-gray, weakly to nonwelded, vitric, pumiceous ash-flow tuffs. The tuffs contained light gray to orange-brown fibrous/porous, glassy pumice, varieties of intermediate volcanic lithics and abundant quartz and sanidine phenocrysts. Also present were trace to minor amounts of red oxidized lithic fragments.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (893–904 ft bgs)

The Guaje Pumice Bed occurred from 893 to 904 ft bgs. The contacts for this unit are readily apparent in geophysical logs, video logs and in the cuttings. Cuttings contain light gray to orange-brown, fibrous, vitric pumice fragments, volcanic lithics, and crystals. The #10 sieved fraction contained about 20% to 35% pumice fragments.

Puye Formation, Tpf (904–1248 ft bgs)

Puye Formation occurred from 904 to 1248 ft bgs and consisted of predominantly fluvial sedimentary deposits. These deposits included volcaniclastic sediments light gray to reddish-gray in color. Cuttings for this unit consist of poorly to well-sorted sand and subangular to subrounded gravel and minor silt. Sand and gravel consisted of up to 100% felsic-intermediate composition volcanic lithics (including dacite), pumice fragments, tuffaceous sandstone and siltstone, and crystals. Fresh angular gravel with remnants of rounded surfaces suggest the borehole penetrated significant deposits of cobbles and boulders that were milled or pulverized during drilling. Massive deposits of cobbles and boulders were observed in the Puye Formation in a video log made before the borehole reached the regional aquifer.

5.2 Groundwater

Perched groundwater was not detected in R-29 during drilling. Although perched water was anticipated at around 918 ft bgs at the base of the Guaje Pumice Bed, perched water was not observed at this interval on the video log from February 17, 2010. An additional zone of perched water anticipated around 1088.0 ft bgs at the top of the Cerros del Rio volcanic rocks or Tschicoma dacite was also absent. Neither unit was present at R-29 based on an analysis of drill cuttings.

On February 21, regional groundwater was first detected in the Puye Formation during drilling at approximately 1175.0 ft bgs. On February 26 and 27, after the TD of 1248.0 ft bgs had been reached, but before well installation began, the depth to regional groundwater was tagged five times over a 4-h period at 1151.5 ft bgs.

6.0 BOREHOLE LOGGING

The following sections describe the video and geophysical logging conducted at R-29. A summary of all logging is provided in Table 6.0-1.

6.1 Video Logging

Laboratory personnel ran video logs at R-29 on February 17 in the open borehole to 972 ft bgs to verify perched water occurrences and on February 28 to 1248 ft bgs (TD) in the cased borehole to verify cut-off of 12-in. casing. Details of these logs are provided in Table 6.0-1. Video logs are provided on DVDs as Appendix D with this report.

6.2 Geophysical Logging

Laboratory personnel ran natural gamma and array induction logs in the R-29 borehole on February 17, 2010. Additionally, a suite of Schlumberger geophysical logs was run inside the temporary 12-in.-inside diameter (I.D.) casing from ground surface to the TD of 1248 ft bgs on February 27, 2010. These geophysical logs included Accelerator Porosity Sonde (APS), Triple Detector Lithodensity (TDL), Elemental Capture Spectroscopy (ECS), Hostile Natural Gamma Spectroscopy (HNGS) and gamma ray logs. Interpretation and details of the logging are presented in the geophysical logging report and accompanying CD included in Appendix E.

7.0 WELL INSTALLATION

The R-29 well was installed between February 28 and March 2, 2010. The following sections provide the well design and a summary of well-construction activities.

7.1 Well Design

The R-29 well was designed in accordance with the R-29 drilling plan. NMED approved the final well design before the well was installed. The well was designed with a single screened interval between 1170.0 ft and 1180.0 ft bgs to monitor the quality of the regional groundwater and the water level in the Puye Formation.

7.2 Well Construction

The R-29 monitoring well was constructed of 5.0-in.-I.D./5.563-in.-O.D. passivated type A304 stainless-steel threaded casing fabricated to American Society for Testing and Materials (ASTM) standard A312. The screened interval consisted of one 10-ft length of 5.0-in.-I.D. rod based, 0.020-in. slot, wire-wrapped well screen. Compatible external stainless-steel couplings (also passivated type A304 stainless-steel fabricated to ASTM A312 standards) were used to join all individual casing and screen section. Casing and the screen were provided by the Laboratory and were steam-pressure washed on-site before they were installed. A 2.5-in.-O.D. steel flush-threaded tremie pipe string, also decontaminated before use, was used to deliver annular fill materials downhole during well construction.

The top of the 10-ft-long screen was set at 1170.0 ft bgs. An 11.8-ft stainless-steel sump was placed below the bottom of the screen. Stainless-steel centralizers (two sets of four) were welded to the well casing approximately 2 ft above and below the well screen. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Decontamination of the stainless-steel well casing, screens, and tremie pipe along with mobilization of initial well-construction materials to the site took place from February 24 to 27, while the borehole water level was being monitored and preparation for geophysical logging was underway.

On February 28 at 0016 h, the first joint of 5-in. stainless-steel well casing was tripped into the borehole. Each casing section was threaded to the string using stainless-steel couplings. The well casing was set that afternoon, with the bottom of the well tagged at 1191.8 ft bgs. Slough was tagged at 1247.3 ft bgs. A water line and materials pump were hooked up to the tremie pipe to deliver the annular fill materials.

The borehole was backfilled with 8/12 silica sand (35.0 ft^3) from 1247.3 to 1202.1 ft bgs (Table 7.2-1). A lower seal of 0.375-in. bentonite chips (15.2 ft^3) was then installed from 1202.1 to1184.8 ft bgs. This section includes a 3-ft section of 12-in. casing from 1198.0 to 1201.0 ft bgs that remained downhole after the casing shoe was cut. A 10/20 silica sand filter pack (21.0 ft^3) was placed from 1184.8 to 1165.2 ft bgs, surrounding the screened interval of the well casing. During placement of the filter pack, the screened interval was swabbed and the borehole surged to promote proper setting and compaction. A 20/40 silica sand transition collar was then installed on top of the filter pack from 1165.2 to 1162.4 ft bgs (2.0 ft^3). The volume of silica sand used differed from the calculated amount (2.6 ft^3) by 23% and is most likely because of washouts across the borehole walls.

A bentonite seal consisting of 1427.4 ft^3 of 0.375-in. bentonite chips was installed above the sand collar from 1162.4 to 74.0 ft bgs. The surface seal of Type I Portland cement was completed from 74.0 to 3.0 ft bgs on March 12 with a volume of 137.2 ft^3, 32% less than the calculated volume of 181.7 ft^3.

A length of 24-in. casing was left in the borehole from ground surface to 52.4 ft, which may account for this discrepancy. Well completion per NMED standards was March 12, 2010, at 1157 h.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation at R-29, well development and aquifer testing were performed. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system was installed. Site-restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees.

8.1 Well Development

Well development was conducted between March 16 and 21, 2010. Well development began with swabbing and bailing water to remove drilling fluids and formation fines in the filter pack and sump. Bailing continued until water clarity visibly improved. Final development was accomplished using a submersible pump.

The bailing tool used was a 4.0-in.-O.D. by 15.0-ft-long carbon-steel bailer with a total capacity of approximately 7 gal. The tool was lowered by wireline using a Semco S1500 pulling unit and repeatedly filled, withdrawn from the well, and dumped into the cuttings pit. A total of 134 gal. of water was bailed between March 16 and 17. The swabbing tool was a 4.5-in.-O.D., 1-in.-thick rubber disc attached to a weighted-steel rod. The swabbing tool was lowered by wireline to 1180 ft bgs and drawn repeatedly upward across the screened interval from 1180 to 1170 ft bgs.

After bailing, a 10-hp, 4-in.-Grundfos submersible pump was installed in the well to a depth of 1170 ft bgs, and pumped at a rate of approximately 4 to 5 gpm from March 18 to 20. Approximately 9875 gal. of water was removed during development.

8.1.1 Well Development Field Parameters

The field parameters turbidity, temperature, potential of hydrogen (pH), dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance were monitored at R-29 during the pumping stage of well development. In addition, water samples were collected for TOC analysis. TOC should be less than 2.0 ppm, and turbidity should be less than 5 nephelometric turbidity units (NTU) to indicate the well has been developed adequately.

Field parameters were measured at well R-29 by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell. Backflow problems had been experienced with its use at a previous well, and it had not been replumbed before well development at R-29.

During development, pH varied from 6.71 to 9.68. Temperature varied from 9.11°C to 19.29°C. DO varied from 2.02 to 8.78 mg/L. Specific conductance ranged from 134 to 347 microsiemens per centimeter (µS/cm). Corrected oxidation-reduction potential (Eh) values varied from 43.8 to 220.5 millvolts. Turbidity ranged from 3008 NTU at the beginning of development (immediately after swabbing) to 4.78 NTU at the end.

The final development parameters at R-29 were pH of 6.71, temperature of 16.26°C, specific conductance of 135 µS/cm, and turbidity of 4.98 NTU. Anomalously high pH values recorded during well development may be attributed to improper operation of the pH probe. It should be noted, NTU readings during the 24-h aquifer test ranged between 0.69 and 4.71 NTU. The final TOC concentration was

0.30 mg/L. Table B 1.2-1 in Appendix B presents a summary of field parameters and volumes discharged during development.

8.2 Aquifer Testing

Aquifer pumping tests, including preliminary step-tests and a 24-h aquifer test, were conducted at R-29 between March 22 and 25, 2010, by David Schafer and Associates. Two short duration pumping and recovery intervals (step tests) were conducted on March 22. The objective of the step-tests was to assess the behavior of the system and properly determine the optimal pumping rate for the 24-h test. A 24-h aquifer test was completed on March 24 and 25. A 10-horsepower (hp), 4-in.-diameter Grundfos submersible pump was used to perform the aquifer tests. Approximately 5364 gal. of groundwater was purged during aquifer testing activities. Data analysis and interpretation of the R-29 aquifer tests are presented in Appendix C.

8.3 Dedicated Sampling System Installation

A dedicated sampling system for R-29 was installed on April 23 and 24, 2010. The system utilizes a single 5-hp Franklin Electric motor and a 4-in.-O.D. environmentally retrofitted Grundfos submersible pump. The pump riser pipe consists of threaded and coupled nonannealed 1-in.-I.D. stainless steel. Two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) tubes were banded to the pump riser. A dedicated In-Situ Level Troll 500 transducer was installed in one of the tubes, and manual water-level measurements will be collected from the second. Both PVC tubes are equipped with a 1.7-ft section of 0.010-in. slotted screen and a closed bottom. Details of the dedicated sampling system are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-29 wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass monument marker was embedded in the northwest corner of the pad. A 16-in.-O.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. Four steel bollards, painted yellow for visibility, were set at the outside edges of the pad to protect the well from traffic. They are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A licensed professional land surveyor conducted a geodetic survey on June 4, 2010. The survey data conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground surface elevation near the concrete pad, the top of the brass marker in the concrete pad, the top of the well casing, and the top of the protective casing for the R-29 monitoring well (Table 8.5-1 and Appendix F).

8.6 Waste Management and Site Restoration

Waste generated from the R-29 project includes drilling fluids, purged groundwater, drill cuttings, decontamination water, and contact waste. A summary of the waste characterization samples collected during drilling, construction, and development of the R-29 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with "Waste Characterization Strategy Form for South Canyon Wells R-29 and R-30 (TA-49, MDA-AB) Regional Groundwater Well Installation and Corehole Drilling" (LANL 2009, 107444).

Fluids produced during drilling and well development are expected to be land-applied after a review of associated analytical results per the waste characterization strategy form (WCSF) and Standard Operating Procedure (SOP) ENV-RCRA SOP-010.0, 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 evaluated for treatment and disposal at one of the Laboratory's wastewater treatment facilities. If analytical data indicate the drilling fluids are hazardous/nonradioactive or mixed low-level waste, they will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA SOP-011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criterion for land application, they will be disposed of at an authorized facility. Decontamination fluid used for cleaning the drill rig and equipment is currently containerized. The fluid waste was sampled and will be disposed of at an authorized facility. Characterization of contact waste will be based upon acceptable knowledge, pending analyses of the waste samples collected from the drill cuttings, purge water, and decontamination fluid.

Site restoration activities will include removing drilling fluids and cuttings from the pit and managing the fluids and cuttings in accordance with applicable SOPs, removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area, as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-29 were performed as specified in "Well R-29 Drill Plan–Final, Installation of Well R-29, TA-49, Los Alamos National Laboratory, Revision 1" (North Wind, Inc., 2009, 109456).

10.0 ACKNOWLEDGMENTS

Layne Christensen drilled borehole R-29 and installed the R-29 monitoring well.

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

Laboratory personnel ran downhole video equipment.

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

Schlumberger Water Services performed geophysical logging of the borehole, and Ned Clayton provided the Schlumberger Geophysical Logging Report.

North Wind, Inc., provided oversight on all preparatory and field-related activities.

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

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

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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

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

LANL (Los Alamos National Laboratory), October 27, 2009. "Waste Characterization Strategy Form for South Canyon Wells R-29 and R-30 (TA-49, MDA-AB) Regional Groundwater Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2009, 107444)

North Wind Inc., January 25, 2010. "Well R-29 Drill Plan - Final, Installation of Well R-29, TA-49, Los Alamos National Laboratory, Revision 1," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (North Wind, Inc., 2010, 109456)

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; 28 February 2008.

Hypsography, 100 and 20 Ft 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.

Fences, Los Alamos National Laboratory,KSL Site Support Services, Planning, Locating and Mapping Section, 06 January 2004, as published 04 January 2008.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

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

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

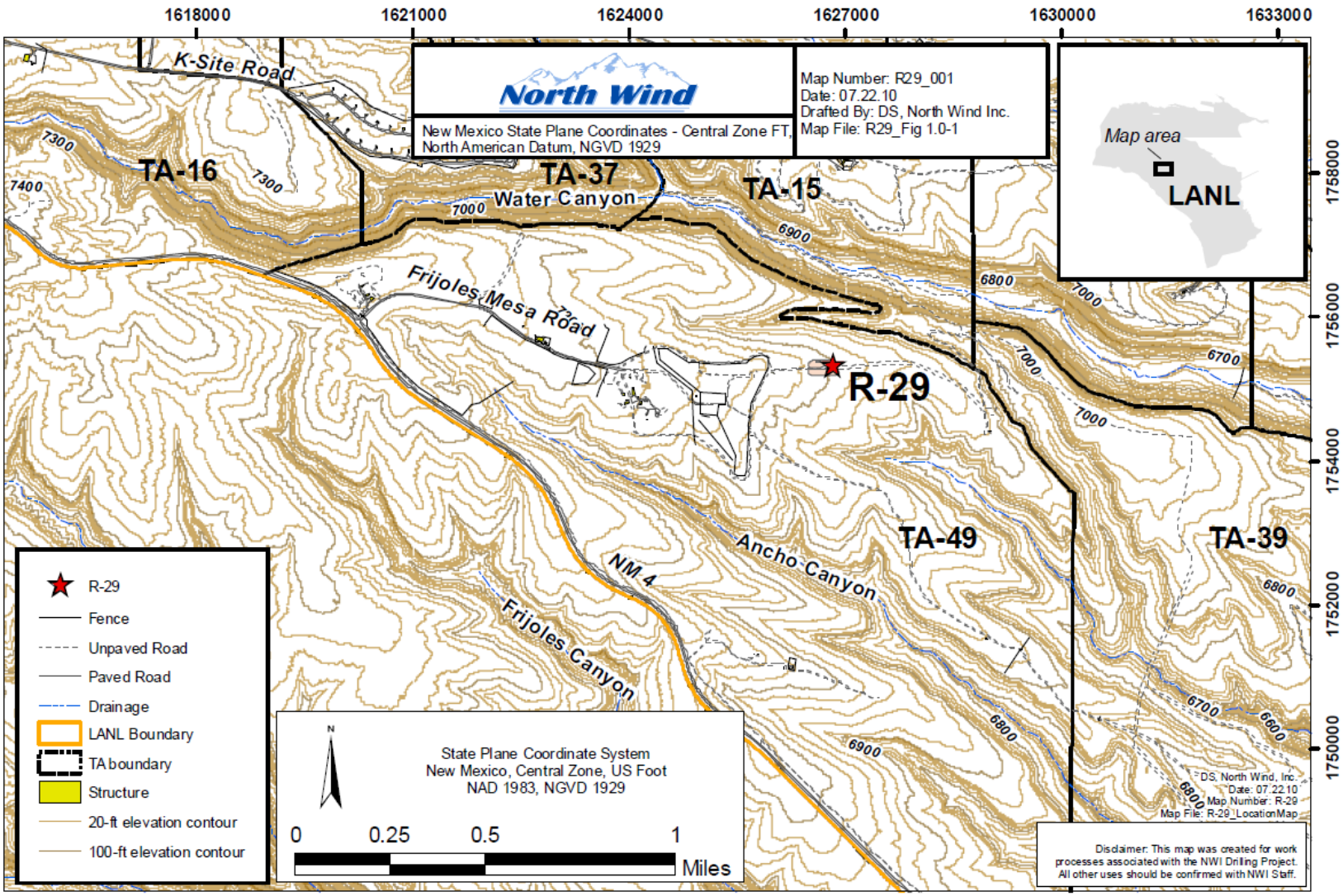

Figure 1.0-1 Location of monitoring well R-29

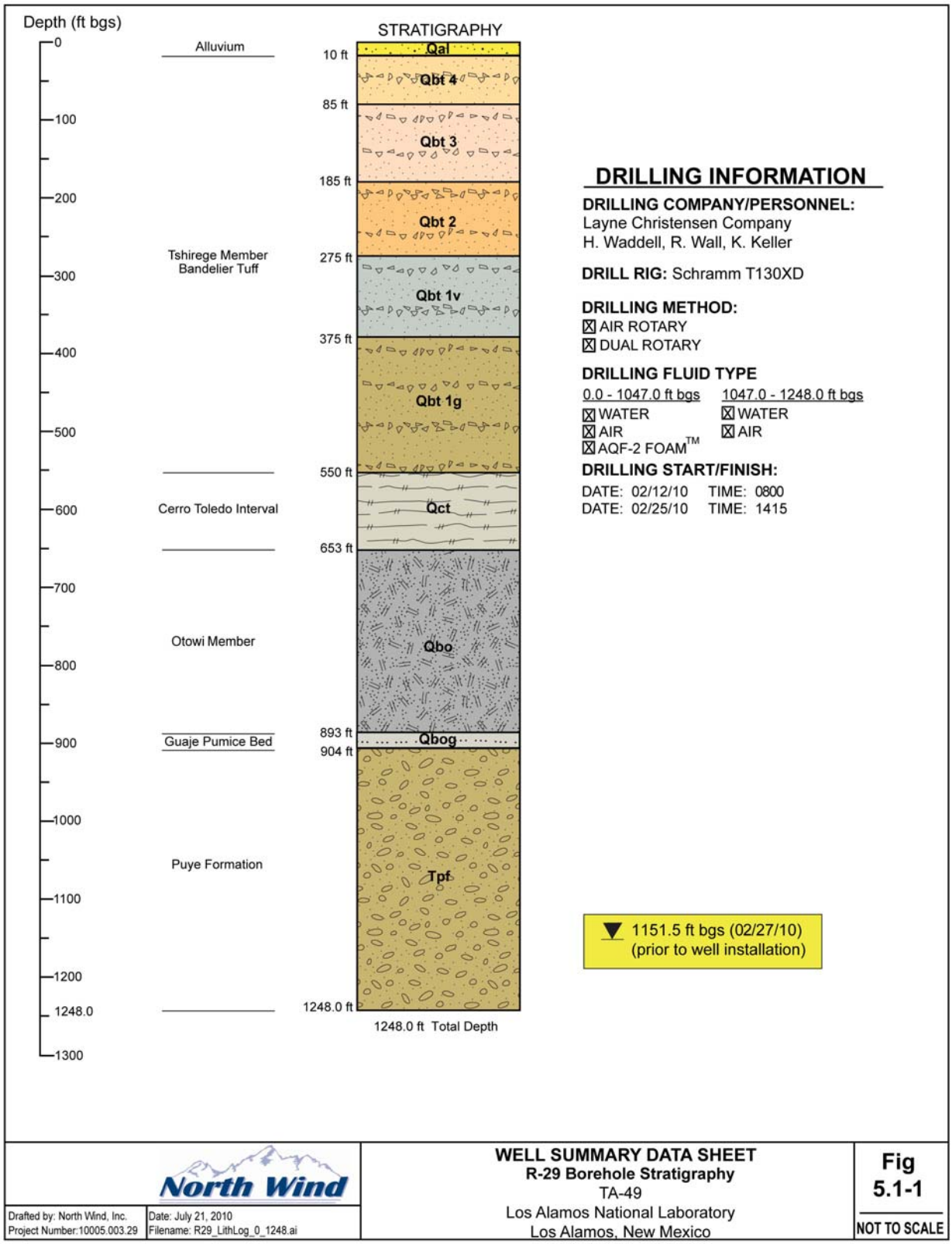

Figure 5.1-1 Monitoring well R-29 borehole stratigraphy

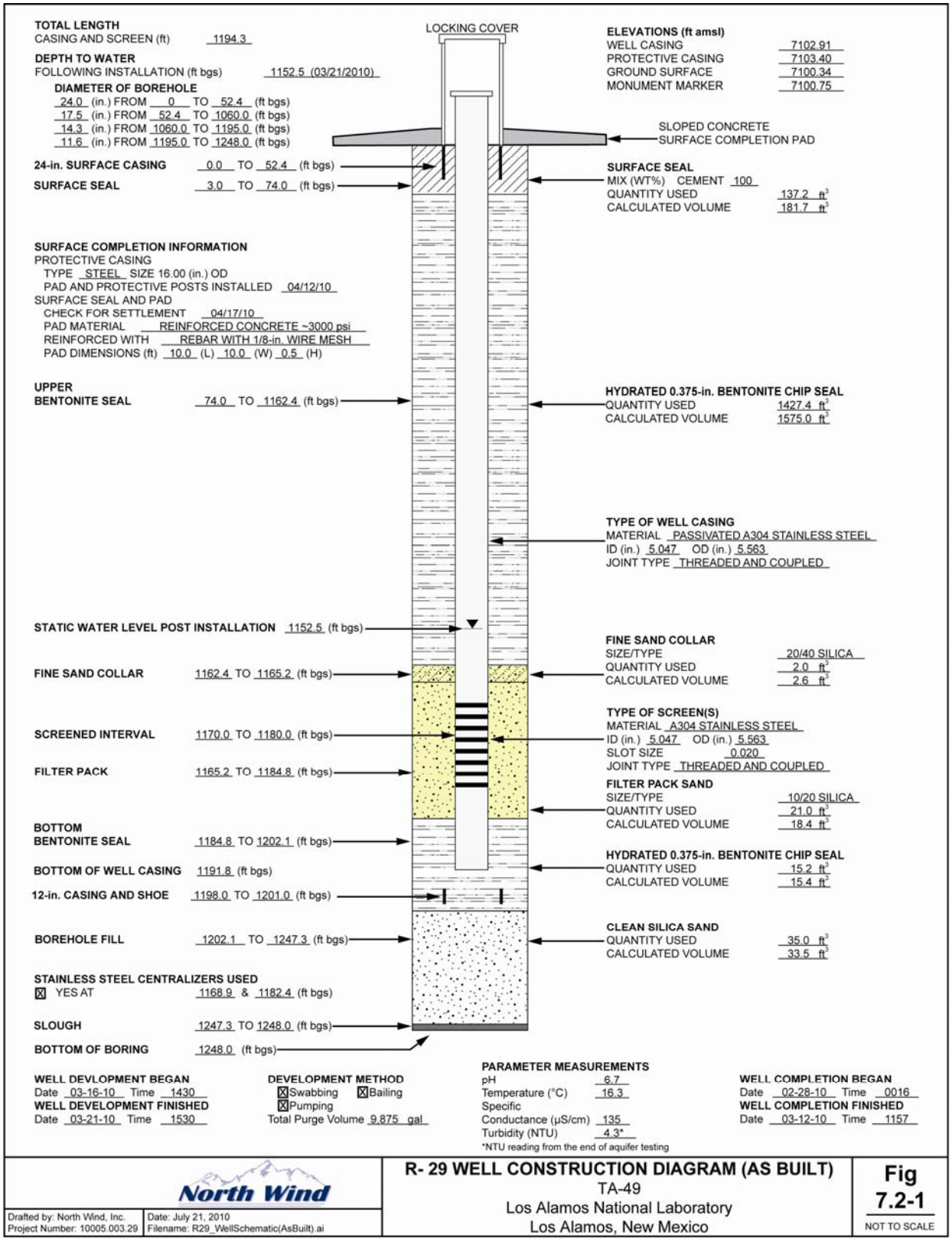

Figure 7.2-1 Monitoring well R-29 as-built well construction diagram

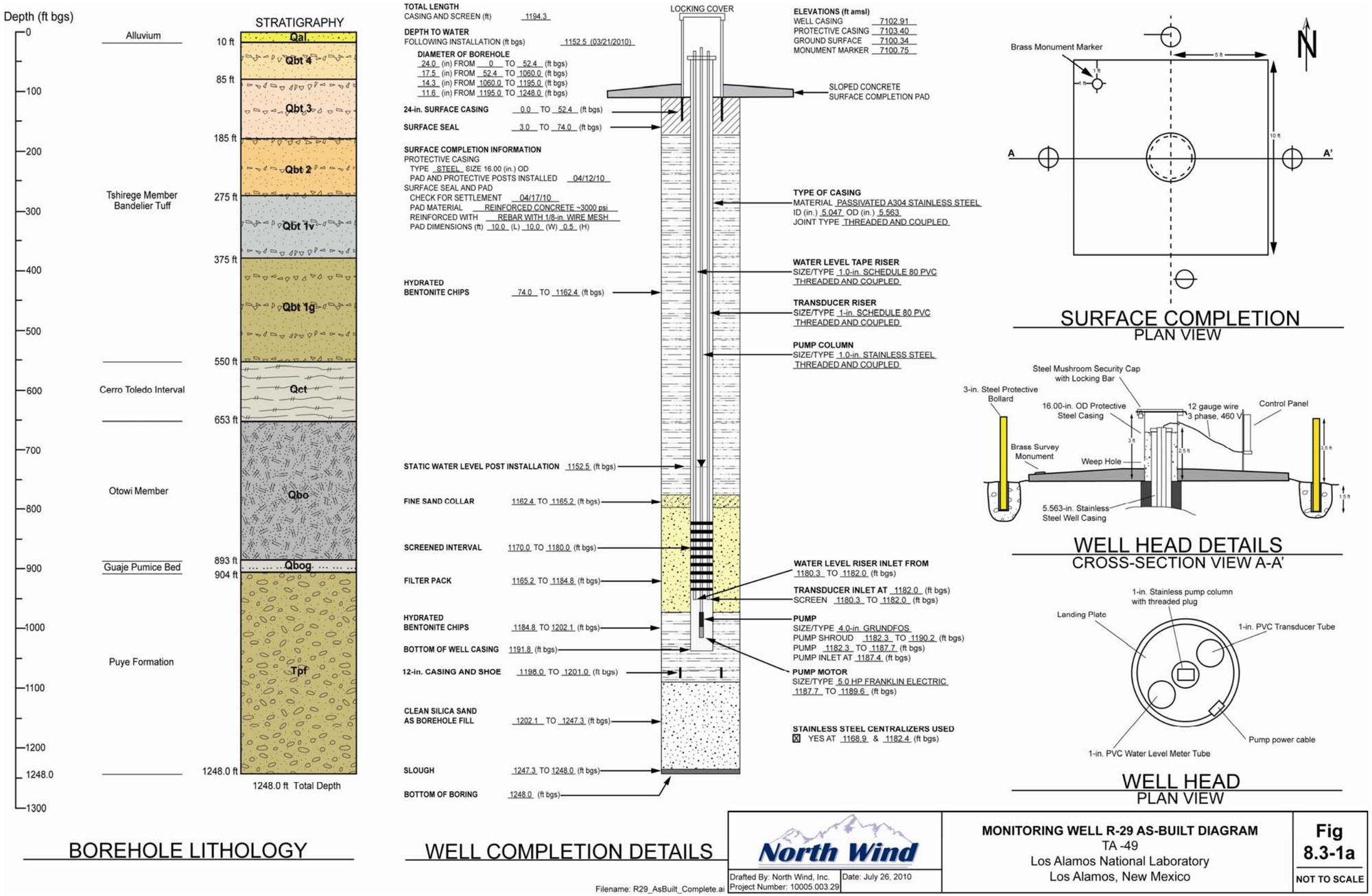

Figure 8.3-1a As-built schematic for monitoring well R-29

R-29 TECHNICAL NOTES

SURVEY INFORMATION[1]

Brass Marker

Northing:	1755383.32 ft
Easting	1626779.91 ft
Elevation	7100.75 ft amsl

Well Casing

Northing:	1755378.87 ft
Easting:	1626782.64 ft
Elevation:	7102.91 ft amsl

BOREHOLE GEOPHYSICAL LOGS

LANL Natural Gamma and Array Induction Logs (02/17/10)
Schlumberger: Hostile Natural Gamma Spectroscopy, Elemental Capture Sonde, Triple Detector Lithodensity, Accelerator Porosity Sonde

DRILLING INFORMATION

Drilling Company
Layne Christensen Company

Drill Rig
Schramm T130XD

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

Drilling Fluids
Air, AQF-2 Foam (discontinued at 1047.0 ft bgs), potable water

MILESTONE DATES

Drilling

Start:	02/12/2010
Finish:	02/25/2010

Well Completion

Start:	02/28/2010
Finish:	03/12/2010

Well Development

Start:	03/16/2010
Finish:	03/21/2010

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Volume Purged: 9875 gallons

Parameter Measurements

pH:	6.7
Temperature:	16.3ºC
Specific Conductance:	135 µS/cm
Turbidity	4.3 NTU*

*NTU reading from the end of aquifer testing

AQUIFER TESTING

Constant Rate Pumping Test

Water Produced:	5,364 gallons
Average Flow Rate:	3.7 gpm
Performed on:	03/22/2010 - 03/25/2010

DEDICATED SAMPLING SYSTEM

Pump Type 10S50-1125CB
Make: Grundfos
Model: B96845812
SN#: P11005208
10.0 U.S. gpm, intake at 1187.4 ft bgs
Environmental Retrofit

Motor
Make: 5 HP Franklin Electric
Model: 2343278602
SN#: 10C14-23-0370

Pump Column
1-in. ID Threaded/Coupled
Schedule 80 Stainless Steel

Transducer Tube
1-in. ID Flush Threaded Schedule 80 PVC with 1.7-ft long 0.010-in. Screen between 1180.3 - 1182.0 ft bgs

Water Level Tube
1-in ID Flush Threaded Schedule 80 PVC
Screen between 1180.3 - 1182.0 ft bgs

Transducer Upper
Installed 04/24/2010
Make: In-Situ
Model: Level Troll 500
SN#: 226939

NOTES:
1) Coordinates based on New Mexico State Plane Grid Coordinates, Central Zone (NAD 83); Elevation expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

North Wind

Drafted by: North Wind, Inc. | Date: July 26, 2010
Project Number:10005.003.29 | Filename: R-29_Tech_Specs.ai

R-29 TECHNICAL NOTES
(TA-49)
Los Alamos National Laboratory
Los Alamos, New Mexico

Fig 8.3-1b
NOT TO SCALE

Figure 8.3-1b As-built technical notes for monitoring well R-29

Table 3.1-1
Fluid Quantities Used during R-29 Drilling and Well Construction

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling				
02/12/10	1200	1200	n/a*	n/a
02/13/10	3500	4700	n/a	n/a
02/14/10	1200	5900	12	n/a
02/15/10	4900	10,800	46	n/a
02/16/10	12,500	23,300	n/a	n/a
02/20/10	6500	29,800	n/a	n/a
02/21/10	5200	35,000	n/a	n/a
02/23/10	800	35,800	n/a	n/a
02/25/10	4500	40,300	n/a	n/a
02/28/10	2100	42,400	n/a	n/a
Well Construction				
03/01/10	4000	46,400	n/a	n/a
03/02/10	14,525	60,925	n/a	n/a
03/03/10	4000	64,925	n/a	n/a
03/04/10	19,950	84,875	n/a	n/a
03/05/10	10,000	94,875	n/a	n/a
03/06/10	27,500	122,375	n/a	n/a
03/07/10	27,000	149,375	n/a	n/a
03/08/10	32,700	182,075	n/a	n/a
03/09/10	17,000	199,075	n/a	n/a
03/11/10	16,600	215,675	n/a	n/a
03/12/10	800	216,475	n/a	n/a
Total Water Volume (gal.)				
R-29	216,475			

* n/a = Not applicable. Foam use terminated at 1047.0 ft bgs during drilling; none used during well construction.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Drilling and Well Development of Well R-29

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-29	GW29-10-13277	2/21/10	1175	Groundwater (air lifted)	Metals/anions (including perchlorate) HE, VOCs
R-29	GW29-10-13276	2/25/10	1248	Groundwater (air lifted)	Metals/anions (including perchlorate) HE, VOCs
Well Development					
R-29	GW29-10-13271	3/18/10	1170	Groundwater (air lifted)	TOC
R-29	GW29-10-13272	3/19/10	1080	Groundwater (air lifted)	TOC
R-29	GW29-10-13270	3/20/10	1175	Groundwater (air lifted)	TOC, metals/anions

Table 6.0-1
R-29 Video and Geophysical Logging Runs

Date	Depth (ft bgs)	Description
02/17/10	0–972	LANL borehole video log run. Logging before start of casing advance in Puye Formation. Significant wash-out noted in interval ~566–580 ft bgs. The Guaje Pumice Bed was noted at 893 ft bgs. After defoamer was poured downhole to clear residual foam, a water level of 972 ft bgs was observed in the borehole; this water is believed to be accumulated drilling water. There was no evidence of perched water flowing down the borehole walls.
02/17/10	0–1031	LANL natural gamma log run from ground surface to 1031 ft bgs.
02/17/10	0–1031	LANL induction log run. Borehole was logged up successfully from ~1031 ft bgs with no problems. Open borehole from approximately 52.4 ft bgs, bottom of 24-in. casing, to 1031 ft bgs.
02/27/10	0–1248 (TD)	Schlumberger cased hole geophysical log suite: TDL, ECS, APS, and HNGS Logging depths were measured from rig table (kelly bushing), necessitating later corrections to ground level.
02/28/10	0–1248 (TD)	LANL borehole video log run. Camera was run to verify cut-off of 12 in. casing after pumping ~1900 gal. water downhole for visibility. Cut appeared to be successful at planned depth of 1198 ft bgs.

Table 7.2-1
R-29 Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: Portland cement	137.2 ft^3
Upper bentonite seal: bentonite chips	1427.4 ft^3
Fine sand collar: 20/40 silica sand	2.0 ft^3
Filter pack: 10/20 silica sand	21.0 ft^3
Lower bentonite seal: bentonite chips	15.2 ft^3
Borehole fill: 8/12 silica sand	35.0 ft^3

Table 8.5-1
R-29 Survey Coordinates

Identification	Northing	Easting	Elevation
R-29 brass cap embedded in pad	1755383.32	1626779.91	7100.75
R-29 ground surface near pad	1755391.80	1626776.38	7100.34
R-29 top of protective casing	1755378.94	1626782.59	7103.40
R-29 top of stainless-steel well casing	1755378.87	1626782.64	7102.91

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

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-29

Sample ID/Event ID	Date, Time Collected	Description	Sample Matrix
WST29-10-13280/2652	2/23/10, 1207	Trip blank	Liquid
WST29-10-13281/2652	2/23/10, 1207	Decon water	Liquid
WST29-10-13858/2677	3/4/10, 1600	Decon water	Liquid
WST29-10-13859/2677	3/4/10, 1600	Trip blank	Liquid
WST29-10-14052/2693	3/9/10, 1200	Drilling fluids	Liquid
WST29-10-14053/2693	3/9/10, 1200	Trip blank	Liquid
WST29-10-13870/2678	3/18/10, 1045	Decon water	Liquid
WST29-10-13871/2678	3/18/10, 1045	Trip blank	Liquid
WST29-10-15013/2716	3/26/10, 1325	Decon water	Liquid
WST29-10-15014/2716	3/26/10, 1325	Trip blank	Liquid
WST29-10-15378/2724	3/30/10, 1030	Development water	Liquid
WST29-10-15379/2724	3/30/10, 1030	Development water	Liquid
WST29-10-15380/2724	3/30/10, 1030	Development water	Liquid
WST29-10-15381/2724	3/30/10, 1030	Trip blank	Liquid

Appendix A

Borehole R-29 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 1 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
0–10	**QUATERNARY ALLUVIUM:** Fine to medium grained alluvial sediments (SW-SM), moderately to highly weathered, pale brown (10YR6/3) to light brown (10YR5/3), moderately sorted, subangular to subrounded fragments. WR: Fine- to medium-grained alluvial silts and sands with minor gravels including intermediate composition volcanic lithic fragments and pumice fragments, minor quartz and sanidine crystals. Abundant silt. +10F: 20%–30% welded tuff fragments, 10%–20% milky to clear quartz and sanidine crystals. 50%–60% volcanic lithic fragments, with minor Fe-oxide staining. +35F: 15%–20% quartz and sanidine crystals, 15%–20% tuff fragments, 45%–60% minor volcanic lithic fragments. Abundant woody debris noted.	**Qal**	Note: Construction gravel and base-course fill present in cuttings.
10–20	**UNIT 4 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, very pale brown (10YR7/3) to very pale brown (10YR8/2), weakly welded, crystal poor with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals in an ashy matrix. Pumices have a sugary appearance. +10F: 60%–75% pumice fragments, 10%–25% volcanic lithics, 2%–5% quartz and sanidine crystals (bipyramidal quartz noted). +35F: 15%–20% pumice fragments, 20%–25% volcanic lithics, 45%–65% quartz and sanidine crystals.	**Qbt 4**	Contact between Qal and Qbt 4 was at 10 ft bgs.
20–40	Tuff, very pale brown (10YR8/2) to white (10YR8/1), weakly to nonwelded, crystal poor with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals in an ashy matrix. Pumices have a sugary appearance. Reddish-orange to orange-brown oxidation on some pumice fragments. +10F: 10%–25% pumice fragments, 50%–70% volcanic lithics, 5-10% quartz and sanidine crystals (bipyramidal quartz noted). +35F: 5%–15% pumice fragments, 15%–25% volcanic lithics, 60%–65% quartz and sanidine crystals.	**Qbt 4**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 2 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
40–60	Tuff, light gray (10YR7/1) to reddish gray (10R5/1), weakly welded, crystal poor with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals in an ashy matrix. Pumices have a sugary appearance. Note appearance of purple-gray pumice fragments in 40–45 and 55–60 ft interval. Minor orange-brown oxidation on some pumice fragments. +10F: 55%–65% pumice fragments, 15%–20% volcanic lithics, 15%–20% quartz and sanidine crystals. +35F: 15%–20% pumice fragments, 20%–25% volcanic lithics, 55%–60% quartz and sanidine crystals (bipyramidal quartz noted).	**Qbt 4**	
60–85	Tuff, light gray (10YR7/1) to gray (10YR6/1), weakly welded, crystal poor with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals in an ashy matrix. Pumice fragments have a sugary appearance. +10F: 75%–85% pumice fragments, 2%–5% volcanic lithics, 10%–15% quartz and sanidine crystals (bipyramidal quartz noted). +35F: 30%–35% pumice fragments, 5%–10% volcanic lithics, 55%–60% quartz and sanidine crystals (bipyramidal quartz with inclusions noted).	**Qbt 4**	
85–100	**UNIT 3 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, white (7.5YR8/1) to light gray (7.5YR7/1), weakly to nonwelded, crystal rich with devitrified pumice fragments, minor volcanic lithics, and quartz and sanidine crystals in an ashy matrix. +10F: 90%–95% pumice fragments, 5%–10% volcanic lithics, trace quartz and sanidine crystals. +35F: 35%–40% pumice fragments, 60%–65% quartz and sanidine crystals, trace volcanic lithics. Evidence of vapor phase cavities in 85–90-ft interval.	**Qbt 3**	Contact between Qbt 4 and Qbt 3 at 85 ft bgs

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 3 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
100–110	Tuff, white (7.5YR8/1) to light gray (7.5YR7/1), moderately to weakly welded, crystal rich with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals in an ashy matrix. +10F: 10%–20% pumice fragments, 70%–80% volcanic lithics, trace quartz and sanidine crystals. +35F: 25%–30% pumice, 5%–10% volcanic lithics, 60%–65% quartz and sanidine crystals (bipyramidal quartz noted).	**Qbt 3**	
110–130	Tuff, white (7.5YR8/1) to light gray (7.5YR7/1), minor non-welded, crystal rich with devitrified pumice fragments (relatively unconsolidated), volcanic lithics, and quartz and sanidine crystals. +10F: 5%–10% pumice fragments, 10%–30% volcanic lithics, 60%–65% quartz and sanidine crystals. +35F: 5%–10% pumice fragments, 10%–20% volcanic lithics, 70%–75% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted). Note: abundant metal shavings in 125–130-ft interval.	**Qbt 3**	
130–135	Tuff, white (7.5YR8/1) to light gray (7.5YR7/1), weakly welded, crystal rich with devitrified pumice fragments (relatively unconsolidated), volcanic lithics, and quartz and sanidine crystals. +10F: 15% pumice fragments, 80% volcanic lithics, 5% quartz and sanidine crystals. +35F: 5% pumice fragments, 20% volcanic lithics, 75% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 3**	
135–160	Tuff, white (7.5YR8/1) to light gray (7.5YR7/1), non-welded, crystal rich with devitrified pumice fragments (relatively unconsolidated), volcanic lithics, and quartz and sanidine crystals. +10F: 5%–15% pumice fragments, 35%–50% volcanic lithics, 35%–45% quartz and sanidine crystals. +35F: 5%–10% pumice fragments, 10%–20% volcanic lithics, 70%–75% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 3**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 4 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
160–175	Tuff, white (7.5YR8/1) to light gray (7.5YR7/1), moderately to weakly welded, crystal rich with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. +10F: 20%–30% pumice fragments, 45%–60% volcanic lithics, 10%–12% quartz and sanidine crystals. +35F: 5%–10% pumice fragments, 10%–20% volcanic lithics, 70%–75% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted). Note: abundant metal shavings in 125–130-ft interval. Orange-brown oxidation on lithic fragments.	**Qbt 3**	
175–185	Tuff, light gray (10YR7/1) to reddish gray (10R5/1), weakly welded, crystal rich with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Pumices have a sugary appearance. Minor orange-brown oxidation on some pumice fragments. +10F: 65% pumice fragments, 30% volcanic lithics, 5% quartz and sanidine crystals. +35F: 25% pumice fragments, 35% volcanic lithics, 40% quartz and sanidine crystals (bipyramidal quartz noted).	**Qbt 3**	
185–275	**UNIT 2 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, light gray (10YR7/1) to gray (10YR6/1), moderately to strongly welded, crystal rich with devitrified pumice, minor volcanic lithics, and quartz and sanidine crystals. Evidence of flattened vesicles in pumice fragments. +10F: 95%–100% pumice fragments, 2%–5% volcanic lithics, trace quartz and sanidine crystals (bipyramidal quartz noted). +35F: 65%–80% pumice fragments, 20%–35% quartz and sanidine crystals, trace volcanic lithics. Minor orange-brown staining on pumice fragments.	**Qbt 2**	Contact between Qbt 3 and Qbt 2 at 185 ft bgs based on cuttings and a pronounced shift in the gamma log. Note: Appearance of strongly welded pumice fragments, indicative of Qbt 2.

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 5 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
275–295	**UNIT 1 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff, light gray (10YR7/1) to light brownish gray (10YR6/2), moderately welded with devitrified, porous pumice with evidence of flattening in some fragments, volcanic lithics, and quartz and sanidine crystals. +10F: 60%–75% pumice fragments, 25%–40% volcanic lithics, some quartz and sanidine crystals. +35F: 35%–40% pumice fragments, 5%–10% volcanic lithics, 50%–60% quartz and sanidine crystals (bipyramidal quartz noted).	**Qbt 1v**	Contact between Qbt 2 and Qbt 1v at 275 ft bgs and based on cuttings and a pronounced shift in the gamma log.
295–300	Tuff, light gray (10YR7/1), weakly welded, white (7.5YR8/1) with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Appears to be some evidence of vapor-phase crusts on phenocrysts. +10F: 35% pumice fragments, 50% volcanic lithics, 15% quartz and sanidine crystals. +35F: 30% pumice fragments, 25% volcanic lithics, 45% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted). Some metal scrapings in +10 fraction.	**Qbt 1v**	
300–305	Tuff, light gray (10YR7/1), weakly welded, white (7.5YR8/1) with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Appears to be some evidence of vapor-phase crusts on phenocrysts. +10F: 45% pumice fragments, 40% volcanic lithics, 15% quartz and sanidine crystals. +35F: 30% pumice fragments, 25% volcanic lithics, 45% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 1v**	
305–325	Tuff, light gray (10YR7/1), weakly welded, white (7.5YR8/1) with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Appears to be some evidence of vapor-phase crusts on phenocrysts. +10F: 30%–35% pumice fragments, 40%–50% volcanic lithics, 15% quartz and sanidine crystals. +35F: 30% pumice fragments, 25% volcanic lithics, 45% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 1v**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 6 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
325–335	Tuff, light gray (10YR7/1), weakly welded, white (7.5YR8/1) with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Appears to be some evidence of vapor-phase crusts on phenocrysts. Pumice fragments contain relatively more crystals than above and appear more fibrous and porous. Some orange to orange-brown oxidation on pumice fragments. +10F: 35%–45% pumice fragments, 40%–45% volcanic lithics, 10%–15% quartz and sanidine crystals. +35F: 40%–45% pumice fragments, 15%–20% volcanic lithics, 40%–45% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 1v**	
335–360	Tuff, light gray (10YR7/1), weakly welded, white (7.5YR8/1) to pale brown (10YR6/3) with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Appears to be some evidence of vapor-phase crusts on phenocrysts. Pumice fragments appear fibrous and porous. Some orange to orange-brown oxidation on pumice fragments. +10F: 30%–35% pumice fragments, 45%–60% volcanic lithics, 2%–5% quartz and sanidine crystals. +35F: 40%–45% pumice fragments, 15%–20% volcanic lithics, 40%–45% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 1v**	
360–375	Tuff, light gray (10YR7/1), weakly welded, white (7.5YR8/1) and pale brown (10YR6/3) to pink (7.5YR7/4) with devitrified pumice fragments, volcanic lithics, and quartz and sanidine crystals. Appears to be some evidence of vapor-phase crusts on phenocrysts. Pumice fragments appear fibrous and porous and relatively crystal rich. Some orange to orange-brown oxidation on pumice fragments. +10F: 55%–65% pumice fragments, 35%–40% volcanic lithics, trace-2% quartz and sanidine crystals. +35F: 55%–65% pumice fragments, 5%–10% volcanic lithics, 25%–30% quartz and sanidine crystals (bipyramidal quartz and inclusions in quartz noted).	**Qbt 1v**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 7 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
375–415	Tuff, white (10YR8/1) to light gray (10YR7/1), nonwelded with vitric fibrous/porous, pumice fragments; minor volcanic lithics; and quartz and sanidine crystals. +10F: 75%–95% pumice fragments, 5%–15% volcanic lithics, trace quartz and sanidine crystals. +35F: 70%–95% pumice fragments, trace-5% volcanic lithics, 5%–25% quartz and sanidine crystals (bipyramidal quartz, smoky quartz, and glass shards noted).	**Qbt 1g**	Contact between Qbt 1g and Qbt 1g at 375 ft bgs based on first appearance of vitric pumices in cuttings and a pronounced shift in the gamma log. Note: Appearance of fibrous, porous nonwelded pumice fragments.
415–430	Tuff, light gray (10YR7/1) to dark gray (10YR4/1), nonwelded with vitric fibrous/porous, pumice fragments; volcanic lithics; and quartz and sanidine crystals. +10F: 50%–65% pumice fragments, 35%–50% volcanic lithics, 5% to no quartz and sanidine crystals. +35F: 45%–65% pumice fragments, 25%–30% volcanic lithics, 5%–10% quartz and sanidine crystals (smoky quartz noted).	**Qbt 1g**	
430–440	Tuff, white (10YR8/1) to light gray (10YR7/1), non-welded with vitric fibrous/porous, pumice fragments, minor volcanic lithics, and quartz and sanidine crystals. +10F: 90%–95% pumice fragments, 5%–10% volcanic lithics, no quartz and sanidine. +35F: 75%–80% pumice fragments, 5%–10% volcanic lithics, 10%–15% quartz and sanidine.	**Qbt 1g**	
440–465	Tuff, white (10YR8/1) to light gray (10YR7/1), non-welded with vitric fibrous/porous pumice fragments, volcanic lithics, and quartz and sanidine crystals. +10F: 60%–75% pumice fragments, 25%–40% volcanic lithics, no quartz and sanidine. +35F: 55%–70% pumice fragments, 15%–20% volcanic lithics, 10%–15% quartz and sanidine (smokey quartz noted).	**Qbt 1g**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 8 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
465–500	Tuff, very pale brown (10YR8/2) to pink (7.5YR7/3), non-welded with vitric fibrous/porous pumice fragments, minor volcanic lithics, and quartz and sanidine crystals. +10F: 80%–95% pumice fragments, 5%–20% volcanic lithics, no quartz and sanidine. +35F: 65%–75% pumice fragments, 5%–10% volcanic lithics, 15%–20% quartz and sanidine (bipyramidal and smoky quartz noted). Minor oxidation on pumice fragments.	**Qbt 1g**	
500–520	Tuff, pinkish white (7.5YR8/2) to gray (5YR5/1), white (5YR8/1) to light reddish brown (5YR6/3) nonwelded with vitric fibrous/porous pumice fragments, volcanic lithic fragments, quartz and sanidine crystals. +10F: 60%–75% pumice fragments, 25%–40% lithics, trace to no quartz and sanidine crystals. +35F: 70%–85% pumice fragments, 2%–5% lithics, 10%–20% quartz and sanidine (bipyramidal quartz and minor inclusions in quartz noted). Minor oxidation on pumice fragments.	**Qbt 1g**	
520–525	Tuff, light reddish brown (5YR6/3) to gray (5YR5/1), nonwelded with vitric fibrous/porous pumice fragments, abundant volcanic lithic fragments (relative to above), quartz and sanidine crystals. +10F: 60% pumice fragments, 40% volcanic lithic fragments, no quartz and sanidine. +35F: 70% pumice fragments, 5% volcanic lithics, 25% quartz and sanidine (bipyramidal quartz noted). Minor oxidation on pumice fragments.	**Qbt 1g**	
525–530	Tuff, pinkish white (5YR8/2) to light reddish brown (5YR6/3), nonwelded with vitric fibrous/porous pumice fragments, volcanic lithic fragments, quartz and sanidine crystals. +10F: 85% pumice fragments, 15% lithics, no quartz and sanidine crystals. +35F: 75% pumice fragments, 5% lithics, 20% quartz and sanidine (bipyramidal quartz and minor inclusions in quartz noted). Minor oxidation on pumice fragments.	**Qbt 1g**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 9 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
530–540	Tuff, white (5YR8/1) to light reddish brown (5YR6/3), nonwelded with vitric fibrous/porous pumice fragments (some with a sugary texture), minor volcanic lithic fragments, quartz and sanidine crystals. +10F: 90%–95% pumice fragments, 5%–10% volcanic lithics, no quartz and sanidine. +35F: 75%–85% pumice fragments, 2%–5% volcanic lithics, 10%–20% quartz and sanidine (bipyramidal quartz noted).	**Qbt 1g**	
540–545	Tuff, white (5YR8/1) to light gray 5YR(7/1), non-welded with vitric fibrous/porous pumice fragments (some with a sugary texture), volcanic lithic fragments, quartz and sanidine crystals. +10F: 85% pumice fragments, 15% volcanic lithics, no quartz and sanidine. +35F: 80% pumice fragments, 5% volcanic lithics, 15% quartz and sanidine (bipyramidal quartz and smokey quartz noted).	**Qbt 1g**	
545–550	Tuff, white (5YR8/1) to light reddish brown (5YR6/3), nonwelded with vitric fibrous/porous pumice fragments, minor volcanic lithic fragments, quartz and sanidine crystals. +10F: 90%–95% pumice fragments, 5%–10% volcanic lithics, no quartz and sanidine. +35F: 75%–85% pumice fragments, 2%–5% volcanic lithics, 10%–20% quartz and sanidine (bipyramidal quartz noted).	**Qbt 1g**	
550–565	**CERRO TOLEDO INTERVAL:** Volcaniclastic sediments, very pale brown (10YR8/2) to light gray (10YR7/1), moderately sorted, poorly graded with sand (GM), fine to coarse sand, grains angular to subrounded. +10F: detrital constituents (up to 10 mm) composed of 35%–60% felsic-intermediate composition volcanic lithics (including appearance of obsidian), 40%–65% white to light reddish brown fibrous pumice fragments, trace to no quartz and sanidine crystals. +35F: 50%–55% volcanic lithics, 30%–35% pumice fragments, 10%–15% quartz and sanidine.	**Qct**	Contact between Qbt 1g and upper Qct at 550 ft bgs corresponds with significant shift on gamma log.

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 10 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
565–570	Volcaniclastic sediments, light gray (5YR7/1) to gray (5YR6/1), moderately sorted, poorly graded with sand (GM), fine to coarse sand, grains angular to subrounded. +10F: detrital constituents (up to 5 mm) composed of 75% felsic-intermediate composition volcanic lithics, 25% white to light reddish brown fibrous, vitric and devitrified pumice fragments, no quartz and sanidine crystals. +35F: 60% volcanic lithics, 20% pumice fragments, 20% quartz and sanidine.	**Qct**	
570–595	Volcaniclastic sediments, light gray (7.5YR7/1) to dark gray (5YR4/1), poorly sorted, well-graded with sand (GW), fine to coarse sand, grains angular to subrounded. +10F: detrital constituents (up to 15 mm) include 85%–90% felsic-intermediate composition volcanic lithics (including obsidian and dacite), 10%–15% white to reddish-orange vitric and devitrified pumice fragments, trace to no quartz and sanidine. +35F: 60%–70% volcanic lithics, 15%–20% pumice fragments, 10%–20% quartz and sanidine. Orange-brown oxidation on most pumice fragments.	**Qct**	
595–600	Volcaniclastic sediments, white (5YR8/1) to light gray (7.5YR7/1), poorly sorted, well-graded with sand (GW), fine to coarse sand, grains subangular to subrounded. +10F: detrital constituents (up to 15 mm) include 20% felsic-intermediate composition volcanic lithics, 80% white to light gray vitric and devitrified pumice. +35F: 30% volcanic lithics, 60% pumice fragments, 10% quartz and sanidine.	**Qct**	
600–620	Volcaniclastic sediments, light gray (7.5YR7/1) to dark gray (5YR4/1), poorly sorted, well graded with sand (GW), fine to coarse sand, grains subangular to subrounded. +10F: detrital constituents (up to 10 mm) include 80%–90% felsic-intermediate composition volcanic lithics (including dacite), 10%–20% white to light gray vitric and devitrified pumice fragments. +35F: 55%–60% volcanic lithics, 25%–30% pumice fragments, 10%–20% quartz and sanidine. Orange-brown oxidation on most clasts.	**Qct**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 11 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
620–625	Volcaniclastic sediments, dark gray (5YR4/1), moderately sorted, well-graded with sand (GW), medium to coarse sand, grains subangular to subrounded. +10F: detrital constituents (up to 5 mm) include 95% felsic-intermediate composition volcanic lithics (including dacite), 5% light gray to orange-brown vitric and devitrified pumice fragments. +35F: 70% volcanic lithics, 20% pumice fragments, 10% quartz and sanidine. Orange-brown oxidation on most clasts.	**Qct**	
625–653	Volcaniclastic sediments, light gray (7.5YR7/1) to brown (7.5YR5/2), moderately sorted, well-graded with sand (GW), fine to coarse sand, grains subangular to subrounded. +10F: detritral constituents (up to 5 mm) composed of 60%–70% felsic-intermediate composition volcanic lithics (including dacite), 30%–40% white to light reddish brown vitric and devitrified pumice fragments, trace tuffaceous sandstone. +35F: 50%–55% volcanic lithics, 30%–35% pumice fragments, 10%–15% quartz and sanidine.	**Qct**	
653–735	**OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff, light gray (7.5YR7/1) to light brown (7.5YR6/4), weakly to nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics (up to 10 mm), and crystals. WR: ashy/sandy texture. +10F: 35%–55% pumice fragments, 45%–65% volcanic lithics. +35F: 50%–65% pumice fragments, 15%–35% volcanic lithics, 15%–20% quartz and sanidine crystals (trace obsidian and minor red oxidized rock fragments noted).	**Qbo**	Contact between upper Qct and Qbo at 653 ft bgs and corresponds with significant shift on gamma log.

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 12 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
735–760	Tuff, white (7.5YR8/1) to gray (7.5YR6/1), non-welded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20–25 mm), and crystals. WR: ashy/sugary texture. +10F: 25%–40% pumice fragments, 60%–75% volcanic lithics. (Trace obsidian). +35F: 40%–60% pumice fragments, 20%–35% volcanic lithics, 15%–25% quartz and sanidine crystals (minor red oxidized rock fragments noted).	**Qbo**	
760–775	Tuff, light gray (7.5YR7/1) to pinkish gray (7.5YR7/2), nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 10 mm), and crystals. WR: No sandy texture. +10F: 55%–65% pumice fragments, 35%–45% volcanic lithics, trace quartz and sanidine crystals. +35F: 55%–65% pumice fragments, 10%–15% volcanic lithics (including red oxidized fragments), 15%–20% quartz and sanidine crystals.	**Qbo**	
775–780	Tuff, pinkish gray (7.5YR6/2), nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20 mm), and crystals. WR: ashy/sugary texture. +10F: 20% pumice fragments, 80% volcanic lithics, trace quartz and sanidine crystals. +35F: 40% pumice fragments, 30% volcanic lithics, 30% quartz and sanidine.	**Qbo**	
780–785	No cuttings returned in this interval.		

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 13 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
785–800	Tuff, pale brown (10YR6/3) to dark gray (7.5YR4/1), nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20 mm), and crystals. WR: sugary texture. +10F: 25%–30% pumice fragments, 70%–75% volcanic lithics (including red oxidized fragments). +35F: 45%–55% pumice fragments, 25%–35% volcanic lithics, 10%–30% quartz and sanidine crystals.	**Qbo**	
800–815	Tuff, pale brown (10YR6/3) to dark gray (7.5YR4/1), nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20 mm), and crystals. WR: Minor significant texture. +10F: 25%–35% pumice fragments, 65%–75% volcanic lithics (including red oxidized fragments). +35F: 60%–65% pumice fragments, 25%–30% volcanic lithics, 5%–15% quartz and sanidine crystals.	**Qbo**	
815–825	Tuff, pale brown (10YR6/3) to dark gray (7.5YR4/1), nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 5-mm), and crystals. WR: sugary texture. +10F: 35%–40% pumice fragments, 60%–65% volcanic lithics (including red oxidized fragments). +35F: 60%–65% pumice fragments, 25%–30% volcanic lithics, 5%–15% quartz and sanidine crystals.	**Qbo**	
825–870	Tuff, pale brown (10YR6/3) to dark gray (7.5YR4/1), non-welded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20%–25 mm), and crystals. WR: sugary texture. +10F: 20%–35% pumice fragments, 65%–80% volcanic lithics (including red oxidized fragments). Minor tuffaceous sandstone. Trace to no quartz and sanidine crystals. +35F: 40%–55% pumice fragments, 30%–40% volcanic lithics, 5%–20% quartz and sanidine crystals.	**Qbo**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 14 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
870–875	Tuff as above, higher pumice content in +35F fraction to 65%–70% pumice fragments.	**Qbo**	
875–880	Tuff, pale brown (10YR6/3) to dark gray (7.5YR4/1), nonwelded with light gray to orange-brown fibrous vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20–25 mm), and crystals. WR: sugary texture. +10F: 20%–35% pumice fragments, 65%–80% volcanic lithics (including red oxidized fragments). Minor tuffaceous sandstone. Trace to no quartz and sanidine crystals. +35F: 40%–55% pumice fragments, 30%–40% volcanic lithics, 5%–20% quartz and sanidine crystals.	**Qbo**	
880–893	Tuff as above, no sugary texture.	**Qbo**	
893–904	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff, pale brown (10YR6/3) to dark gray (7.5YR4/1), light gray to orange-brown fibrous, vitric pumice fragments, varieties of aphanitic to porphyritic intermediate volcanic lithics including dacite (up to 20–25 mm), and crystals. WR: sugary texture. +10F: 20%–35% pumice fragments, 65%–80% volcanic lithics (including dacite and red oxidized fragments). Minor tuffaceous sandstone. Trace to no quartz and sanidine crystals. +35F: 40%–55% pumice fragments, 30%–40% volcanic lithics, 5%–20% quartz and sanidine crystals.	**Qbog**	Contact between Qbo and Qbog at 893 ft bgs based on gamma log and video log observations.

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 15 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
904–935	**PUYE FORMATION:** Volcaniclastic sediments, light gray (5YR7/1) to reddish gray (2.5YR6/1), poorly sorted, well-graded with minor sand (GW), grains subangular to subrounded (up to 25 mm). +10F: 85%–97% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 3%–15% pumice fragments. Minor tuffaceous sandstone and siltstone. +35F: 70%–85% volcanic lithics, 5%–10% pumice fragments, 5%–20% quartz and sanidine crystals.	**Tpf**	Contact between Qbog and Tpf at 904 ft bgs corresponds with major shift on gamma log as well as shift in borehole structure and texture in video log. At 904 ft bgs there is a significant change in color, clast size (up to 20–30 mm), and composition (loss of pumice).
935–940	Volcaniclastic sediments, light gray (5YR7/1) to reddish gray (2.5YR6/1), well sorted, poorly graded with sand (GP), grains subangular to subrounded (up to 2–5 mm). +10F: 97% Volcaniclastic sediments, light gray (5YR7/1) to reddish gray (2.5YR6/1), poorly sorted, well-graded with minor sand (GW), grains subangular to subrounded (up to 25 mm). +10F: 85%–97% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 3%–15% pumice fragments. Minor tuffaceous sandstone and siltstone. +35F: 70%–85% volcanic lithics, 5%–10% pumice fragments, 5%–20% quartz and sanidine crystals, aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 3% pumice fragments, trace tuffaceous sandstone. +35F: 40% volcanic lithics, 15% pumice fragments, 45% quartz and sanidine crystals.	**Tpf**	Massive deposits of cobbles and boulders were observed in the Puye Formation in video log. The cuttings descriptions provided here represent milled or pulverized material circulated to the surface during drilling.

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 16 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
940–1000	Volcaniclastic sediments, light gray (7.5YR7/1) to reddish brown (2.5YR4/3), poorly sorted, well-graded with sand (GW), grains subangular to subrounded (up to 20–25 mm). +10F: 100% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), trace to no pumice fragments. Minor tuffaceous sandstone. +35F: 65%–90% volcanic lithics, 3%–5% pumice fragments, 5%–15% quartz and sanidine crystals.	**Tpf**	
1000–1015	Volcaniclastic sediments, light gray (7.5YR7/1) to reddish brown (2.5YR5/4), poorly sorted, well-graded with sand (GW) and silty coating on some clasts, grains subangular to subrounded (up to 20 mm). +10F: 95%–97% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 3%–5% pumice fragments, trace tuffaceous sandstone. +35F: 65%–85% volcanic lithics, 5%–10% pumice fragments, 5%–10% quartz and sanidine crystals.	**Tpf**	
1015–1055	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR7/3), poorly sorted, well-graded with sand (GW), grains subangular to subrounded (up to 20–25 mm). +10F: 97%–100% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 3% to no pumice fragments and tuffaceous sandstone. +35F: 85%–93% volcanic lithics, 1%–3% pumice fragments, 4%–15% quartz and sanidine crystals.	**Tpf**	
1055–1065	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR5/3), poorly sorted, well-graded with sand (GW), grains subangular to subrounded (up to 5–10 mm). WR: sandy texture. +10F: 95%–97% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 3%–5% pumice fragments and tuffaceous sandstone. +35F: 85%–93% volcanic lithics, 1%–3% pumice fragments, 4%–15% quartz and sanidine crystals.	**Tpf**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 17 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
1065–1070	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR7/3), poorly sorted, well-graded with sand (GW), grains subangular to subrounded (up to 20 mm). +10F: 100% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite). +35F: 98% volcanic lithics, 2% pumice fragments, trace quartz and sanidine crystals.	**Tpf**	
1070–1075	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR5/3), poorly sorted, well graded with sand (GW), grains subangular to subrounded (up to 5 mm). WR: sandy texture. +10F: 95% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 5% pumice fragments and tuffaceous sandstone. +35F: 95% volcanic lithics, 1% pumice fragments, 4% quartz and sanidine crystals.	**Tpf**	
1075–1195	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR7/3), poorly to moderately sorted, well graded with sand (GW-GP), grains subangular to subrounded (up to 20–25 mm). +10F: 95%–100% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 5% to no pumice fragments and tuffaceous sandstone. +35F: 90%–100% volcanic lithics, 0%–5% pumice fragments, 0%–5% quartz and sanidine crystals.	**Tpf**	
1195–1225	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR7/3), moderately to well sorted, poorly graded with minor coarse sand (GP), grains subangular to subrounded (up to 5 mm). +10F: 95%–100% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 5% to no pumice fragments and tuffaceous sandstone. +35F: 90%–100% volcanic lithics, 0%–5% pumice fragments, 0%–5% quartz and sanidine crystals.	**Tpf**	

Borehole Identification (ID): R-29	**Technical Area (TA):** 49	**Page:** 18 of 18
Drilling Company: Layne Christensen Co.	**Start Date/Time:** 02/12/10 0800	**End Date/Time:** 02/25/10 1415
Drilling Method: Dual Rotary	**Machine:** Schramm T130XD	**Sampling Method:** Grab
Ground Elevation: 7100.34 ft amsl		**Total Depth:** 1248 ft bgs
Drillers: H. Waddell, K. Keller, R. Wall, J. Allen	**Site Geologists:** T. Klepfer, B. Lucero, G. Kinsman, S. Thomas, M. Whitson, D. Oshlo, D. Staires	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
1225–1248	Volcaniclastic sediments, light gray (5YR7/1) to light reddish brown (2.5YR5/3), poorly sorted, well-graded with sand (GW), grains subangular to subrounded (up to 5–10 mm). +10F: 95%–100% aphanitic to porphyritic felsic-intermediate composition volcanic lithics (including dacite), 5% to no pumice fragments and tuffaceous sandstone. +35F: 90%–100% volcanic lithics, 0%–5% pumice fragments, 0%–5% quartz and sanidine crystals.	**Tpf**	Bottom of borehole at 1248 ft bgs.

Abbreviations

10YR6/3 = Munsell soil color notation where hue, value, and chroma are expressed (e.g., hue=10YR, value=6, and chroma=3).

GW = well graded

GP = poorly graded

Qal = Quaternary Alluvium

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

Qbt 3 = Unit 2 of the Tshirege Member of the Bandelier Tuff

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

Qbt 1v = Unit 1v of the Tshirege Member of the Bandelier Tuff

Qbt 1g = Unit 1g of the Tshirege Member of the Bandelier Tuff

Qct = Cerro Toledo Interval

Qbo = Otowi Member of the Bandelier Tuff

Qbog = Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff

Tpf = Puye Formation

SM = silty sands, sand-silt mixtures

SW = well graded sands, gravelly sands, little or no fines

WR = whole rock

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-29

Five screening groundwater samples were collected during drilling and development at well R-29 at Los Alamos National Laboratory's (LANL's or the Laboratory's).

- Two samples were collected during drilling at 1175.0 and 1248.0 ft below ground surface (bgs) from regional saturation within the Puye Formation. Aliquots of these samples were submitted to an off-site laboratory for high explosive (HE) compounds, volatile organic compounds (VOCs), and metals analyses. Aliquots were also submitted to the Laboratory's Earth and Environmental Sciences Group 14 (EES-14) laboratory for metals and anions (including perchlorate) analyses.
- Three samples were collected during development at R-29 from the well screen at 1170.0 to 1180.0 ft bgs in the Puye Formation and analyzed for total organic carbon (TOC), two by EES-14 and one by an off-site laboratory; the third sample was also analyzed by EES-14 for inorganic solutes.

B-1.1 Analytical Techniques

B-1.1.1 EES-14 Analytical Techniques

Groundwater samples were filtered using 0.45-µm membranes before preservation and chemical analyses. Samples were acidified at the EES-14 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater-screening samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (IC) (EPA Method 300, Revision 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques. The instrument detection limit for perchlorate was 0.005 ppm (EPA Method 314.0, Revision 1). Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) (EPA Method 200.7, Revision 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, total chromium, iron, lithium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved antimony, arsenic, beryllium, cadmium, cesium, cobalt, copper, lead, lithium, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS) (EPA Method 200.8, Revision 5.4).

Analyses of TOC were performed on groundwater-screening samples collected during development following EPA Method 415.1. Borehole samples were not analyzed for TOC because of potential sample matrix interference and/or the presence of drilling fluids.

Charge balance errors for total cations and anions for the samples ranged from –6% to –14%. The negative cation-anion charge balance values indicate excess anions for the filtered samples. The precision limits (analytical error) for major ions and trace elements were generally less than ±7%.

B-1.1.2 Off-site Laboratory Analytical Techniques

GEL Laboratories, LLC, analyzed aliquots of the two unfiltered borehole groundwater samples (for VOCs, HE and metals) as well as one of the well development samples (for TOC) using the following EPA analytical methods:

- VOCs by SW846:8260B
- HE by SW846:8321A_MOD

- Metals by SW-846:6010B (ICPOES), SW-846:6020 (ICPMS), or SW-846:7470A
- TOC by EPA:415.1

B-1.2 Field Parameters

B-1.2.1 Well Development

Water samples were drawn from the pump discharge line into sealed containers, and field parameters were measured using a YSI multimeter. Results of field parameters, consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity are provided in Table B-1.2-1.

During development, pH and temperature varied from 6.71 to 9.68 and from 9.11°C to 19.29°C, respectively. The regional aquifer has background pH values ranging from 6.43 to 8.96 with a median value of 7.85 (LANL 2007, 095817). Elevated pH readings likely resulted from the improper use of the pH probe. Concentrations of DO ranged from 2.98 to 8.78 mg/L. Specific conductance varied from 134 to 347 microsiemens per centimeter (μS/cm), and turbidity varied from 3008 nephelometric turbidity units (NTU) at the beginning to 4.78 NTU near the end of development (Table B-1.2-1). The final turbidity reading at the end of development was 4.98 NTUs.

Corrected Eh values determined from field ORP measurements ranged from 48.8 to 220.5 millivolts (mV) during development. The correction factor applied to the ORP field measurements was 208.9 mV, calculated from an Ag/AgCl-saturated KCl electrode filling solution at 15°C. With one exception, all the noncorrected ORP values recorded during development were negative, which resulted in lower overall corrected Eh values. Corrected Eh values associated with well R-29 are considered to be generally reliable and representative of the known relatively oxidizing conditions characteristic of the regional aquifer beneath the Pajarito Plateau.

B-1.2.2 Aquifer Testing

During aquifer testing, pH and temperature varied from 5.09 to 11.24 and from 13.82°C to 17.85°C, respectively. The pH values measured during aquifer testing consistently exceeded the pH concentrations measured during well development; 27 of 49 pH measurements exceeded the regional aquifer background maximum value of 8.96. Therefore, it is likely that the meter was again being operated incorrectly during much of the aquifer testing. Concentrations of DO varied from 1.91 to 5.67 mg/L. Corrected Eh values determined from field ORP measurements varied from 55.1 to 207.8 mV. Specific conductance varied from 146 to 167 μS/cm, and turbidity values varied from 103.2 to 0.69 NTU, with a final value of 4.27 NTU.

B-1.3 Analytical Results

Analytical results from GEL Laboratories and the EES-14 laboratory are presented in Tables B-1.3-1 and B-1.3-2, respectively, and are discussed below. Some analytical results for well R-29 are screened against background regional aquifer concentrations from completed wells that apply to the Laboratory as a whole (LANL 2007, 095817). It should be noted that because of localized variations in geochemistry, background concentrations for the area upgradient of well R-29 may vary from the sitewide background concentrations.

B-1.3.1 Volatile Organic Compounds and High Explosive Compounds

Two samples, GW29-10-13276 and GW29-10-13277, were collected during drilling and analyzed for VOCs and HE compounds (Table B-1.3-1). No VOCs or HE compounds were detected in either of the borehole screening samples.

B-1.3.2 Cations, Anions, Perchlorate and Metals

EES-14 analytical results for cations, anions, perchlorate, and metals from two borehole samples collected during drilling (GW29-10-13276 and GW29-10-13277) and for one sample collected at the end of well development (GW29-10-13270) are provided in Table B-1.3-2. The results for metal analyses conducted by GEL Laboratories on the two borehole samples are included in Table B-1.3.1.

The filtered borehole samples for GW29-10-13276 and GW29-10-13277 that were analyzed by EES-14 consisted of colloidal aquifer material, drilling material, water used during drilling, and native groundwater. The borehole water samples analyzed by GEL Laboratories were not filtered.

Dissolved concentrations of fluoride were 0.37 and 0.25 ppm in the two borehole water samples collected during drilling of R-29. During development of well R-29, the dissolved concentration of fluoride was 0.22 ppm, below the median fluoride concentration from completed wells in the regional aquifer of 0.35 ppm. Dissolved nitrate(N) concentrations were 0.35 and 0.43 ppm in the two borehole water samples collected during drilling of R-29. Dissolved sulfate concentrations were 3.97 and 2.84 ppm in the same borehole water samples. Dissolved nitrate(N) and sulfate concentrations were 0.44 and 9.84 ppm, respectively, during development at well R-29. Median background concentrations for dissolved nitrate(N) and sulfate in the regional aquifer are 0.31 mg/L and 2.83 mg/L, respectively (LANL 2007, 095817). Perchlorate was not detected in the two borehole water samples or in the one sample from well development at well R-29.

The following metal results are from the two borehole samples and the one well development sample submitted to EES-14 for metals analyses (GW29-10-13270) (Table B-1.3-2).

- The dissolved molybdenum concentration for GW29-10-13277 from 1175,0 ft bgs was 0.012 ppm, which is slightly elevated relative to the regional aquifer maximum background concentration of 0.0044 ppm, suggesting this sample may contain a component of lubricant used during drilling. In contrast, the groundwater sample GW29-10-13270 collected during well development from 1175.0 ft bgs in the completed well contained 0.002 ppm of dissolved molybdenum.
- Dissolved concentrations of iron, manganese, and zinc were 0.31, 0.045, and 0.041 ppm, respectively, in the sample collected during well development. Maximum regional aquifer background concentrations for these three metals are 0.147, 0.124, and 0.032 ppm, respectively. A corroded carbon-steel discharge pipe was used during well development at R-29, which likely resulted in the slightly elevated concentrations of colloidal iron, manganese, and zinc.
- Dissolved concentrations of boron were 0.244 and 0.070 ppm in the two borehole water samples. The dissolved concentration of boron from the well development sample was 0.058 ppm. Maximum background concentration for dissolved boron in the regional aquifer is 0.0516 ppm (LANL 2007, 095817).
- Dissolved concentrations of barium were 0.869 and 0.454 ppm in the two borehole water samples collected during drilling of R-29. The dissolved concentration of barium was 0.208 ppm in GW29-10-13270 collected during development. Maximum background concentration for dissolved barium in the regional aquifer is 0.115 ppm (LANL 2007, 095817).
- Total dissolved concentrations of chromium were 0.007 and 0.003 ppm in the two borehole water samples. The dissolved concentration of chromium from the sample collected during well development was 0.004 ppm. Background mean, median, and maximum concentrations of total dissolved chromium are 0.0031, 0.0031, and 0.0072 ppm, respectively, for developed wells in the regional aquifer (LANL 2007, 095817).

Analytical results for 23 metals from GEL Laboratories for the two unfiltered borehole samples (Table B-1.3-1) were consistently higher in concentration that the EES-14 analytical results for the same metals. The difference in results is because the samples analyzed by GEL Laboratories were not filtered.

B-1.3.3 Total Organic Carbon

The TOC concentrations for the three samples collected during well development are: undetected (1 mgC/L) for the sample submitted to GEL Laboratories, and 0.25 and 0.30 mgC/L for the two samples analyzed by EES-14. All results were below the target concentration of 2.0 mgC/L. The median background concentration of TOC is 0.34 mgC/L for regional aquifer groundwater (LANL 2007, 095817).

B-1.4 Summary

In summary, regional aquifer groundwater at well R-29 is relatively oxidizing based on corrected, positive Eh values. Redox conditions based on corrected field ORP measurements at well R-29 are similar to other previously drilled wells on the Pajarito Plateau. Elevated molybdenum from one borehole sample is likely associated with drilling lubricant; the molybdenum concentration from the developed well was within the range of Laboratory background concentrations. No VOCs or HE compounds were detected at R-29. Concentrations of TOC were less than the target value of 2.0 mgC/L in the three well development samples.

B-2.0 REFERENCE

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

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

LANL (Los Alamos National Laboratory), May 2007. "Groundwater Background Investigation Report, Revision 3," Los Alamos National Laboratory document LA-UR-07-2853, Los Alamos, New Mexico. (LANL 2007, 095817)

Table B-1.2-1
Purge Volumes and Water Quality Parameters during Development at Well R-29

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP, Eh[a] (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development									
03/16/10 (Bailing)	1430	n/r[b]	n/r	n/r	n/r	n/r	n/r	0	0
	1800	n/r	n/r	n/r	n/r	n/r	n/r	56	56
03/17/10 (Bailing)	1300	n/r	n/r	n/r	n/r	n/r	n/r	78	134
03/18/10 (Pump)	1032	7.37	17.33	7.47	16.6, 220.5	347	3008.0	5	139
	1132	6.71	15.40	7.27	-134.8, 74.1	213	1479.0	196	335
	1232	9.68	18.26	4.60	-88.9, 115.0	207	164.0	259	594
	1332	7.90	18.80	8.78	-58.9, 145.0	191	97.8	304	899
	1432	8.00	18.48	7.64	-59.3, 144.6	179	48.8	310	1208
	1532	8.09	18.58	7.11	-93.0, 110.9	168	30.4	298	1507
	1632	8.02	17.89	5.84	-97.2, 106.7	162	26.5	343	1849
	1732	7.95	17.32	5.22	-69.1, 139.8	157	22.9	331	2180
	1800	7.99	17.29	5.31	-70.2, 138.7	156	21.1	120	2300
03/19/10 (Pump)	0800	8.09	19.29	5.16	-160.1, 48.8	169	69.1	2	2303
	0900	7.55	15.03	8.35	-139.6, 69.3	170	36.2	364	2667
	1000	7.69	16.47	6.71	-145.5, 63.4	159	34.9	327	2994
	1106	7.96	17.94	4.62	-86.8, 117.1	155	20.6	389	3383
	1200	7.81	17.10	4.94	-90.3, 118.6	150	9.76	287	3670
	1300	7.68	16.80	4.92	-73.1, 135.8	147	13.3	343	4013
	1430[c]	7.98	14.75	4.26	-54.1, 154.8	147	14.4	507	4520
	1530	6.72	15.27	4.50	-87.3, 121.6	146	13.1	338	4858
	1630	7.39	15.74	4.55	-71.1, 137.8	144	10.92	342	5200
	1730	8.31	15.69	3.61	-53.8, 155.1	143	7.70	336	5536
	1830	8.01	15.22	3.75	-60.1, 148.8	141	7.91	334	5870
	1900	7.79	15.32	3.78	-67.5, 141.4	143	8.00	161	6031
03/20/10 (Pump)	0730	7.82	9.11	4.23	-127, 86.0	141	61.10	4	6035
	0830	7.93	14.89	6.61	-106.0, 102,9	146	11.90	340	6375
	0930	8.81	14.35	5.08	-134.7, 74.2	144	8.62	346	6721
	1030	8.57	15.93	3.97	-122.3, 86.6	141	6.85	339	7060
	1130	8.97	15.96	3.46	-111.4, 97.5	139	6.48	343	7403
	1230	8.98	16.04	3.06	-89.9, 119.0	139	5.92	343	7746
	1330	9.01	16.03	2.98	-90.2, 118.7	138	5.22	340	8085
	1430	7.48	15.51	4.81	-96.1, 112.8	137	4.78	333	8418
	1530	6.99	16.34	4.85	-102.1, 106.8	137	5.54	348	8766
	1630	7.49	15.47	3.90	-131.4, 77.5	134	4.78	328	9093
	1730	6.98	16.59	3.12	-87.5,121.4	135	5.05	328	9422
	1830	6.71	16.26	3.11	-81.3, 127.6	135	4.98	335	9757
03/21/10 (Pump)	1530	n/r	n/r	n/r	n/r	n/r	n/r	119	9875

Table B-1.2-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP, Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Testing									
03/22/10 (Step Tests)	1052	5.09	14.24	2.02	-110.8, 98.1	149	103.2	n/r	9875
	1100	n/r	n/r	n/r	n/r	n/r	n/r	120.98	9996
	1201	9.15	17.37	3.72	11.0, 123.0	161	30.4	n/r	9996
	1231	9.93	17.07	3.61	-1.1, 207.8	167	16.3	n/r	9996
	1251	10.14	17.85	3.02	-19.7, 184.2	164	9.24	n/r	9996
	1300	n/r	n/r	n/r	n/r	n/r	n/r	243.41	10240
03/24/10 (24-H Pumping Test)	0801	n/r	n/r	n/r	n/r	n/r	n/r	0	10240
	0900	11.24	15.96	2.05	-153.8, 55.1	163	4.71	124	12336
	1000	10.45	16.36	5.04	-117.4, 91.5	161	4.22	123	12459
	1100	9.40	17.08	5.17	-78.2, 130.7	155	3.88	124	12583
	1130	8.66	17.53	5.40	-80.9, 123.0	158	3.42	123	12706
	1204	9.69	17.41	5.67	-81.7, 127.2	157	2.44	123	12829
	1230	10.23	17.32	5.38	-76.6, 132.3	155	3.34	124	12953
	1300	8.80	17.67	5.33	-71.5, 132.4	156	3.35	124	13077
	1330	8.48	17.49	5.28	-64.6, 144.3	155	3.68	124	13201
	1400	8.22	17.55	5.18	-65.4, 138.5	154	4.05	124	13325
	1430	8.36	17.49	4.69	-65.9, 143.0	153	3.91	124	13449
	1500	8.42	17.42	3.76	-65.7, 143.2	155	3.54	124	13573
	1530	8.19	17.41	3.90	-65.1, 143.8	152	4.00	124	13696
	1600	7.92	17.36	3.93	-69.5, 139.4	152	4.60	124	13820
	1630	7.59	17.37	3.97	-60.4, 148.5	153	3.43	123	13943
	1700	7.48	17.45	4.12	-53.8, 155.1	153	3.43	128	14071
	1730	7.71	17.31	3.44	-71.1, 137.8	153	3.66	103	14174
	1800	7.60	17.25	4.04	-53.0, 155.9	153	3.25	124	12336
	1830	7.46	17.32	4.61	-52.3, 156.6	154	3.75	123	12459
	1900	7.57	17.03	4.40	-54.1, 154.8	154	3.68	124	12583
	1930	7.76	16.17	3.99	-63.1, 145.8	152	4.01	123	12706
	2000	8.68	15.95	3.94	-67.9, 141.0	151	4.09	123	12829
	2030	8.36	16.30	3.76	-94.0, 114.9	150	2.68	124	12953
	2100	8.83	15.64	3.83	-95.5, 113.4	153	4.20	124	13077
	2130	8.98	15.60	3.61	-99.8, 109.1	153	3.07	124	13201
	2200	9.29	15.44	3.57	-80.0, 128.9	152	2.65	124	13325
	2230	8.68	15.76	3.31	-89.5, 119.4	152	2.51	124	13449
	2300	8.38	15.79	3.16	-84.3,124.6	157	3.95	124	13573
	2333	8.70	15.78	3.05	-84.5, 124.4	153	3.01	124	13696
	2400	8.42	16.28	2.93	-83.1, 125.8	149	1.95	124	13820

Table B-1.2-1 (continued)

Date	Time	pH	Temp (°C)	DO (mg/L)	ORP, Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Testing									
03/25/10 (24-H Pumping Test)	0030	9.19	15.77	2.91	-77.2, 126.7	152	2.16	104	14278
	0100	9.11	16.20	2.70	-76.4, 132.5	152	1.86	92	14370
	0130	9.00	16.36	2.59	-77.3, 131.6	150	1.60	106	14475
	0200	9.05	16.28	2.43	-76.3, 132.6	151	1.10	92	14568
	0230	9.08	16.07	2.39	-78.5, 130.4	151	0.97	92	14660
	0300	9.18	15.77	2.29	-77.0, 131.9	152	1.26	64	14724
	0330	9.05	14.79	3.38	-74.5, 134.4	149	0.69	70	14794
	0400	9.47	15.24	2.24	-76.8, 132.1	150	1.59	65	14859
	0430	9.45	16.09	2.10	-74.3, 134.6	150	1.14	63	14923
	0500	9.32	16.50	2.03	-74.3, 134.6	152	1.14	60	14983
	0530	9.48	15.86	2.09	-74.3, 134.6	150	2.09	40	15023
	0600	9.47	15.34	2.07	-76.4, 132.5	148	1.37	29	15052
	0630	9.38	14.90	1.93	-77.0, 131.9	148	1.77	27	15078
	0700	9.34	14.28	1.91	-73.7, 135.2	146	2.73	23	15101
	0730	9.45	14.17	1.91	-77.5, 131.4	147	4.27	20	15121
	0800	9.42	13.82	1.93	-69.6, 139.3	147	n/r	15	15136

[a] Eh (mV) is calculated from a Ag/AgCl saturated KCl electrode filling solution at 10ºC, 15ºC, and 20ºC by adding a temperature-sensitive correction factors of 213.8 mV, 208.9 mV, and 203.9 mV, respectively.

[b] n/r = Not recorded.

[c] 1430 = Lightning delay.

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

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2534	GW29-10-13271	TOC	EPA:415.1	TOC	1	ug/L	U[a]
10-2185	GW29-10-13275	VOC	SW-846:8260B	Acetone	10	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Acetonitrile	25	ug/L	R[b]
10-2185	GW29-10-13275	VOC	SW-846:8260B	Acrolein	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Acrylonitrile	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Benzene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Bromobenzene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Bromochloromethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Bromodichloromethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Bromoform	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Bromomethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Butanol[1-]	50	ug/L	R
10-2185	GW29-10-13275	VOC	SW-846:8260B	Butanone[2-]	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Butylbenzene[n-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Butylbenzene[sec-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Butylbenzene[tert-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Carbon Disulfide	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Carbon Tetrachloride	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	ug/L	UJ[c]
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chlorobenzene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chlorodibromomethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chloroethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chloroform	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chloromethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chlorotoluene[2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Chlorotoluene[4-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dibromo-3-Chloropropane[1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dibromomethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichlorodifluoromethane	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Diethyl Ether	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Ethyl Methacrylate	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Ethylbenzene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Hexachlorobutadiene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Hexanone[2-]	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Iodomethane	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Isobutyl alcohol	50	ug/L	R
10-2185	GW29-10-13275	VOC	SW-846:8260B	Isopropylbenzene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Methacrylonitrile	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Methyl Methacrylate	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Methyl tert-Butyl Ether	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Methylene Chloride	10	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Naphthalene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Propionitrile	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Propylbenzene[1-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Styrene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Tetrachloroethene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Toluene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichloroethene	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichlorofluoromethane	1	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Vinyl acetate	5	ug/L	UJ
10-2185	GW29-10-13275	VOC	SW-846:8260B	Vinyl Chloride	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Xylene[1,2-]	1	ug/L	U
10-2185	GW29-10-13275	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2	ug/L	U
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	2,4-Diamino-6-nitrotoluene	1.3	ug/L	U
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	2,6-Diamino-4-nitrotoluene	1.3	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	3,5-Dinitroaniline	1.3	ug/L	U
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Amino-2,6-dinitrotoluene[4-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Amino-4,6-dinitrotoluene[2-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Dinitrobenzene[1,3-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Dinitrotoluene[2,4-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Dinitrotoluene[2,6-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	HMX[d]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Nitrobenzene	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Nitrotoluene[2-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Nitrotoluene[3-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Nitrotoluene[4-]	0.649	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	PETN[e]	1.3	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	RDX[f]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	TATB[g]	1.3	ug/L	U
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Tetryl	0.649	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Trinitrobenzene[1,3,5-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Trinitrotoluene[2,4,6-]	0.325	ug/L	UJ
10-2185	GW29-10-13276	HE	SW-846:8321A_MOD	Tris (o-cresyl) phosphate	1.3	ug/L	U
10-2185	GW29-10-13276	METALS	SW-846:6010B	Aluminum	25400	ug/L	NQ[h]
10-2185	GW29-10-13276	METALS	SW-846:6020	Antimony	3	ug/L	U
10-2185	GW29-10-13276	METALS	SW-846:6010B	Arsenic	5.59	ug/L	J[i]
10-2185	GW29-10-13276	METALS	SW-846:6010B	Barium	249	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6020	Beryllium	0.734	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6020	Cadmium	0.342	ug/L	J
10-2185	GW29-10-13276	METALS	SW-846:6010B	Calcium	17900	ug/L	J+[j]
10-2185	GW29-10-13276	METALS	SW-846:6010B	Chromium	37.8	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Cobalt	39.7	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Copper	30.8	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Iron	25500	ug/L	NQ

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2185	GW29-10-13276	METALS	SW-846:6020	Lead	9.08	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Magnesium	6000	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6020	Manganese	443	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:7470A	Mercury	0.2	ug/L	U
10-2185	GW29-10-13276	METALS	SW-846:6010B	Nickel	19.5	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Potassium	4210	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Selenium	30	ug/L	U
10-2185	GW29-10-13276	METALS	SW-846:6010B	Silver	1.17	ug/L	J
10-2185	GW29-10-13276	METALS	SW-846:6010B	Sodium	14800	ug/L	J+
10-2185	GW29-10-13276	METALS	SW-846:6020	Thallium	1.01	ug/L	U
10-2185	GW29-10-13276	METALS	SW-846:6010B	Vanadium	25.8	ug/L	NQ
10-2185	GW29-10-13276	METALS	SW-846:6010B	Zinc	240	ug/L	NQ
10-2185	GW29-10-13276	VOC	SW-846:8260B	Acetone	10	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Acetonitrile	25	ug/L	R
10-2185	GW29-10-13276	VOC	SW-846:8260B	Acrolein	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Acrylonitrile	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Benzene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Bromobenzene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Bromochloromethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Bromodichloromethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Bromoform	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Bromomethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Butanol[1-]	50	ug/L	R
10-2185	GW29-10-13276	VOC	SW-846:8260B	Butanone[2-]	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Butylbenzene[n-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Butylbenzene[sec-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Butylbenzene[tert-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Carbon Disulfide	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Carbon Tetrachloride	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	ug/L	UJ
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chlorobenzene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chlorodibromomethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chloroethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chloroform	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chloromethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chlorotoluene[2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Chlorotoluene[4-]	1	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dibromo-3-Chloropropane[1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dibromomethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichlorodifluoromethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Diethyl Ether	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Ethyl Methacrylate	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Ethylbenzene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Hexachlorobutadiene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Hexanone[2-]	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Iodomethane	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Isobutyl alcohol	50	ug/L	R
10-2185	GW29-10-13276	VOC	SW-846:8260B	Isopropylbenzene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Methacrylonitrile	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Methyl Methacrylate	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Methyl tert-Butyl Ether	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Methylene Chloride	10	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Naphthalene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Propionitrile	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Propylbenzene[1-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Styrene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2185	GW29-10-13276	VOC	SW-846:8260B	Tetrachloroethene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Toluene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichloroethene	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichlorofluoromethane	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Vinyl acetate	5	ug/L	UJ
10-2185	GW29-10-13276	VOC	SW-846:8260B	Vinyl Chloride	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Xylene[1,2-]	1	ug/L	U
10-2185	GW29-10-13276	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2	ug/L	U
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	2,4-Diamino-6-nitrotoluene	13	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	2,6-Diamino-4-nitrotoluene	13	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	3,5-Dinitroaniline	13	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Amino-2,6-dinitrotoluene[4-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Amino-4,6-dinitrotoluene[2-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Dinitrobenzene[1,3-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Dinitrotoluene[2,4-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Dinitrotoluene[2,6-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	HMX	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Nitrobenzene	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Nitrotoluene[2-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Nitrotoluene[3-]	3.25	ug/L	R
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Nitrotoluene[4-]	6.49	ug/L	R
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	PETN	13	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	RDX	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	TATB	13	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Tetryl	6.49	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Trinitrobenzene[1,3,5-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Trinitrotoluene[2,4,6-]	3.25	ug/L	UJ
10-2007	GW29-10-13277	HE	SW-846:8321A_MOD	Tris (o-cresyl) phosphate	13	ug/L	UJ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Aluminum	4770	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6020	Antimony	3	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2007	GW29-10-13277	METALS	SW-846:6010B	Arsenic	8.89	ug/L	J
10-2007	GW29-10-13277	METALS	SW-846:6010B	Barium	352	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6020	Beryllium	0.452	ug/L	J
10-2007	GW29-10-13277	METALS	SW-846:6020	Cadmium	0.214	ug/L	J
10-2007	GW29-10-13277	METALS	SW-846:6010B	Calcium	26800	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Chromium	25.6	ug/L	J
10-2007	GW29-10-13277	METALS	SW-846:6010B	Cobalt	78.5	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Copper	33.5	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Iron	51700	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6020	Lead	4.26	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Magnesium	6410	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6020	Manganese	900	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:7470A	Mercury	0.2	ug/L	U
10-2007	GW29-10-13277	METALS	SW-846:6010B	Nickel	44	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Potassium	4470	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Selenium	30	ug/L	U
10-2007	GW29-10-13277	METALS	SW-846:6010B	Silver	5	ug/L	U
10-2007	GW29-10-13277	METALS	SW-846:6010B	Sodium	21600	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6020	Thallium	1	ug/L	U
10-2007	GW29-10-13277	METALS	SW-846:6010B	Vanadium	16.2	ug/L	NQ
10-2007	GW29-10-13277	METALS	SW-846:6010B	Zinc	3320	ug/L	NQ
10-2007	GW29-10-13277	VOC	SW-846:8260B	Acetone	10	ug/L	UJ
10-2007	GW29-10-13277	VOC	SW-846:8260B	Acetonitrile	25	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Acrolein	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Acrylonitrile	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Benzene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Bromobenzene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Bromochloromethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Bromodichloromethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Bromoform	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Bromomethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Butanol[1-]	50	ug/L	R
10-2007	GW29-10-13277	VOC	SW-846:8260B	Butanone[2-]	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Butylbenzene[n-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Butylbenzene[sec-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Butylbenzene[tert-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Carbon Disulfide	5	ug/L	UJ
10-2007	GW29-10-13277	VOC	SW-846:8260B	Carbon Tetrachloride	1	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chlorobenzene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chlorodibromomethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chloroethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chloroform	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chloromethane	1	ug/L	UJ
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chlorotoluene[2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Chlorotoluene[4-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dibromo-3-Chloropropane[1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dibromomethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichlorodifluoromethane	1	ug/L	UJ
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Diethyl Ether	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Ethyl Methacrylate	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Ethylbenzene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Hexachlorobutadiene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Hexanone[2-]	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Iodomethane	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Isobutyl alcohol	50	ug/L	R
10-2007	GW29-10-13277	VOC	SW-846:8260B	Isopropylbenzene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Methacrylonitrile	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Methyl Methacrylate	5	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2007	GW29-10-13277	VOC	SW-846:8260B	Methyl tert-Butyl Ether	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Methylene Chloride	10	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Naphthalene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Propionitrile	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Propylbenzene[1-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Styrene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Tetrachloroethene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Toluene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichloroethene	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichlorofluoromethane	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Vinyl acetate	5	ug/L	UJ
10-2007	GW29-10-13277	VOC	SW-846:8260B	Vinyl Chloride	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Xylene[1,2-]	1	ug/L	U
10-2007	GW29-10-13277	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Acetone	10	ug/L	UJ
10-2007	GW29-10-13278	VOC	SW-846:8260B	Acetonitrile	25	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Acrolein	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Acrylonitrile	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Benzene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Bromobenzene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Bromochloromethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Bromodichloromethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Bromoform	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Bromomethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Butanol[1-]	50	ug/L	R
10-2007	GW29-10-13278	VOC	SW-846:8260B	Butanone[2-]	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Butylbenzene[n-]	1	ug/L	U

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2007	GW29-10-13278	VOC	SW-846:8260B	Butylbenzene[sec-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Butylbenzene[tert-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Carbon Disulfide	5	ug/L	UJ
10-2007	GW29-10-13278	VOC	SW-846:8260B	Carbon Tetrachloride	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chloro-1-propene[3-]	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chlorobenzene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chlorodibromomethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chloroethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chloroform	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chloromethane	0.31	ug/L	J
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chlorotoluene[2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Chlorotoluene[4-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dibromo-3-Chloropropane[1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dibromoethane[1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dibromomethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichlorodifluoromethane	1	ug/L	UJ
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloroethane[1,1-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloroethane[1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloroethene[1,1-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloropropane[1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloropropane[1,3-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloropropane[2,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloropropene[1,1-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Diethyl Ether	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Ethyl Methacrylate	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Ethylbenzene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Hexachlorobutadiene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Hexanone[2-]	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Iodomethane	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Isobutyl alcohol	50	ug/L	R

Table B-1.3-1 (continued)

Lab Request Number	Sample ID	Analytical Suite Code	Analytical Method	Analyte Description	Lab Result	Unit	Validation Qualifier Code
10-2007	GW29-10-13278	VOC	SW-846:8260B	Isopropylbenzene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Isopropyltoluene[4-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Methacrylonitrile	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Methyl Methacrylate	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Methyl tert-Butyl Ether	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Methylene Chloride	10	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Naphthalene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Propionitrile	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Propylbenzene[1-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Styrene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Tetrachloroethene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Toluene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichloroethene	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichlorofluoromethane	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Vinyl acetate	5	ug/L	UJ
10-2007	GW29-10-13278	VOC	SW-846:8260B	Vinyl Chloride	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Xylene[1,2-]	1	ug/L	U
10-2007	GW29-10-13278	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2	ug/L	U

Notes: Sample GW29-10-13275 is a VOC trip blank for sample GW29=10-13276. Sample GW29-10-13278 is a VOC trip blank for sample GW29=10-13277.

[a] U = The analyte was analyzed for but not detected.

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

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

[d] HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

[e] PETN = Pentaerythritol tetranitrate.

[f] RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.

[g] TATB = Triaminotrinitrobenzene.

[h] NQ = Data are valid and not qualified.

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

[j] J + = The analyte was positively identified, and the result is likely to be biased high.

Table B-1.3-2
EES-14 Analytical Data

Sample ID	Date Received	Sample Type	ER/RRES-WQH	Depth (feet)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)	Br(-) ppm	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl(-) ppm	ClO4(-) ppm	ClO4(-) (U)	Co rslt (ppm)	stdev (Co)	Alk-CO3 rslt (ppm)
GW29-10-13277	2/22/2010	Borehole	10-2008	1175	0.001	U*	0.162	0.001	0.0010	0.0000	0.244	0.003	0.869	0.006	0.001	U	0.04	11.14	0.10	0.001	U	9.55	0.005	U	0.004	0.000	0.8
GW29-10-13276	3/1/2010	Borehole	10-2186	1248	0.001	U	0.090	0.000	0.0006	0.0000	0.070	0.001	0.454	0.005	0.001	U	0.04	8.42	0.04	0.001	U	4.77	0.005	U	0.007	0.000	0.8
GW29-10-13270	3/23/2010	Development	10-2558	1170-1180	0.001	U	0.007	0.000	0.0008	0.0000	0.058	0.001	0.208	0.001	0.001	U	0.03	10.51	0.07	0.001	U	4.10	0.005	U	0.001	U	0.8

Sample ID	Date Received	Sample Type	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F(-) ppm	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)
GW29-10-13277	2/22/2010	Borehole	U	0.007	0.000	0.001	U	0.001	U	0.37	0.64	0.01	114	0.00037	0.00000	2.30	0.03	0.048	0.006	4.04	0.02	0.114	0.001	0.012	0.000	23.35
GW29-10-13276	3/1/2010	Borehole	U	0.003	0.000	0.001	U	0.001	U	0.25	0.40	0.00	69	0.00011	0.00001	1.14	0.01	0.020	0.000	2.69	0.03	0.078	0.001	0.002	0.000	11.11
GW29-10-13270	3/23/2010	Development	U	0.004	0.000	0.001	U	0.002	0.000	0.22	0.31	0.00	81	0.00008	0.00001	1.20	0.01	0.023	0.001	3.34	0.01	0.045	0.000	0.002	0.000	16.29

Sample ID	Date Received	Sample Type	stdev (Na)	Ni rslt (ppm)	stdev (Ni)	NO2 (ppm)	NO2-N rslt	NO3 ppm	NO3-N rslt	C2O4 rslt (ppm)	Pb rslt (ppm)	stdev (Pb)	Lab pH	PO4(-3) rslt (ppm)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)	Si rslt (ppm)	stdev (Si)	SiO2 rslt (ppm)	stdev (SiO2)	Sn rslt (ppm)	stdev (Sn)	SO4(-2) rslt (ppm)	Sr rslt (ppm)
GW29-10-13277	2/22/2010	Borehole	0.11	0.006	0.003	0.12	0.037	1.53	0.35	0.01, U	0.0002	U	7.48	0.26	0.001	0.000	0.001	U	0.002	0.000	18.1	0.1	38.7	0.2	0.001	U	3.97	0.046
GW29-10-13276	3/1/2010	Borehole	0.07	0.002	0.000	0.01	0.003, U	1.91	0.43	0.01, U	0.0002	U	6.98	0.15	0.001	U	0.001	U	0.001	U	30.6	0.2	65.6	0.3	0.001	U	2.84	0.040
GW29-10-13270	3/23/2010	Development	0.08	0.002	0.000	0.01	0.003, U	1.97	0.44	0.01, U	0.0002	U	7.23	0.05	0.001	U	0.001	U	0.001	U	30.2	0.1	64.6	0.1	0.001	U	9.84	0.048

Sample ID	Date Received	Sample Type	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)	stdev (Tl)	U rslt (ppm)	stdev (U)	U rslt (ppm)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
GW29-10-13277	2/22/2010	Borehole	0.002	0.001	U	0.002	U	0.001	U	0.0003	0.0000	0.0003	0.002	0.000	0.093	0.003	228	1.99	2.63	-0.14
GW29-10-13276	3/1/2010	Borehole	0.000	0.001	U	0.006	0.000	0.001	U	0.0002	0.0000	0.0002	0.003	0.000	0.066	0.011	170	1.17	1.40	-0.09
GW29-10-13270	3/23/2010	Development	0.000	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.0006	0.005	0.000	0.041	0.000	195	1.55	1.73	-0.06

*U = The analyte was analyzed for but not detected.

Table B-1.3-3
TOC Concentrations

Sample ID	Analyte Description	Lab Result	Unit	Validation Qualifier Code
GW-29-10-13271	TOC	1	mg/L	U[a]
GW-29-10-13272	TOC	0.25	mg/L	NQ[b]
GW-29-10-13270	TOC	0.30	mg/L	NQ

[a] U = The analyte was analyzed for but not detected.

[b] NQ = Data are valid and not qualified.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted in March 2010 at well R-29 located at Technical Area 49 (TA-49) at Los Alamos National Laboratory (the Laboratory). The tests on R-29 were conducted to evaluate the hydraulic properties of the Puye Formation sediments in which the well was completed.

Testing consisted of brief trial pumping of R-29, background water level data collection, and a 24-h constant-rate pumping test. As with most of the R-well pumping tests conducted on the Pajarito Plateau (the Plateau), an inflatable packer system was used in R-29 to minimize the effects of casing storage on the test data.

As described below, air or gas in the formation affected a portion of the data collected during the pumping tests. Numerous pumping tests conducted recently on the Plateau have shown this effect. It was assumed that the source of the gas was compressed air introduced into the formation during the drilling process. It is possible, however, that naturally occurring gas could be responsible for the observed effect.

Conceptual Hydrogeology

Well R-29 is drilled into sediments of the Puye Formation. The well was completed with 10 ft of 5-in. stainless-steel well screen from 1170 to 1180 ft below ground surface (bgs). The static water level measured on March 21, 2010, was 1152.5 ft bgs, 17.5 ft above the top of the well screen. The estimated ground surface elevation at R-29 was 7097 ft above mean sea level (amsl), making the water level approximately 5944.5 ft amsl.

No distinctive aquitards or other tight zones were identified for R-29, so the permeability distribution of the saturated zone and the effective aquifer thickness in the vicinity of the well were not well defined.

R-29 Testing

Well R-29 was tested from March 21 to 26, 2010. After filling the drop pipe on March 21, testing consisted of brief trial pumping on March 22, background data collection, and a 24-h constant-rate pumping test that began on March 24.

Two trial tests were conducted on March 22. Trial 1 was conducted at a discharge rate of 4.07 gallons per minute (gpm) for 30 min from 10:30 to 11:00 a.m. and was followed by 60 min of recovery until 12:00 p.m.

Trial 2 was conducted for 60 min from 12:00 to 1:00 p.m. at a discharge rate of 4.05 gpm. Following shutdown, recovery data were recorded for 2580 min until 8:00 a.m. on March 24.

At 8:00 a.m. on March 24, the 24-h pumping test was begun at a rate of 4.04 gpm. After a few hours, the rate inexplicably increased gradually, reaching a maximum of 4.3 gpm before midnight, less than 16 h into the test. It was surmised that varying gas content in the pumped water may have affected the pump bowl efficiency and the resulting pumping rate.

Just before midnight on March 24, the discharge rate began declining steadily and continued to do so throughout the remainder of the pumping test. By the end of the test, the discharge rate had declined to 0.4 gpm. It was surmised that steady buildup of gas or air within the casing beneath the inflatable packer gradually forced the water level in the well downward, reducing the distance between the water level and the pump intake, limiting the available drawdown for pumping.

At 8:00 a.m. on March 25, the pump was shut off. Following shutdown, recovery measurements were recorded for 1410 min until 7:30 a.m. on March 26.

C-2.0 BACKGROUND DATA

The background water-level data collected in conjunction with running the pumping tests allow the analyst to see what water-level fluctuations occur naturally in the aquifer and help distinguish between water-level changes caused by conducting the pumping test and changes associated with other causes.

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

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

Subsequent pumping tests, including at R-29, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When a well is monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency, and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from the Technical Area 54 (TA-54) tower site from the Waste and Environmental Services Division–Environmental Data and Analysis (WES-EDA). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is approximately 7097 ft amsl. The static water level in R-29 was 1152.5 ft below land surface, making the calculated water-table elevation 5944.5 ft amsl. Therefore, the measured barometric pressure data from TA-54 had to be adjusted to reflect the pressure at the elevation of the water table within R-29.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{R-29} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-29}}{T_{WELL}} \right) \right] \qquad \textbf{Equation C-1}$$

where, P_{WT} = barometric pressure at the water table inside R-29

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

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

R = gas constant, in J/kg/degree kelvin (287.04 J/kg/degree kelvin)

$E_{R\text{-}29}$ = land surface elevation at R-29 site, in feet (approximately 7097 ft)

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

E_{WT} = elevation of the water level in R-29, in feet (approximately 5944.5 ft)

T_{TA54} = air temperature near TA-54, in degrees kelvin (assigned a value of 36.4 degrees Fahrenheit, or 275.6 degrees kelvin)

T_{WELL} = air temperature inside R-29, in degrees kelvin (assigned a value of 59.7 degrees Fahrenheit, or 288.5 degrees kelvin)

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

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

C-3.0 IMPORTANCE OF EARLY DATA

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

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

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

Equation C-2

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

D = inside diameter of well casing, in inches

d = outside diameter of column pipe, in inches

Q = discharge rate, in gallons per minute

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

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

For wells screened across the water table (not applicable here), there can be an additional storage contribution from the filter pack around the screen. The following equation provides an estimate of the storage duration accounting for both casing and filter pack storage.

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

Equation C-3

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

D_B = diameter of borehole, in inches

D_C = outside diameter of well casing, in inches

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

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. Therefore, this option has been implemented for the R-well testing program, including R-29.

C-4.0 TIME-DRAWDOWN METHODS

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

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

Equation C-4

where,

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

Equation C-5

and

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

Equation C-6

and where, s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

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

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

Equation C-7

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

Equation C-8

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

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

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

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

Equation C-9

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

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

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

Equation C-10

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

Q = discharge rate, in gallons per minute

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

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

Equation C-11

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

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

b = aquifer thickness

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

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

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

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

K_z = vertical hydraulic conductivity

K_r = horizontal hydraulic conductivity

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

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

Equation C-12

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

C-5.0 RECOVERY METHODS

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

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

$$T = \frac{264Q}{\Delta s}$$ **Equation C-13**

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

C-6.0 SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is not known, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

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

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

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right]$$ **Equation C-14**

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

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right)$$ **Equation C-15**

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

To apply this procedure, a storage coefficient value must be assigned. Unconfined conditions were assumed for R-29 because of the modest water level rise above the well screen. Storage coefficient values for unconfined conditions can be expected to range from about 0.01 to 0.25 (Driscoll 1986, 104226). A value of 0.1 was used for the R-29 calculations. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate of the storage coefficient is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. For the purposes of this exercise, an arbitrary saturated thickness of 30 ft was assigned. As long as the aquifer thickness is greater than the well-screen length, the calculation result is not especially sensitive to the selected value because sediments far above and/or below the screen do not contribute significantly to the specific capacity.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-29 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure C-7.0-1 shows aquifer pressure data from R-29 along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-29 data are referred to in the figure as the “apparent hydrograph” because the measurements reflect the sum of water pressure and barometric pressure, having been recorded using a nonvented pressure transducer. The times of the pumping periods for the R-29 pumping tests are included in the figure for reference.

The data from March 25 and 26 on Figure C-7.0-1 showed virtually no change in aquifer pressure during a period of large barometric pressure change. This finding suggested a barometric efficiency of close to 100% and implied that water-level measurements did not have to be adjusted for changes in barometric pressure.

A rise in aquifer pressure of a couple hundredths of a foot occurred on March 23 just before midnight. The cause of this “blip” was not identified, although one possibility is that it may have been a result of drilling activities at R-30 (0.3 mi away) that were underway at that time. Another possibility is that the pumping string (pump, pipe and packer) may have shifted or settled slightly.

C-8.0 WELL R-29 DATA ANALYSIS

This section presents the data obtained from the R-29 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for trials 1 and 2 as well as drawdown from the 24-h constant-rate pumping test.

C-8.1 Well R-29 Trial 1

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from trial 1. Two parallel traces were evident in the data, separated by a gradual transition about a minute after pumping began. This likely was a response to a pumping rate decline that occurred as the discharge hose filled to the elevation of the top of the storage tank, about 10 ft above ground level. The increase in head reduced the discharge rate slightly.

The transmissivity calculated from the line of fit shown on the graph was 630 gallons per day (gpd) per foot. The saturated thickness corresponding to this transmissivity value could not be determined, precluding calculating a corresponding hydraulic conductivity.

Figure C-8.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. Two distinct slopes were evident on the graph. The early slope supported a transmissivity calculation of 370 gpd/ft. It was assumed this represented the transmissivity of just the 10-ft-thick screened interval, making the hydraulic conductivity 37 gpd/ft^2, or 4.9 ft/d.

The late-time slope yielded a transmissivity of 780 gpd/ft. It was assumed this value represented an unknown contiguous thickness of permeable sediments in which the screen is placed.

Note that nearly full recovery occurred prematurely, well before a t/t' value of 1.0, possibly an indication of hysteretic effects. In unconfined aquifers, the rate of recovery can be more rapid than that of drawdown because of a smaller effective storage coefficient during recovery. During pumping, the capillary fringe above the water table increases in thickness, while during recover it gets thinner (Bevan et al. 2005, 105186). If the rate of thinning during recovery exceeds the rate of growth during pumping, the effective storage coefficient during recovery will be less than that during pumping, resulting in a more rapid recovery rate than drawdown rate. Additionally, as the water table rebounds during recovery, it can trap air in the previously dewatered pore spaces, further decreasing the effective recovery storage coefficient. It was also possible that extraneous air already in the formation, or air that was dissolved in the groundwater and came out of solution during pumping, contributed to a reduced storage coefficient.

C-8.2 Well R-29 Trial 2

Figure C-8.2-1 shows a semilog plot of the drawdown data collected from trial 2. The early inertial effect masked the early-time data trend. The late data produced a transmissivity value of 690 gpd/ft for the contiguous hydraulic unit of unknown thickness penetrated by the well screen, consistent with the results from trial 1.

Figure C-8.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. The early data yielded a transmissivity of 390 gpd/ft with a corresponding average hydraulic conductivity for the screened interval of 39 gpd/ft^2, or 5.2 ft/d. The very early data points fell off the line of fit shown on the graph, probably because the u value was greater than 0.05.

The late data shown in Figure C-8.2-2 suggested a formation transmissivity of 730 gpd/ft for the entire contiguous aquifer zone, consistent with previous results.

Because of the u-value limitations suggested by the data plot, the early-time data were analyzed using Theis curve matching as shown in Figure C-8.2-3. The data match was better than the straight-line fit, although a few of the early data points still fell off the type curve, likely an indication of inertial effects. (Because these data approached the type curve from above, rather than below, storage effects were ruled out.) The Theis analysis suggested a transmissivity value of 380 gpd/ft and a corresponding hydraulic conductivity of 38 gpd/ft^2, or 5.1 ft/d.

C-8.3 Well R-29 24-H Constant-Rate Pumping Test

Figure C-8.3-1 shows a semilog plot of the drawdown data collected during the 24-h pumping test. The data collected during the first 200 min of the test (at a pumping rate of 4.04 gpm) supported a transmissivity value calculation of 770 gpd/ft for the contiguous hydraulic unit penetrated by the well screen. This value was in agreement with previous results.

Between 200 and 900 min, the discharge rate increased steadily to 4.3 gpm, with a corresponding increase in drawdown. Analysis showed that the drawdown increase was greater than the discharge rate increase. It is likely that gas or air in the formation contributed to the unusual pumping rate and drawdown responses shown. For example, a gradual reduction in gas content in the pumped water would allow the

pump bowl to operate more efficiently, increasing the flow rate. Meanwhile, gradual accumulation of gas in the formation could reduce the permeability and increase the drawdown disproportionately. These explanations are speculative. However, it is certain that a submersible pump cannot produce both increased flow and increased head unless its efficiency changes, so it was likely that air or gas in the groundwater influenced the operation.

After a little more than 900 min of pumping, the discharge rate began to decline steadily throughout the balance of the pumping test, reaching 0.4 gpm by the end of the pumping period. As a result, the measured drawdown declined steadily as well. The gap in the data at around 1100 min occurred when the pumping rate was adjusted manually by reducing the pump rotational speed using the variable frequency drive unit operating the pump.

The drawdown data were replotted on a linear scale as shown in Figure C-8.3-2. Because late-time drawdown is roughly proportional to discharge rate, the shape of the drawdown curve can serve as a surrogate of the discharge rate itself. Thus, the linear drawdown plot conveyed a sense of the change that was occurring in the pumping rate late in the test, providing a vivid illustration of the observed reduction in discharge rate over time.

It was hypothesized that gas or air from the groundwater accumulated in the well casing beneath the inflatable packer forming a “bubble” above the pump. As the bubble grew, it pushed the water level in the casing lower, eventually driving it down to the pump intake. At that point, further accumulation of gas or air would effectively reduce the available drawdown for the pump, forcing a reduction in discharge rate.

Because of the dramatic changes in discharge rate during the final hours of pumping, the recovery data were not usable and are not included here.

C-8.4 Well R-29 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by R-29 to provide a frame of reference for evaluating the above analyses.

During the 24-h pumping test, the discharge rate remained constant at 4.04 gpm for 180 min with a drawdown of 6.55 ft, making the specific capacity 0.62 gpm/ft at that time. In addition to specific capacity and pumping time, other input values used in the calculations included a storage coefficient value of 0.1, an arbitrary aquifer thickness of 30 ft, and a borehole radius of 0.63 ft (inferred from the volume of filter pack required to backfill the screen zone).

Applying the Brons and Marting method to these inputs yielded a lower-bound hydraulic conductivity of 38 gpd/ft^2, or 5.1 ft/d. This value coincided with the average hydraulic conductivity obtained from analysis of the early recovery data from the trial pumping tests, providing good corroboration of the results.

C-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-29 to gain an understanding of the hydraulic characteristics of the Puye Formation sediments in which R-29 is screened. Several observations and conclusions were drawn for the tests as summarized below.

A comparison of barometric pressure and R-29 water-level data suggested a barometric efficiency near 100%.

Transmissivity values computed from early data averaged 380 gpd/ft, making the average hydraulic conductivity of the screened interval 38 gpd/ft^2, or 5.1 ft/d. The late data produced an average transmissivity of 720 gpd/ft, presumably the transmissivity of the contiguous aquifer of unknown thickness penetrated by the well.

R-29 produced 4.04 gpm with 6.55 ft of drawdown after 180 min of pumping, resulting in a specific capacity of 0.62 gpm/ft at that particular pumping time. The corresponding computed lower-bound hydraulic conductivity value was 38 gpd/ft^2, the same as the average of the pumping-test values.

After 180 min, the discharge rate and drawdown increased gradually over the next 12 h or so. It was presumed that varying gas or air content in the formation pores and pumped groundwater caused the observed changes.

During the final 8 h of the 24-h pumping test, the discharge rate declined steadily from 4.3 to 0.4 gpm. It was likely than accumulation of gas beneath the inflatable packer forced the water level down to the pump intake, restricting the available drawdown and, thus, reducing the pumping rate..

C-10.0 REFERENCES

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

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

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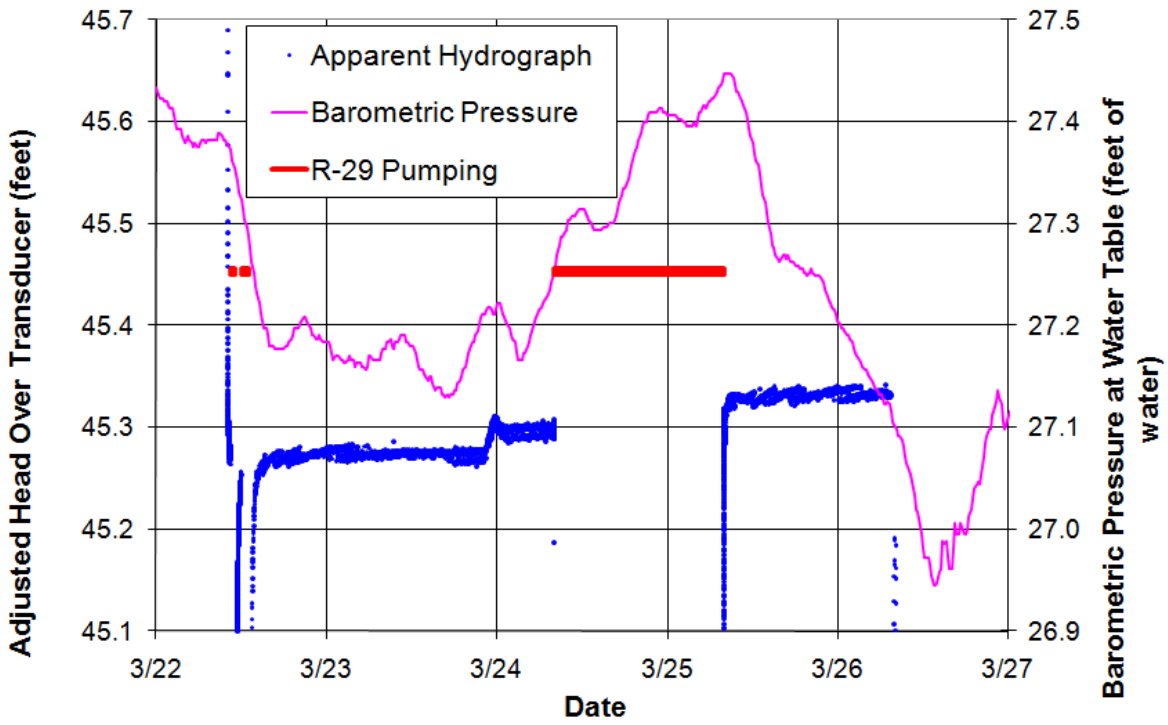


Figure C-7.0-1 Well R-29 apparent hydrograph

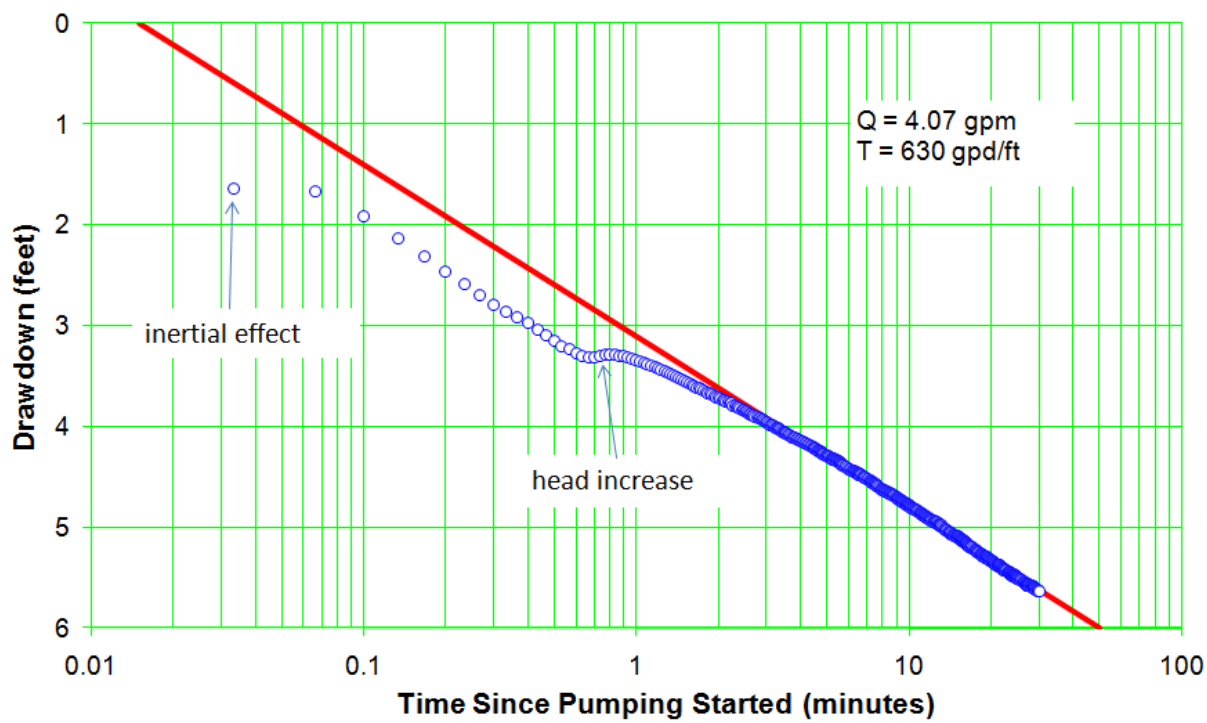


Figure C-8.1-1 Well R-29 trial 1 drawdown

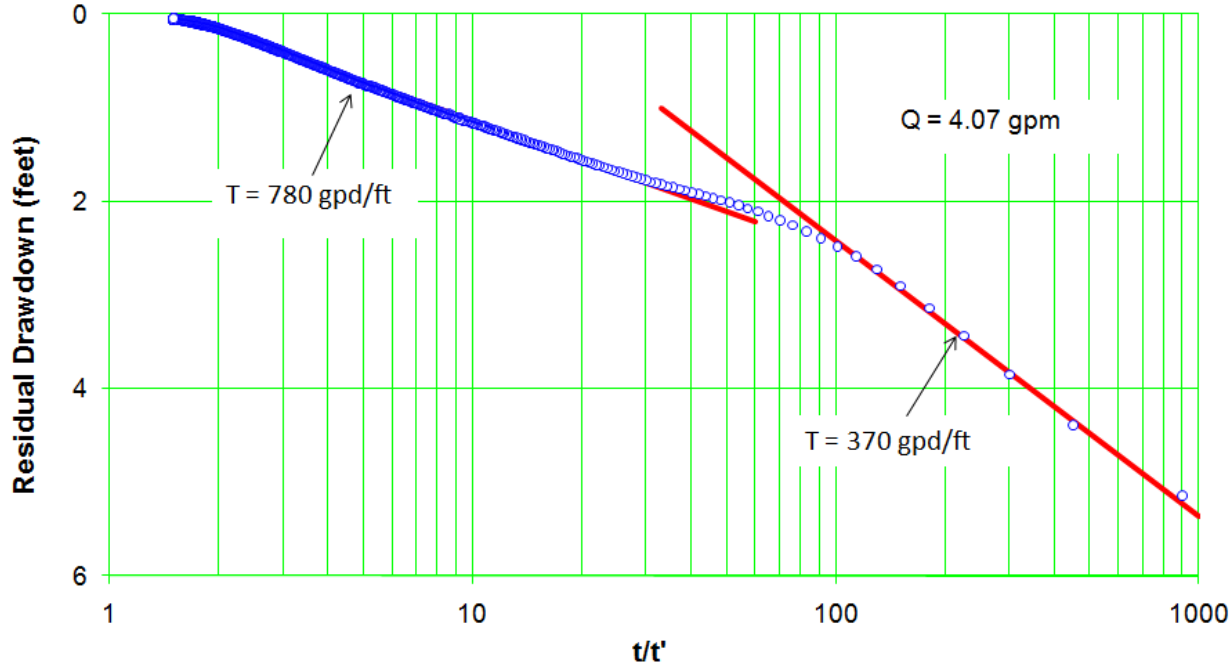


Figure C-8.1-2 Well R-29 trial 1 recovery

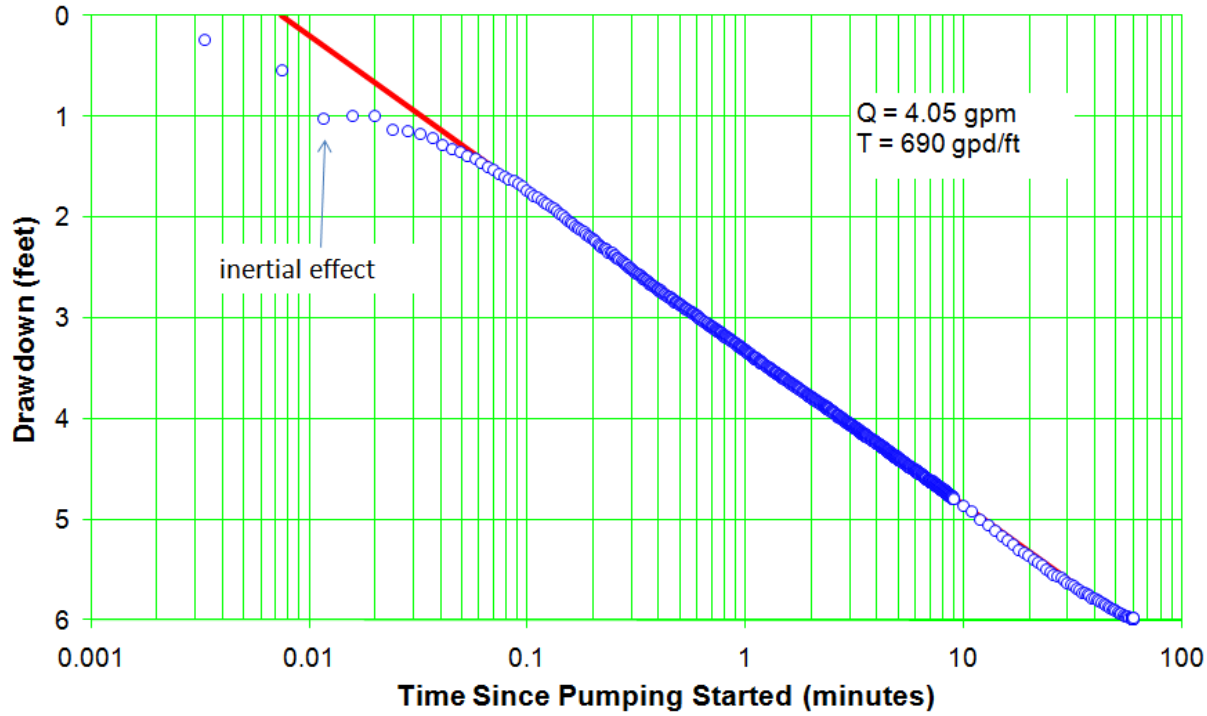


Figure C-8.2-1 Well R-29 trial 2 drawdown

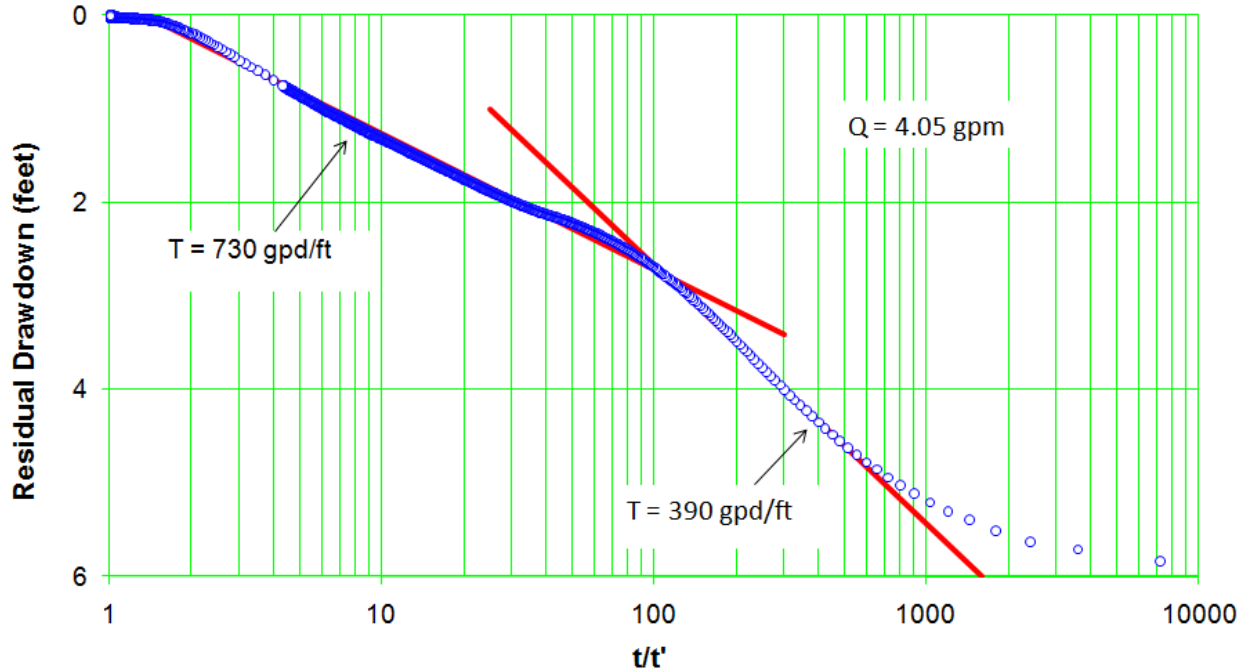


Figure C-8.2-2 Well R-29 trial 2 recovery

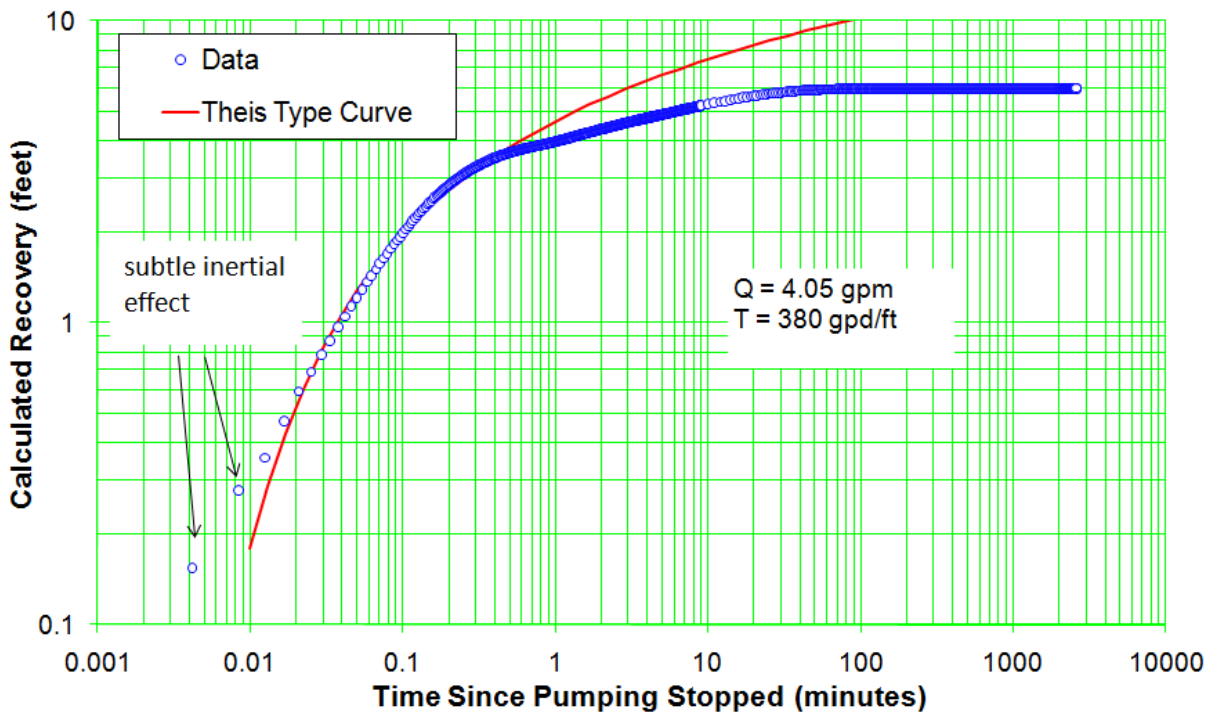


Figure C-8.2-3 Well R-29 trial 2 early recovery—Theis analysis

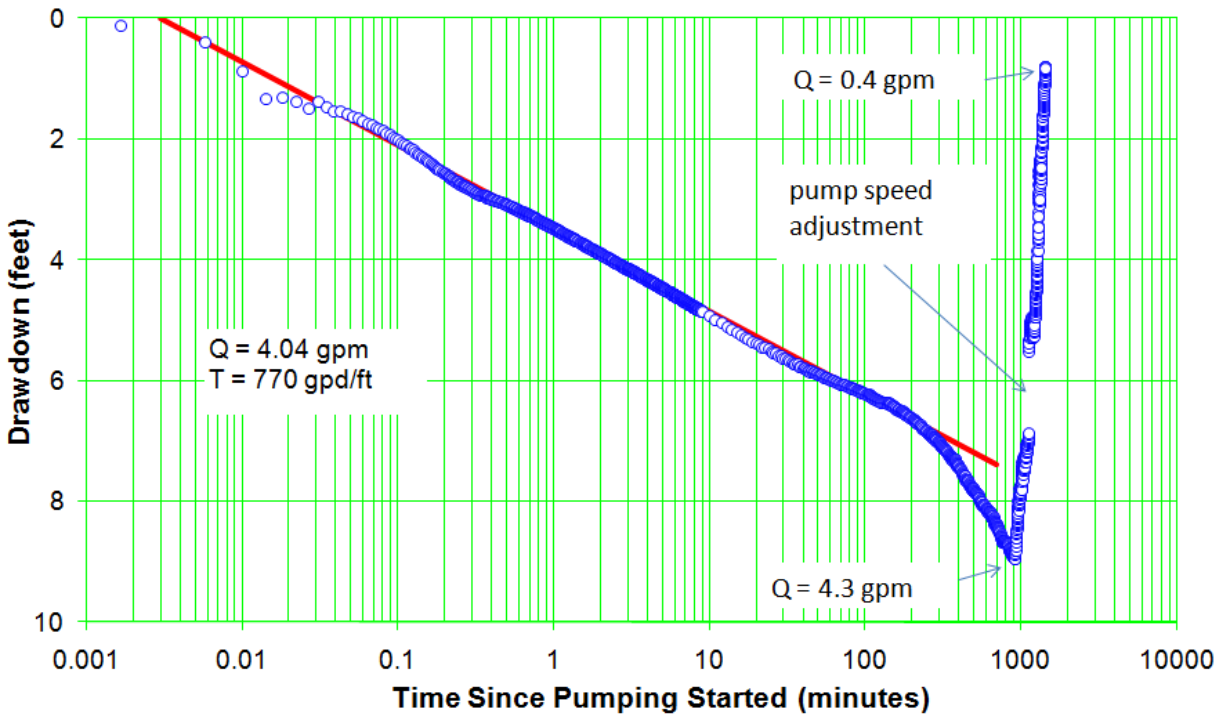


Figure C-8.3-1 Well R-29 drawdown

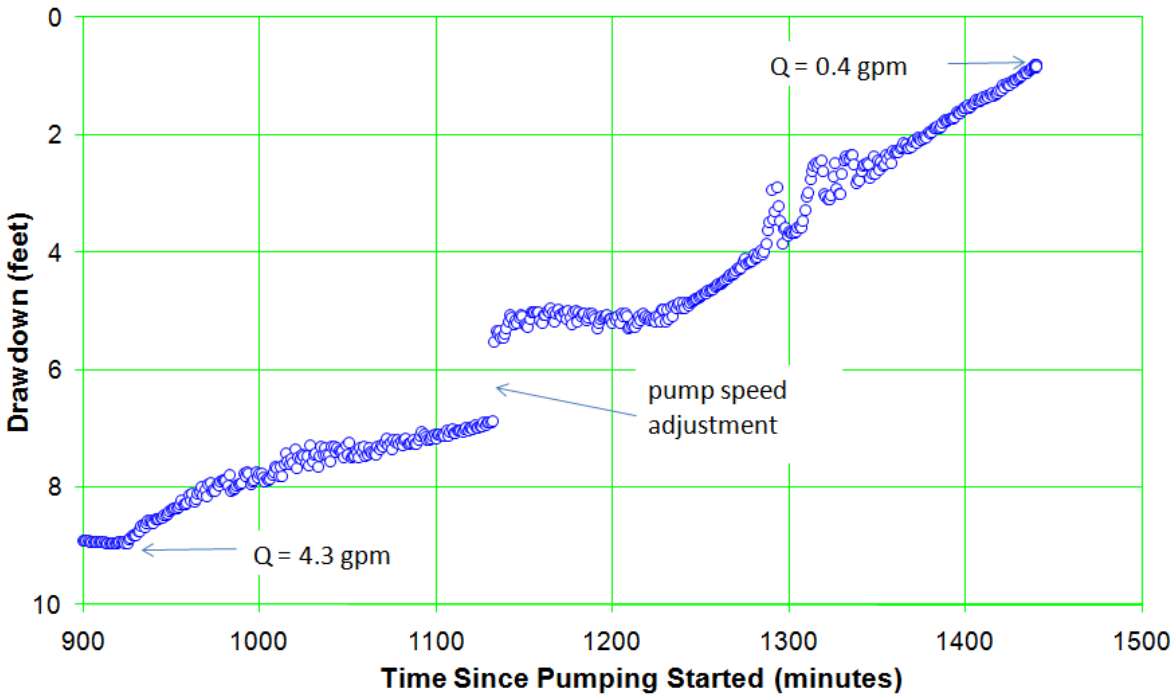


Figure C-8.3-2 Well R-29 drawdown—linear plot

Appendix D

Borehole Video Logging
(on DVD included with this document)

TO VIEW THE VIDEO THAT ACCOMPANIES THIS DOCUMENT, PLEASE CALL THE HAZARDOUS WASTE BUREAU AT 505-476-6000 TO MAKE AN APPOINTMENT

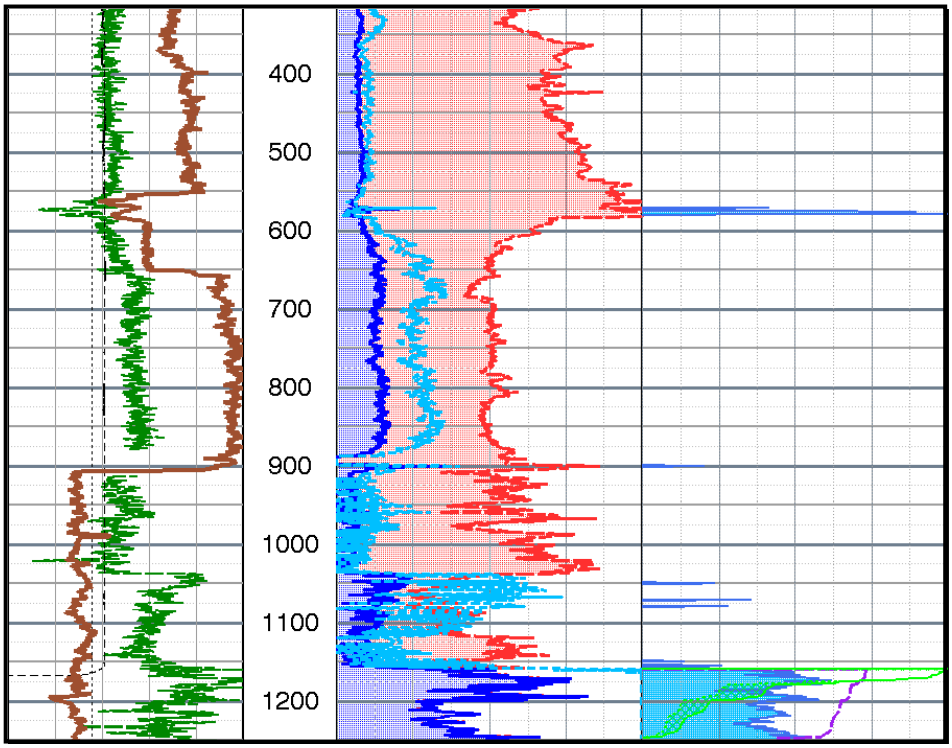
Appendix E

Geophysical Log Logging Report
(on CD included with this document)

DOE LANL Project Subcontract # 72006-000-009

Advanced Borehole Geophysical Logging of LANL Regional Monitoring and Characterization Well R-29

Los Alamos National Laboratory, New Mexico



Prepared for:

North Wind Inc.

Master Task Order Subcontract No. 10005S.03P

June 2010

Prepared by:

Schlumberger Water Services

Tucson, Arizona

Schlumberger WATER SERVICES

Table of Contents

Executive Summary 3
1. Introduction 7
2. Methodology 8
2.1. Acquisition Procedure 8
2.2. Log Quality Control and Assessment 9
2.3. Processing Procedure 11
2.3.1. Environmental Corrections and Raw Measurement Reprocessing 11
2.3.2. Depth-Matching 13
2.3.3. Integrated Log Analysis 13
3. Results 15
3.1. Well Fluid Level 16
3.2. Regional Aquifer 16
3.3. Vadose Zone Perched Water 17
3.4. Geology 17
3.5. Summary Logs 20
3.6. Integrated Log Montage 24
4. References 30

Attachments

Attachment 1 – Color Print of Integrated Log Well Montage for Well R-29
Attachment 2 – Color Print of ELAN Optimized Mineral and Pore Volume Model Results for Well R-29

Executive Summary

Geophysical logging was performed by Schlumberger in characterization well R-29 in February 2009 before well completion. The logging measurements were acquired from 32 to 1,243 feet (ft) below ground surface (bgs), when the borehole contained 12.1 inch (in.) inner diameter (ID) freestanding steel casing from ground surface to 1,185 ft and uncased borehole to 1,248 ft (measured total depth from the geophysical logs), drilled with an approximately 11.625 in. diameter bit size in the bottom section.

The primary purpose of the geophysical logging was to characterize the geology and hydrogeology across the depth section where well screens were being considered, with emphasis on determining regional aquifer groundwater level, relative water saturation, depths of porous aquifer zones, and stratigraphy/lithology of geologic units. These objectives were accomplished by measuring, nearly continuously, along the length of the well (1) total water-filled porosity from which, in combination with lithologic composition estimated from the other logs, an indirect estimate of hydraulic conductivity (production capacity) is made; (2) bulk density (sensitive to total water plus air-filled porosity and grain density); (3) neutron induced gamma ray spectroscopy, providing bulk concentrations of a number of important mineral-forming elements, as well as hydrogen; and (4) gross natural gamma ray.

The following Schlumberger geophysical logging tools were used in the project (Table 1):

- Accelerator Porosity Sonde (APS*);
- Triple Detector Litho-Density (TLD*) tool
- Elemental Capture Spectroscopy (ECS*) tool
- Hostile Natural Gamma Spectroscopy (HNGS*) and gamma ray (GR)

Table 1: Geophysical Logging Tool, Technology, Corresponding Measured Properties

Tool	Technology	Properties Measured
Accelerator Porosity Sonde (APS*)	Epithermal neutron porosity and neutron capture cross-section	Water/moisture content, lithologic variations
Triple Detector Litho-Density (TLD*)	Gamma-gamma bulk density	Bulk density, total porosity, lithology
Elemental Capture Spectroscopy (ECS*)	Neutron induced gamma ray spectroscopy	Formation matrix geochemistry, lithology and mineralogy, formation hydrogen content
Hostile Natural Gamma Spectroscopy (HNGS*) and gamma ray (GR)	Gross and spectral natural gamma ray, including potassium, thorium, and uranium concentrations	Formation matrix geochemistry, lithology and mineralogy

* Mark of Schlumberger

Once the North Wind Inc. well drilling project team provided Schlumberger final notification that R-29 was ready for geophysical well logging, the Schlumberger district in Farmington, NM, mobilized a wireline logging truck, the appropriate wireline logging tools and associated equipment, and crew to the job site. Table 2 summarizes the geophysical logging runs performed in R-29.

Table 2: Geophysical logging services, their combined tool runs and intervals logged, as performed by Schlumberger in well R-29

Date of Logging	Run #	Tool 1 (bottom)	Tool 2 (top)	Depth Interval (ft bgs)
27-Feb-2010	1	TLD	GR	40–1159
	2	ECS	GR	32–1175
	3	APS	GR	198–1243
	4	HNGS	GR	37–1240

Preliminary results of these measurements were generated in the logging truck at the time the geophysical services were performed and are documented in field logs provided on site. However, the measurements presented in the field results are not fully corrected for borehole conditions (particularly casing) and are provided as separate, individual logs. The field results were reprocessed by Schlumberger to (1) correct/improve the measurements, as best as possible, for borehole/formation environmental conditions; (2) perform an integrated analysis of the log measurements so that they are all coherent and provide consistent hydrogeologic and geologic results; and (3) combine the logs in a single presentation, enabling integrated interpretation. The reprocessed log results provide better quantitative property estimates that are consistent for all applicable measurements, as well as estimates of properties that otherwise could not be reliably estimated from the single measurements alone (e.g., total porosity inclusive of all water and air present, water saturation, relative hydraulic conductivity, lithology).

The geophysical log measurements from Well R-29 provide, overall, decent quality results that are consistent with each other across the logged interval. However, the existence, extent, and effect on the geophysical logs of a water or air-filled annulus between the casing and the borehole wall (voids behind the casing), especially prevalent and significant in this well, is difficult to determine and, thus, there is uncertainty about how well some of the log measurements represent true geologic formation conditions (unaffected by drilling). The distance between the logging tool sensor and formation is unknown and, thus, difficult to account or correct for. The measurements most affected by voids behind the casing were ones that have a shallow depth of investigation and that require close contact to the uncased borehole wall—the bulk density and the neutron porosity measurements (particularly the former). One indicator that the bulk density is being adversely affected by voids behind the casing is when the computed density porosity is unrealistically high. Where the total porosity estimated from the processed logs reaches above 55% the bulk density measurement is very likely being affected by voids. There are large sections of R-29 where the density porosity is unreasonably high, indicating the impact of annular voids on the density measurement (and, consequently, the derived total porosity): 37–88, 98–214, 225–266, 276–314, 350–410, 416–580, 957–966, 981–1034, 1165–1175, 1178–1180, 1188–1190, and 1240–1242 ft bgs. Through the integrated analysis and interpretation of all the logs, the individual shortcomings of the specific measurements are reduced. Thus, the results derived from integrated log analysis (e.g., the optimized water-filled porosity log)

are the most robust single representation of the geophysical log measurements—providing valuable high-resolution information on the geologic and hydrogeologic environment of the R-29 locale.

Important results from the processed geophysical logs in R-29 include the following:

1. The well standing water level in R-29 was 1152–1153 ft bgs at the time of logging, and did not vary much between the different logging runs.

2. The processed logs indicate that the intersected geologic section is fully saturated with water from the bottom of the borehole (1,248 ft bgs) to likely 1,152 ft bgs, which lies within alluvium/fanglomerate. Below 1,152 ft the log estimated water content increases significantly and total porosity come together, tracking each other to the bottom of the bulk density log at 1,159 ft (the TLD tool could not be run below since it contains a gamma ray source and the bottom of the borehole did not contain casing at the time of the logging). Water content ranges between 20 and over 40% of total rock/sediment volume from 1,152 ft to the bottom of the well (1,148 ft), very high values corresponding to water-filled borehole washouts. Above 1,152 ft the water content drops considerably to less than 15% and the total porosity ranges from 25 to over 50%. The estimated water saturation below 1,152 ft is 100% (relative to pore space volume) while above 1,152 ft it immediately drops to below 25%. Based on these results, the depth of the Regional Aquifer water level (depth at which there is full water saturation) is most likely in close proximity to 1,152 ft. Water content remains very low up to 1,100 ft (below 10%), then slowly increases up to 1,034 ft, but water saturation never increases above 60%.

3. Above 1,152 ft bgs, which the processed logs indicate to be within the vadose zone (above the top of the Regional Aquifer), the estimated water content ranges 7–20% of total rock volume up to 1,034 ft (generally increasing above 1,100 ft), dropping substantially above 1,034 ft to 0–10% (average about 4%). There is increased water content in the zone 893–901 ft, with a peak of 28% at 896 ft (corresponding water saturation is 40%). From 628 to 874 ft the water content is slightly elevated relative to much of the unsaturated zone, ranging 10–13%. Another peak in water content occurs at 566 ft (25% water content). However, there is no indication from the processed geophysical logs that any of these zones are fully saturated. Estimated water content above 566 ft is 8% or less.

4. The location of productive zones within the saturated section is difficult to determine due to the adverse cased well and borehole conditions (washouts and annular voids). Higher porosity is not necessarily indicative of higher production capacity since fine grained sediments often have higher porosity and lower productivity than coarser grained sediments. The highest porosities are likely associated with washouts (water-filled voids) behind the casing or in the uncased borehole section. The predicted relative flow capacity profile generated from the integrated log analysis estimated permeability results suggest that the most productive intervals are 1158–1162, 1166–1175, 1189–1195, 1208–1216, and 1234–1243 ft bgs.

5. The geophysical log results clearly delineate that the saturated/water-filled section of the borehole consists of alluvium/fanglomerate that extends into the unsaturated section probably all the way up to the bottom of the volcanic tuff section at 904 ft bgs. Through this alluvium/fanglomerate

interval the integrated log analysis results indicate varying small amounts of clay (montmorillinite). The geophysical log response in the zone above 903 ft is characteristic of the Guaje Pumice Bed, with a large increase in thorium and uranium concentrations, although it is difficult to delineate the top of the pumice bed from the geophysical logs alone (possibly 888 or 893 ft). The log results corroborate volcanic tuff overlying the Guaje and extending to the top of the log interval (32 ft), with zonal variations in density/porosity and geochemical signature, although it is possible the top section is alluvium composed of reworked tuff-like material. A significant change (reduction) in thorium and uranium concentrations, as well as in the neutron capture cross section measurement, occurs in the interval 547–582 ft, possibly corresponding to a different tuff bed.

1. Introduction

Geophysical logging services were performed in characterization well R-29 by Schlumberger in February 2010 before initial well completion. The purpose of these services was to acquire in-situ measurements to help characterize the near-borehole geologic formation environment. The primary objective of the geophysical logging was to provide in-situ evaluation of formation properties (hydrogeology and geology) intersected by the well. This information was used by scientists, engineers, and project managers in the Los Alamos Characterization and Monitoring Well Project to help design the well completion, to better understand subsurface site conditions, and assist in overall decision-making.

The primary geophysical logging tools used by Schlumberger in well R-29 were the

- Array Porosity Sonde (APS*), which measures, through casing and in water or air-filled hole, volumetric water content of the formation at several depths of investigation to evaluate moist/porous zones using a pulsed epithermal neutron measurement, as well as neutron capture cross section, which is sensitive to water and clay content;

- Triple Detector Litho-Density (TLD*) tool, which measures formation bulk density through casing to estimate total porosity;

- Elemental Capture Spectroscopy (ECS*) tool, which measures neutron-induced spectral gamma ray activity; this determines elemental weight fraction concentrations of a number of key rock-forming elements used to characterize geochemistry, mineralogy, and lithology of the formation, as well as hydrogen content (closely related to water content); and

- Hostile Natural Gamma Spectroscopy (HNGS*) tool, which measures gross natural gamma and spectral natural gamma ray activity, including potassium, thorium, and uranium concentrations, to evaluate geology/lithology, particularly the amount of thorium and potassium-bearing minerals.

Calibrated gross gamma ray (GR) was recorded with every service for the purpose of correlating depths between the different logging runs. Table 3 summarizes the geophysical logging runs performed in R-29.

Table 3: Geophysical logging services, their combined tool runs and intervals logged, as performed by Schlumberger in borehole R-29

Date of Logging	Borehole Status	Run #	Tool 1 (bottom)	Tool 2 (top)	Depth Interval (ft bgs)
27-Feb-2010	Single string of 12.1 in. ID steel free-standing casing from surface to 1,185 ft and uncased borehole to the bottom at 1248 ft, with bit size of ~11.625 in. across the bottom section	1	TLD	GR	40–1159
		2	ECS	GR	32–1175
		3	APS	GR	198–1243
		4	HNGS	GR	37–1240

A more detailed description of these geophysical logging tools can be found on the Schlumberger website (http://www.slb.com/content/services/evaluation/index.asp?).

2. Methodology

This section describes the methods Schlumberger employed for geophysical logging of Well R-29, including the following stages/tasks:

- Measurement acquisition at the well site
- Quality assessment of logs
- Reprocessing of field data

2.1. Acquisition Procedure

Once the well drilling project team notified Schlumberger that R-29 was ready for geophysical well logging, the Schlumberger district in Farmington, NM, mobilized a wireline logging truck, the appropriate wireline logging tools and associated equipment, and crew to the job site. Upon arriving at the LANL site, the crew completed site-entry paperwork and received a site-specific safety briefing.

After arriving at the well site, the crew proceeded to rig up the wireline logging system, including:

1. Parking and stabilizing the logging truck in a position relative to the borehole that was best for performing the surveys
2. Setting up a lower and an upper sheave wheel (the latter attached to, and hanging above, the borehole from the drilling rig)
3. Threading the wireline cable through the sheaves
4. Attaching to the end of the cable the appropriate sonde(s) for the first run

Next, pre-logging checks and any required calibrations were performed on the logging sondes, and the tool string was lowered into the borehole. If any of the tools required active radioactive sources (in this case, a neutron and gamma source for the ECS and TLD, respectively) the sources were taken out of their carrying shields and placed in the appropriate tool source-holding locations using special source-handling tools just before lowering the tool string. The tool string was lowered to the bottom of the borehole and brought up at the appropriate logging speed as measurements were made. At least two logging runs (one main and one repeat) were made with each tool string.

Upon reaching the surface, any radioactive sources were removed from the tools and were returned to their appropriate storage shields, thus eliminating any radiation hazards. Any post-logging measurement checks were performed as part of log quality control and assurance. The tool string was cleaned as it was pulled out of the hole, separated, and disconnected.

The second tool string was attached to the cable for another logging run, followed by subsequent tool strings and logging runs. After the final logging run was completed, the cable and sheave wheels were rigged down.

Before departure, the logging engineer printed field logs and created a compact disc containing the field log data for on-site distribution and sent the data via satellite to the Schlumberger data storage center. The Schlumberger Water Services data processing center was alerted that the data were ready for post-acquisition processing.

2.2. Log Quality Control and Assessment

Schlumberger has a thorough set of procedures and protocols for ensuring that the geophysical logging measurements are of very high quality. This includes full calibration of tools when they are first built,

regular recalibrations and tool measurement/maintenance checks, and real-time monitoring of log quality as measurements are made. Indeed one of the primary responsibilities of the logging engineer is to ensure, before and during acquisition, that the log measurements meet prescribed quality criteria.

A tool-specific base calibration that directly relates the tool response to the physical measurement using the designed measurement principle is performed on all Schlumberger logging tools when first assembled in the engineering production centers. This is accomplished through a combination of computer modeling and controlled measurements in calibration models with known chemical and physical properties.

The base calibration for most Schlumberger tools is augmented through regular "master calibrations" typically performed every one to six months in local Schlumberger shops (such as Farmington, NM), depending on tool design. Master calibrations consist of controlled measurements using specially designed calibration tanks/jigs and internal calibration devices that are built into the tools, both with known physical properties. The measurements are used to fine-tune the tool's calibration parameters and to verify that the measurements are valid.

In addition, on every logging job, before and after on-site "calibrations" are executed for most Schlumberger tools directly before/after lowering/removing the tool string from the borehole. For most tools, these represent a measurement verification instead of an actual calibration used to confirm the validity of the measurements directly before acquisition and to ensure that they have not drifted or been corrupted during the logging job.

All Schlumberger logging measurements have a number of associated depth-dependent quality control (QC) logs and flags to assist with identifying and determining the magnitude of log quality problems. These QC logs are monitored in real-time by the logging engineer during acquisition and are used in the post-acquisition processing of the logs to determine the best processing approach for optimizing the overall validity of the property estimates derived from the logs.

Additional information on specific tool calibration procedures can be found on the Schlumberger web page (http http://www.slb.com/content/services/evaluation/index.asp).

The geophysical log measurements from Well R-29 provide, overall, decent quality results that are consistent with each other across the logged interval. However, the existence, extent, and effect on the geophysical logs of a water or air-filled annulus between the casing and the borehole wall (voids behind the casing), especially prevalent and significant in this well, is difficult to determine and, thus, there is uncertainty about how well some of the log measurements represent true geologic formation conditions (unaffected by drilling). The distance between the logging tool sensor and formation is unknown and, thus, difficult to account or correct for. The measurements most affected by voids behind the casing were ones that have a shallow depth of investigation and that require close contact to the uncased borehole wall—the bulk density and the neutron porosity measurements (particularly the former). One indicator that the bulk density is being adversely affected by voids behind the casing is when the computed density porosity is unrealistically high. Where the total porosity estimated from the processed logs reaches above 55% the bulk density measurement is very likely being affected by voids. There are large sections of R-29 where the density porosity is unreasonably high, indicating the impact of annular voids on the density measurement (and, consequently, the derived total porosity): 37–88, 98–214, 225–266, 276–314, 350–410, 416–580, 957–966, 981–1034, 1165–1175, 1178–1180, 1188–1190, and 1240–1242 ft bgs.

2.3. Processing Procedure

After the geophysical logging job was completed in the field and the data was archived, the data was downloaded to the Schlumberger processing center. There, the data were processed in the following sequence: (1) the measurements were corrected for near-wellbore environmental conditions and the measurement field processing for certain tools (in this case, the TLD, APS and ECS) was redone using better processing algorithms and parameters, (2) the log curves from different logging runs were depth matched and spliced, if required, and (3) the near-wellbore substrate lithology/mineralogy and pore fluids were modeled through integrated log analysis. Afterwards, an integrated log montage was built to combine and compile all the processed log results.

2.3.1. Environmental Corrections and Raw Measurement Reprocessing

If required, the field log measurements were processed to correct for conditions in the well, including fluid type (water or air), presence of steel casing, and (to a much lesser extent) pressure, temperature, and fluid salinity. Basically, these environmental corrections entail subtracting from the measurement response the

known influences of the set of prescribed borehole conditions. In R-29, the log measurements requiring these corrections are the APS porosity, TLD bulk formation density, ECS elemental concentrations, and HNGS spectral gamma ray logs.

Two neutron porosity measurements are available – one that measures thermal ("slow") neutrons and one that measures epithermal ("fast") neutrons (the APS tool). Measurement of epithermal neutrons is required to make neutron porosity measurements in air-filled holes. In water/mud-filled holes, both the epithermal and thermal neutron measurements are valid. Both measurements can be environmentally corrected for a single string of steel-casing. Epithermal neutron porosity measurements were made in R-29. The APS measurements were reprocessed for casing, borehole fluid type (air versus water), and other environmental conditions. The APS also makes a measurement of neutron capture cross section; this measurement was also corrected for well environmental conditions at the time of logging. For further processing and analysis (e.g., integrated log analysis), the reprocessed neutron porosity and neutron capture cross section logs were used.

The raw ECS elemental yield measurements include the contribution of iron from steel casing. The processing consists of subtracting this unwanted contribution from the raw normalized yield, then performing the normal elemental yields-to-weight fraction processing. The contribution to subtract is a constant baseline amount (or zoned constant values if there are bit/casing size changes), usually determined by comparing the normalized raw yields in zones directly below/above the borehole casing/fluid change. Casing corrections were applied to the ECS logs across the entire log interval, attempting to account for one string of steel casing below 57 ft and multiple strings above.

The HNGS spectral gamma ray is affected by the material (fluid, air, and casing) in the borehole because different types and amounts of these materials have different gamma ray shielding properties; the HNGS measures incoming gamma rays emitted by radioactive elements in the formation surrounding the borehole. The processing algorithms try to correct for the damping influence of the borehole material. The HNGS logs from R-29 were reprocessed to account, as best as possible, for the environmental effects of the casing (above 1,185 ft), borehole fluid (water below 1,152 ft and air above), and hole size.

The measurements cannot be fully corrected for borehole washouts or rugosity since the specific characteristics (e.g., geometry) of these features are unknown (especially in this scenario where they are

hidden by casing) and their effects on the measurements are often too significant to account for. Thus, the compromising effects of these conditions on the measurements should be accounted for in the interpretation of the log results.

2.3.2. Depth-Matching

Once the logs were environmentally corrected for the conditions in the borehole and the raw measurement reprocessing was completed, the logs from different tool runs were depth-matched to each other, as needed, using the gross gamma ray log, acquired in all the logging runs, for depth correlation, or other logs that are well correlated (e.g., porosity). The depth reference for all field prints and processed logs, including those presented in this report, is ground surface.

2.3.3. Integrated Log Analysis

An integrated log analysis, using as many of the processed logs as possible, was performed to model the near-wellbore substrate lithology/mineralogy and pore fluids. This analysis was performed using the Elemental Log Analysis (ELAN) program (Juneer and Sibbit, 1980; Quieren et al, 1986) – a petrophysical interpretation program designed for depth-by-depth quantitative formation evaluation from borehole geophysical logs. ELAN estimates the volumetric fractions of user-defined rock matrix and pore constituents at each depth based on the known log measurement responses to each individual constituent by itself. ELAN requires an a priori specification of the volume components present within the formation, i.e., fluids, minerals, and rocks. For each component, the relevant response parameters for each measurement are also required. For example, if one assumes that quartz is a volume component within the formation and the bulk density tool is used, then the bulk density parameter for this mineral is well known to be 2.65 grams per cubic centimeter (g/cc).

The logging tool measurements, volume components, and measurement response parameters used in the ELAN analysis for R-29 are provided in Table 4. The final results of the analysis – an optimized mineral-fluid volume model – are shown on the integrated log montage (see Attachment 1), 6th track from the right (inclusive of the depth track). In addition, the ELAN program provides a direct comparison of the modeled versus the actual measured geophysical logs, as well as a composite log of all of the key ELAN-derived results, including geologic/hydrogeologic properties computed from the mineral-fluid volume model (see Attachment 2). To make best use of all the measurement data and to perform the analysis across as much

of the well interval as possible (38 to 1,243 ft bgs), as many as possible of the processed logs were included in the analysis, with less weighting applied to less robust logs. Not all of the tool measurements shown in Table 4 and the ELAN modeled versus measured log display are used for the entire interval analyzed, as not all the measurements are available, or of good quality, across certain sections of the borehole. To accommodate fewer tool measurements, certain model constituents are removed from the analysis in some intervals. In particular, no moisture/water content measurement was available above 198 ft so water was removed from the analysis above this depth.

The ELAN analysis was performed with as few constraints or prior assumptions as possible. A considerable effort was made to choose a set of minerals or mineral types for the model that is representative of Los Alamos area geology and its volcanic origins. For the ELAN analysis, the log interval from 38 to 908 ft bgs was assumed to be volcanic tuff or pumice, and a mineral suite considered representative of this volcanic tuff, based on LANL cuttings mineral analysis, was used (primary "minerals" silica glass/cristobalite/tridymite [indistinguishable from the log measurements], quartz, and potassium feldspar). The results of laboratory analyses of Bandelier Tuff and Puye Formation samples from around the LANL site were also used to constrain the proportion of quartz versus the combination of glass/cristobalite/tridymite in the ELAN analysis. The log interval 908 to 1,243 ft bgs was assumed to be the Puye Formation, or fanglomerate/alluvium with somewhat similar composition, and a mineral suite considered representative of this geology, based on LANL cuttings mineral analysis, was used (primary "minerals" silica glass/cristobalite/tridymite [indistinguishable from the log measurements], plagioclase and potassium feldspar; quartz at a defined small fraction of the silica glass content; with possible accessory/trace minerals biotite, augite, hematite, and pyrite).

No prior assumption is made about water saturation—where the boundary between saturated and unsaturated zones lies (e.g., the depth to the top of the regional aquifer or perched zones). However, water was not included in the analysis above 198 ft bgs, as mentioned above, because there are no log measurements sensitive to water above that depth. There is no way to objectively correct for the adverse effect on the log measurements from borehole washouts; therefore the decision was made to perform the ELAN analysis so as to primarily honor the log measurements (other than the total porosity constraint). Accordingly, interpretations should be made from the ELAN results with the understanding that the mineral-fluid model represents a mathematically optimized solution that is not necessarily a physically accurate

representation of the native geologic formation. Within this context, the ELAN model is a robust estimate of the bulk mineral-fluid composition that accounts for the combined response from all the geophysical measurements.

Table 4: Tool measurements, volumes, and respective parameters used in the well R-29 ELAN analysis

Volume / Tool Measurement	Air	Water	Hematite	Labradorite	Silica Glass, Cristo., Tridy.	Magnetite	Augite	Montmorillinite	Biotite	Pyrite	Orthoclase	Calcite	Quartz
Bulk density (g/cc)	–0.19	1.00	5.16	2.68	2.33	5.08	3.08	2.02	3.04	4.99	2.54	2.71	2.64
Epithermal neutron poro. (ft^3/ft^3)	0	1.00	0.06	-0.01	0.0	0.022	-0.01	0.6	0.14	0.165	-0.01	0.0	-0.05
Dry weight silicon (lbf/lbf)	0.0	0.0	0.0	0.247	0.468	0.184	0.225	0.242	0.178	0.0	0.3	0.0	0.468
Dry weight calcium (lbf/lbf)	0.0	0.0	0.0	0.09	0.0	0.0	0.10	0.012	0.007	0.0	0.0	0.405	0.0
Dry weight iron (lbf/lbf)	0.0	0.0	0.70	0.023	0.0	0.22	0.112	0.02	0.199	0.466	0.015	0.0	0.0
Dry weight sulfur (lbf/lbf)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.535	0.0	0.0	0.0
Dry weight titanium (lbf/lbf)	0.0	0.0	0.01	0.0	0.0	0.0	0.048	0.001	0.016	0.0	0.0	0.0	0.0
Wet weight potassium (lbf/lbf)	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.004	0.070	0.0	0.12	0.0	0.0
Wet weight thorium (ppm)	0.0	0.0	0.0	3	2	10	10	44	50	0	7	0	0
Neutron capture cross section (cu)	0	22.21	101.4	7.87	4	103	25.66	20	54.1	90	15.82	7.4	4.7

ft^3 = cubic feet
ppm = parts per million
cu = neutron capture units
lbf = pounds force
g/cc = grams per cubic centimeter

3. Results

Preliminary results from the wireline geophysical logging measurements acquired by Schlumberger in R-29 were generated in the logging truck at the time the geophysical services were performed and were documented in the field logs provided on site. However, the measurements presented in the field results are not fully corrected for undesirable influence (from a measurement standpoint) of borehole and geologic conditions and are provided as separate, individual logs. The field log results have been processed (1) to correct/improve the measurements, as best as possible, for borehole/formation environmental conditions, and (2) to ensure that all the logs from different tool runs are on depth. Additional logs were generated

from integrated analysis of processed measured logs, providing valuable estimates of key geologic and hydrologic properties.

The processed log results are presented as continuous curves of the processed measurement versus depth and are displayed as (1) a one-page, compressed summary log display for selected directly related sets of measurements (see Figures 1, 2, and 3); and (2) an integrated log montage that contains all the key processed log curves, on depth and side by side (see Attachment 1). The summary log displays address specific characterization needs, such as porosity, production capacity, moisture content, water saturation, and lithologic changes. The purpose of the integrated log montage is to present, side by side, all the most salient processed logs and log-derived models, depth-matched to each other, so that correlations and relationships between the logs can be identified.

Important results from the processed geophysical logs in R-29 are described below.

3.1. Well Fluid Level

The well standing water level in R-29 (within the freestanding 12.1 in. ID casing) was 1152–1153 ft bgs at the time of logging, and did not vary much between the different logging runs.

3.2. Regional Aquifer

The processed logs indicate that the intersected geologic section is fully saturated with water from the bottom of the borehole (1,248 ft bgs) to likely 1,152 ft bgs, which lies within alluvium/fanglomerate. Below 1,152 ft the log estimated water content increases significantly and total porosity come together, tracking each other to the bottom of the bulk density log at 1,159 ft (the TLD tool could not be run below since it contains a gamma ray source and the bottom of the borehole did not contain casing at the time of the logging). Water content ranges between 20 and over 40% of total rock/sediment volume from 1,152 ft to the bottom of the well (1,148 ft), very high values corresponding to water-filled borehole washouts. Above 1,152 ft the water content drops considerably to less than 15% and the total porosity ranges from 25 to over 50%. The estimated water saturation below 1,152 ft is 100% (relative to pore space volume) while above 1,152 ft it immediately drops to below 25%.

Conclusions that can be drawn from these geophysical log results are that the Regional Aquifer water level (depth at which there is full water saturation) is most likely 1,152 ft. Water content is very low up to 1,100 ft (below 10%), then slowly increases up to 1,034 ft, but water saturation never increases above 60%.

The location of productive zones within the saturated section is difficult to determine due to the adverse cased well and borehole conditions (washouts and annular voids). Higher porosity is not necessarily indicative of higher production capacity since fine grained sediments often have higher porosity and lower productivity than coarser grained sediments. The highest porosities are likely associated with washouts (water-filled voids) behind the casing or in the uncased borehole section. The predicted relative flow capacity profile generated from the integrated log analysis estimated permeability results suggest that the most productive intervals are 1158–1162, 1166–1175, 1189–1195, 1208–1216, and 1234–1243 ft bgs (see porosity summary display in Figure 1 or integrated log montage in Attachment 1).

3.3. Vadose Zone Perched Water

As mentioned above, the depth to the top of the Regional Aquifer and, thus, the extent of the vadose zone most likely extends above 1,152 ft bgs. Above 1,152 ft bgs the estimated water content ranges 7–20% of total rock volume up to 1,034 ft (generally increasing above 1,100 ft), dropping substantially above 1,034 ft to 0–10% (average about 4%). There is increased water content in the zone 893–901 ft, with a peak of 28% at 896 ft (corresponding water saturation is 40%). From 628 to 874 ft the water content is slightly elevated relative to much of the unsaturated zone, ranging 10–13%. Another peak in water content occurs at 566 ft (25% water content). However, there is no indication from the processed geophysical logs that any of these zones are fully saturated. Estimated water content above 566 ft is 8% or less.

3.4. Geology

The processed geophysical log results, particularly the matrix geochemistry logs, provide information on lithology and potential formation contacts intersected by R-29 across the log interval (from 38 to 1,243 ft bgs). The generalized geologic stratigraphy observed from the logs across the measured interval is as follows (depth below ground surface):

- **<u>38–130 ft bgs (top of log interval):</u> Very high porosity silicon and potassium rich material (likely surface alluvium or volcanic tuff)** – characterized by very high total porosity (40–80% of

total rock volume, assuredly elevated due to voids behind the casing); high silica glass/tridymite/cristobalite and/or quartz content; moderate potassium feldspar; and trace to minor amounts of augite, calcite, pyrite or similar minerals

- **130–170 ft bgs: Extremely high porosity silicon and potassium rich material (likely surface alluvium or volcanic tuff)** – characterized by unrealistically high total porosity (close to 100%, obviously elevated due to voids behind the casing); high silica glass/tridymite/cristobalite and/or quartz content; and trace to minor amounts of augite, calcite, pyrite or similar minerals

- **170–262 ft bgs: Very high porosity silicon and potassium rich volcanic tuff** – characterized by very high total porosity (over 50%, likely elevated due to voids behind the casing); high silica glass/tridymite/cristobalite and/or quartz content; moderate potassium feldspar; and trace to minor amounts of augite and calcite or similar minerals

- **262–372 ft bgs: Very high porosity silicon and potassium rich volcanic tuff** – characterized by very high total porosity (40–65%, the highest porosities likely elevated due to voids behind the casing); high silica glass/tridymite/cristobalite and/or quartz content; moderate potassium feldspar; and trace to minor amounts of augite and calcite or similar minerals

- **372–548 ft bgs: Very high porosity silicon and thorium rich volcanic tuff** – characterized by very high total porosity (50–75%, likely elevated due to voids behind the casing); high silica glass/tridymite/cristobalite and/or quartz content; moderate potassium feldspar; and trace to minor amounts of augite and calcite or similar minerals

- **548–581 ft bgs: Extremely high porosity silicon rich volcanic tuff** – characterized by unrealistically high total porosity (close to 100%, obviously elevated due to voids behind the casing); high silica glass/tridymite/cristobalite and/or quartz content; moderate potassium feldspar; and trace to minor amounts of augite and calcite or similar minerals

- **581–888 ft bgs: High porosity silicon, thorium, and uranium rich volcanic tuff** – characterized by high total porosity (38–55%); high silica glass/tridymite/cristobalite and/or quartz

content; moderate potassium feldspar; and trace to minor amounts of augite and calcite or similar minerals

- **888–903 ft bgs: Very high porosity, silicon, thorium and uranium rich volcanic tuff (likely Guaje Pumice Bed)** – characterized by very high total porosity (45 to over 60); high silica glass/tridymite/cristobalite and/or quartz content; moderate potassium feldspar; and trace to minor amounts of augite and calcite or similar minerals

- **903–1,033 ft bgs: Very high, highly variable porosity, silicon-rich alluvium/fanglomerate** – characterized by variably high to unrealistically high total porosity (30–60%); high silica glass/tridymite/cristobalite or quartz content; highly varying minor to high amounts of plagioclase feldspar; moderate potassium feldspar; and trace to minor amounts of montmorillinite, augite, biotite, magnetite, hematite and pyrite (or similar minerals)

- **1,033–1,112 ft bgs: Moderate to high porosity, silicon-rich alluvium/fanglomerate** – characterized by moderate to high total porosity (18–38%); high silica glass/tridymite/cristobalite or quartz content; highly varying minor to high amounts of plagioclase feldspar; moderate potassium feldspar; and varying trace to minor amounts of montmorillinite, augite, biotite, magnetite, hematite and pyrite (or similar minerals)

- **1,112–1,196 ft bgs: Very high, highly variable porosity, silicon-rich alluvium/fanglomerate** – characterized by variably high to unrealistically high total porosity (30–60%); high silica glass/tridymite/cristobalite or quartz content; highly varying minor to high amounts of plagioclase feldspar; moderate potassium feldspar; and trace to minor amounts of montmorillinite, augite, biotite, magnetite, hematite and pyrite (or similar minerals)

- **1,196–1,243 ft bgs (bottom of log interval): Moderate to high porosity, silicon-rich alluvium/fanglomerate** – characterized by moderate to high total porosity (20–40%); high silica glass/tridymite/cristobalite or quartz content; highly varying minor to high amounts of plagioclase feldspar; moderate potassium feldspar; and varying trace to minor amounts of montmorillinite, augite, biotite, magnetite, hematite and pyrite (or similar minerals)

3.5. Summary Logs

Three summary log displays have been generated for R-29 to highlight the key hydrogeologic and geologic information provided by the processed geophysical log results:

- Porosity and hydrogeologic properties summary log showing continuous hydrogeologic property logs, including total porosity (water and air), water-filled porosity, water saturation, estimated hydraulic conductivity, transmissivity, and relative producibility (production capacity); highlights key derived hydrologic information obtained from the integrated log results, including (Figure 1)
- Density and clay content summary showing a continuous logs of formation bulk density and estimated grain density, as well as estimated clay volume, highlights key geologic rock matrix information obtained from the log results (Figure 2)
- Geochemical and lithology summary showing a high vertical resolution, continuous volumetric analysis of formation mineral and pore fluid composition (based on an integrated analysis of the logs), and elemental concentration logs from the ECS geochemical measurement (neutron induced gamma ray spectroscopy); highlights the geologic lithology, stratigraphy, and correlation information obtained from the log results (Figure 3)

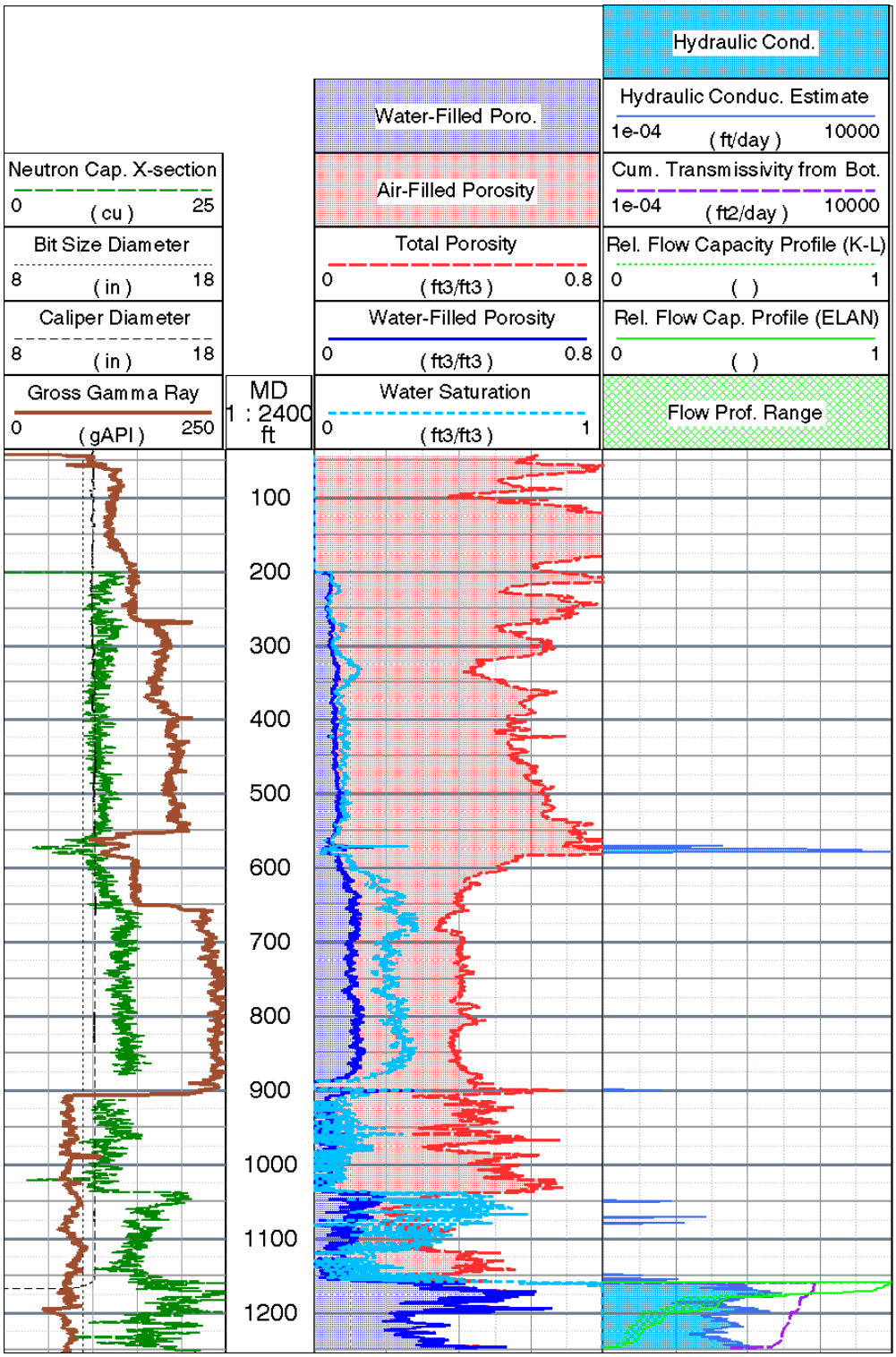


Figure 1: Summary of porosity logs in R-29 borehole from processed geophysical logs, interval of 37 to 1,243 ft bgs, with caliper, gross gamma, neutron capture cross-section, water saturation, estimated relative flow capacity profile, hydraulic conductivity, and transmissivity logs also displayed. Porosity, water saturation, and hydraulic conductivity logs are derived from the ELAN integrated log analysis.

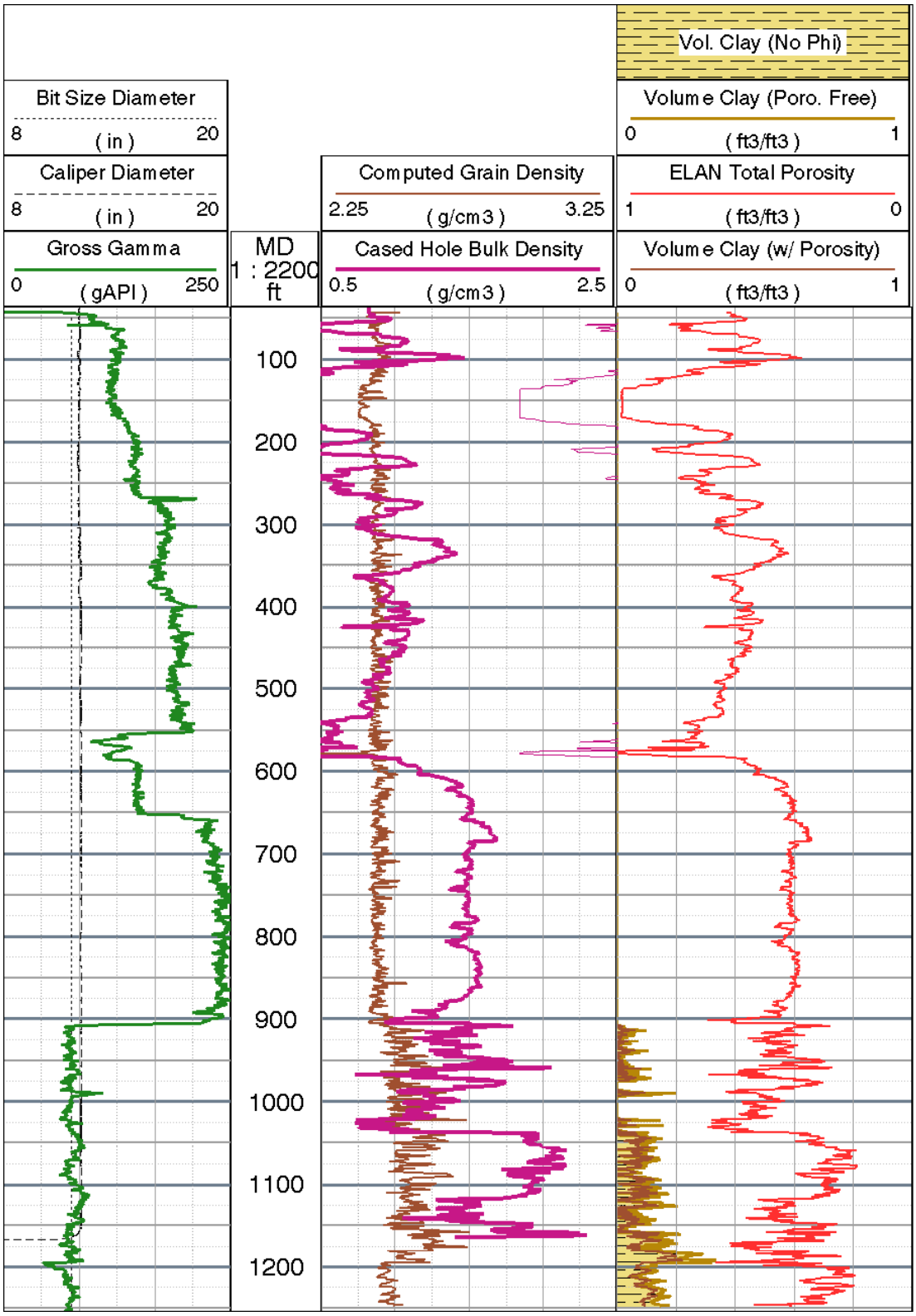


Figure 2: Summary of bulk density and apparent grain density logs in R-29 borehole from processed geophysical logs, interval of 37 to 1,243 ft bgs. Also shown are caliper, gross gamma, volume of clay, and total porosity logs (the latter two derived from the ELAN analysis).

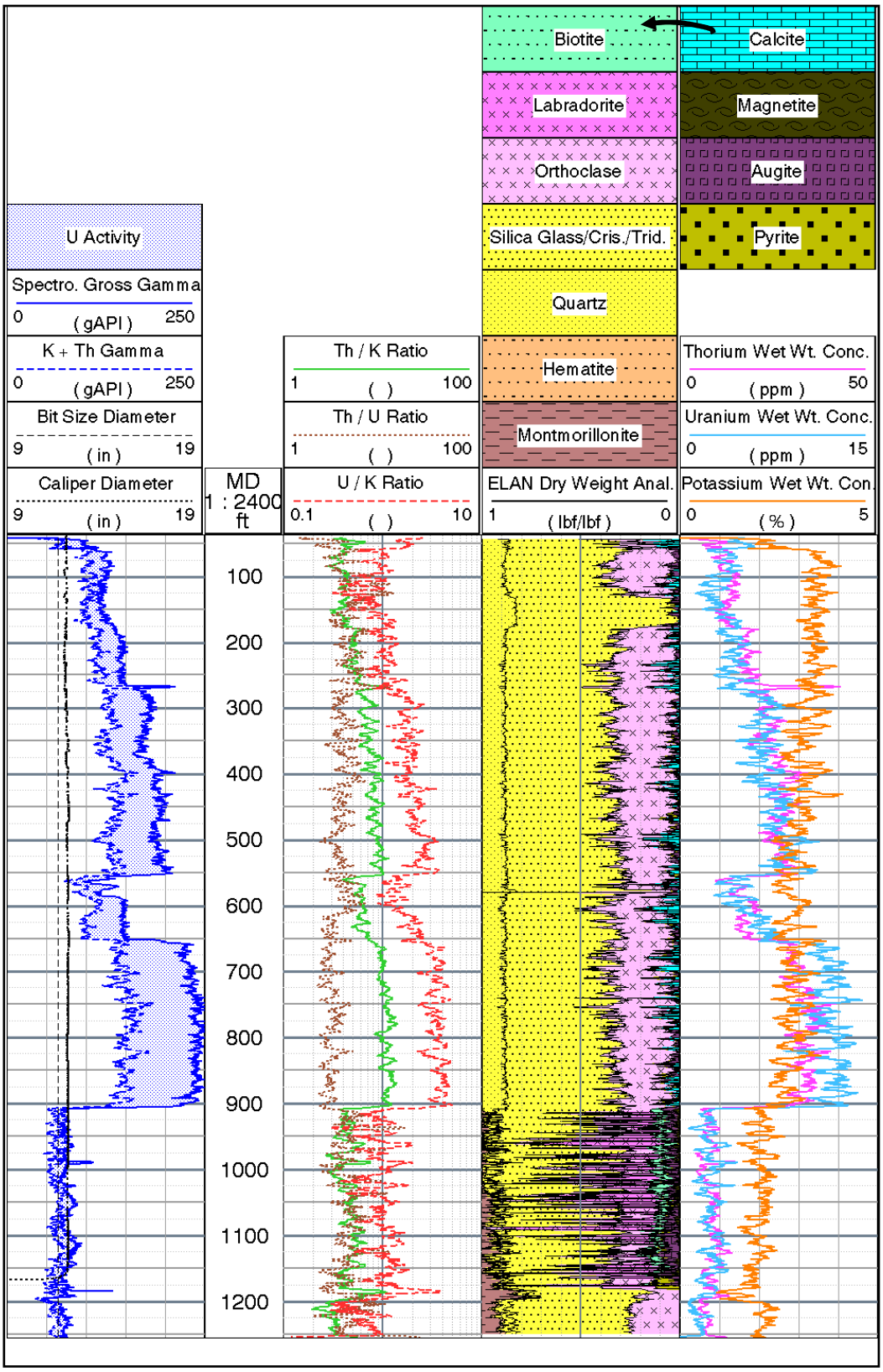


Figure 3: Summary of spectral natural gamma ray logs and ELAN mineralogy/lithology model dry weight fractions derived from the ELAN integrated log analysis for R-29 borehole, interval 37 to 1,243 ft bgs. Caliper log is also shown.

3.6. Integrated Log Montage

This section summarizes the integrated geophysical log montage for R-29. The montage is provided in Appendix 1. A description of each log curve in the montage follows, organized under the heading of each track, starting from track 1 on the left-hand side of the montage. Note that the descriptions in this section focus on what the curves are and how they are displayed; the specific characteristics and interpretations of the R-29 geophysical logs are provided in the previous section.

Track 1–Depth

The first track on the left contains the depth below ground surface in units of feet, as measured by the geophysical logging system during the TLD logging run. All the geophysical logs are depth-matched to the gross gamma log acquired with this logging run.

Track 2–Basic Logs

The second track on the left (inclusive of the depth track) presents basic curves:

- gamma ray (thick black), recorded in American Petroleum Institute gamma ray standard units (gAPI) and displayed on a scale of 0 to 250 gAPI units;
- single arm caliper from the TLD (thin solid pink) with nominal bit size as a reference (dashed-dotted black) to show nominal annular distance between inside of inner casing to borehole wall (pink shading), recorded as hole diameter in inches and displayed on a scale of 9 to 19 in.;
- cable tension (dashed-dotted dark red) recorded at logging truck and displayed to indicate tool pickup at bottom on a scale of 0 to 800 lbf;
- neutron capture cross section from the APS (bold long-dashed green), recorded in standard capture units (cu) and displayed on a scale of 0 to 30 cu (left to right).

Two gamma ray curves from the HNGS are displayed:

- total gross gamma (thick solid black curve)
- gross gamma minus the contribution of uranium (dotted black)

- yellow shading between the two curves to show uranium contribution to the total gamma ray response.

Track 3–Porosity

The third track displays the primary porosity log results. All the porosity logs are recorded in units of volumetric fraction and are displayed on a linear scale of 0.75 (left side) to -0.1 (right side). Specifically, these logs consist of

- APS epithermal neutron porosity derived from near-far detector pairing (bold solid dark blue curve) – deepest reading epithermal neutron porosity from APS tool, processed for zoned air-filled and water-filled cased hole;
- APS epithermal neutron porosity derived from near-array detector pairing (solid sky blue curve) – medium depth of investigation epithermal neutron porosity from APS tool, processed for zoned air-filled and water-filled cased hole;
- APS slowing down time porosity derived from pulsed neutron time series in the array detectors (thin dotted green curve) – shallowest reading epithermal neutron porosity from APS tool, processed for zoned air-filled and water-filled cased hole;
- ECS relative hydrogen yield (short-dashed sky blue);
- Total porosity derived from bulk density and ELAN water-filled porosity using a grain density of 2.4/2.55 g/cc (dashed red curve), 2.45/2.6 g/cc (long-dashed red curve), and 2.5/2.65 g/cc (dotted red curve)–with red shading between the 2.4/2.55 g/cc and 2.5/2.65 g/cc porosity curves to show the range (the lowest grain density range used across the tuff/pumice interval [37–903 ft], the highest grain density range used across the alluvium/fanglomerate interval [903–1,243 ft]; and
- ELAN water-filled porosity (bold dashed-dotted cyan with dark blue shading to right)–derived from the ELAN integrated analysis of all log curves to estimate optimized matrix and pore volume constituents.

Track 4–Density

The fourth track displays the

- bulk density, corrected for single string of steel casing (thick solid maroon curve) on a wrapping scale of 0.5 to 2.5 g/cc;
- apparent grain density (dashed brown curve), derived from the ELAN analysis, on a scale of 2.3 to 3.1 g/cc.
- density standoff flag (thin black with yellow area shading) on a scale of 10 to 0 in. (left to right)

Tracks 5 to 10 – Geochemical Elemental Measurements

The narrow tracks 5 to 10 present the geochemical measurements, along with their estimated one standard deviation uncertainty range: iron (Fe) and silicon (Si), sulfur (S) and calcium (Ca), estimated aluminum (Al) and potassium (K), titanium (Ti) and gadolinium (Gd), hydrogen yield (H yield), uranium (U) and carbon yield (C Yield) — from left to right respectively, in units of dry matrix weight fraction (except K in wet-weight fraction, U in wet-weight ppm, and H and C Yield in relative yield units).

Track 11 – ELAN Mineralogy Model Results (Dry Weight Fraction)

Track 11 displays the results from the ELAN integrated log analysis (the matrix portion)–presented as dry-weight fraction of mineral types chosen in the model:

- Montmorillinite clay (brown/tan)
- Hematite (orange with small black dots)
- Quartz (yellow with closely spaced small black dots)
- Combined silica glass, tridymite, and cristobalite (yellow with widely spaced large black dots)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or similar calcium-rich plagioclase feldspar (pink)
- Biotite (light green)
- Pyrite (orange-tan with black squares)
- Augite (maroon)

- Magnetite or other heavy mafic/ultramafic mineral (dark green)
- Calcite (cyan)

Track 12–ELAN Mineralogy and Pore Space Model Results (Wet Volume Fraction)

Track 12 displays the results from the ELAN integrated log analysis–presented as wet mineral and pore fluid volume fractions:

- Montmorillinite clay (brown/tan)
- Clay bound water (checkered black and grey)
- Hematite (orange with small black dots)
- Quartz (yellow with closely spaced small black dots)
- Combined silica glass, tridymite, and cristobalite (yellow with widely spaced large black dots)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or similar calcium-rich plagioclase feldspar (pink)
- Biotite (light green)
- Pyrite (orange-tan with black squares)
- Augite (maroon)
- Magnetite or other heavy mafic/ultramafic mineral (dark green)
- Calcite (cyan)
- Air (red)
- Water (white)
- Moved air (orange)
- Moved water (blue)

Track 13–Water Saturation

Track 13 displays the continuous-in-depth water saturation logs estimated from the processed logs, recorded in units of volumetric fraction of pore space filled with water (ratio of cubic feet per cubic feet [ft3/ft3]) and presented on a scale of 0 to 1 ft3/ft3 (left to right).

- Optimized estimate of water saturation (volumetric fraction of pore space filled with water) from the ELAN analysis (bold dashed-dotted purple curve with blue shading to the right and red shading to the left, corresponding to water-filled and air-filled pore space, respectively);
- Water saturation as calculated directly from the bulk density and ELAN-estimated porosity using a grain density of 2.4/2.55 g/cc (dashed blue curve), 2.45/2.6 g/cc (long-dashed blue curve), and 2.5/2.65 g/cc (dotted blue curve)–with blue shading between the 2.4/2.55 g/cc and 2.5/2.65 g/cc saturation curves to show the range (the lowest grain density range used across the tuff/pumice interval [37–903 ft], the highest grain density range used across the alluvium/fanglomerate interval [903–1,243 ft].

Track 14–Hydraulic Conductivity

Track 14 displays several estimates of hydraulic conductivity (K) derived from the ELAN integrated log analysis (sensitive to the estimated porosities and mineral composition), presented on a logarithmic scale of 10^{-5} to 10^{5} feet per day (ft/day):

- K-versus-depth estimate derived from using the ELAN permeability equation with water-filled porosity and matrix mineral weight fraction values derived from the ELAN analysis, converted to hydraulic conductivity (bold solid blue curve with gradational coloring to represent the range of hydraulic conductivity relative to standard unconsolidated clastic sediments);
- K-versus-depth estimate derived from using the k-Lambda permeability equation with water-filled porosity and matrix mineral weight fraction values derived from the ELAN analysis, converted to hydraulic conductivity (long-dashed sky blue curve); and
- intrinsic K-versus-depth estimate (assuming full saturation) using the ELAN total porosity and mineral-based permeability equation with total porosity and matrix mineral weight fraction values derived from the ELAN analysis, converted to hydraulic conductivity (dotted purple).

Track 15–Predicted Flow (Production Potential) Profile

Track 15 displays the integrated predicted relative flow (production potential) profile from the permeability (hydraulic conductivity) logs that mimics a flow meter (spinner) acquired under flowing conditions:

- Predicted relative water flow profile derived from the k-Lambda water permeability log (long-dashed blue), displayed on a unitless linear scale of 0 to 1 relative volumetric flow rate (ratio of flow rate to flow rate);
- Predicted relative water flow profile derived from the ELAN water permeability log (bold solid blue curve), displayed on a unitless linear scale of 0 to 1 relative volumetric flow rate;
- Predicted relative water flow profile across the saturated zone derived from the ELAN water permeability log (bold solid purple curve), displayed on a unitless linear scale of 0 to 1 relative volumetric flow rate;
- Relative integrated intrinsic permeability profile derived by integrating the k-Lambda intrinsic permeability log (dashed-dotted red), displayed on a unitless linear scale of 0 to 1;
- Relative integrated intrinsic permeability profile derived by integrating the ELAN intrinsic permeability log (dashed red), displayed on a unitless linear scale of 0 to 1.

Track 16–Summary Logs

Track 16, the second track from the right, displays several summary logs that describe the fluid and air-filled volume measured by the geophysical tools

- Optimized estimate of total volume fraction water from the ELAN analysis (solid blue curve and blue plus cyan area shading);
- Optimized estimate of volume fraction moveable water (non-clay bound moveable water-filled porosity) from the ELAN analysis (dashed cyan curve and cyan area shading);
- Optimized estimate of total volume fraction of air-filled porosity from the ELAN analysis (long-dashed red curve and dotted red area shading);and

The porosity and volumetric water content scales are from 0 to 0.6 total volume fraction, left to right.

Track 17–Depth

The final track on the right, the same as the first track on the left, displays the depth below ground surface in units of feet, as measured by the geophysical logging system during the TLD logging run.

4. References

Juneer, C. and A. Sibbit, 1980. "GLOBAL, A New Approach to Computer-Processed Log Interpretation." Paper SPE 9341 presented at the 1980 SPE Annual Technical Conference and Exhibition.

Quirein, J., S. Kimminau, J. LaVigne, J. Singer, and F. Wendel. 1986. "A Coherent Framework for Developing and Applying Multiple Formation Evaluation Models." Paper DD in 27th Annual Logging Symposium Transactions: Society of Professional Well Log Analysts.

Attachment 1 – Color Print of Integrated Log Well Montage for Well R-29

Integrated Wireline Log Well Montage

Processed Aeromicell Cased Hole Geophysical Logs

Using the following logs:

APS™, TLD™, ECS™, HNGS™

© Trademark Schlumberger

COMPANY:	North Wind Inc. (LANL Drilling Ser. Contractor)
WELL:	R-28
FIELD:	Los Alamos (LANL)
STATE:	New Mexico
County:	Los Alamos
Date Logged:	27-Feb-2010
Date Processed:	May-2010

Elevations:
API Number:
Well Location:

K.B. NA
D.F. NA
G.L. NA
Job Number:

GEOFRAME PROCESSED INTERPRETATION

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

All interpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any interpretation, and we will not, except in the case gross or wilful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretations made by any of our officers, agents or employees. These interpretations are also subject to Clause of our Standard Terms and Conditions as set out in our Price Schedule.

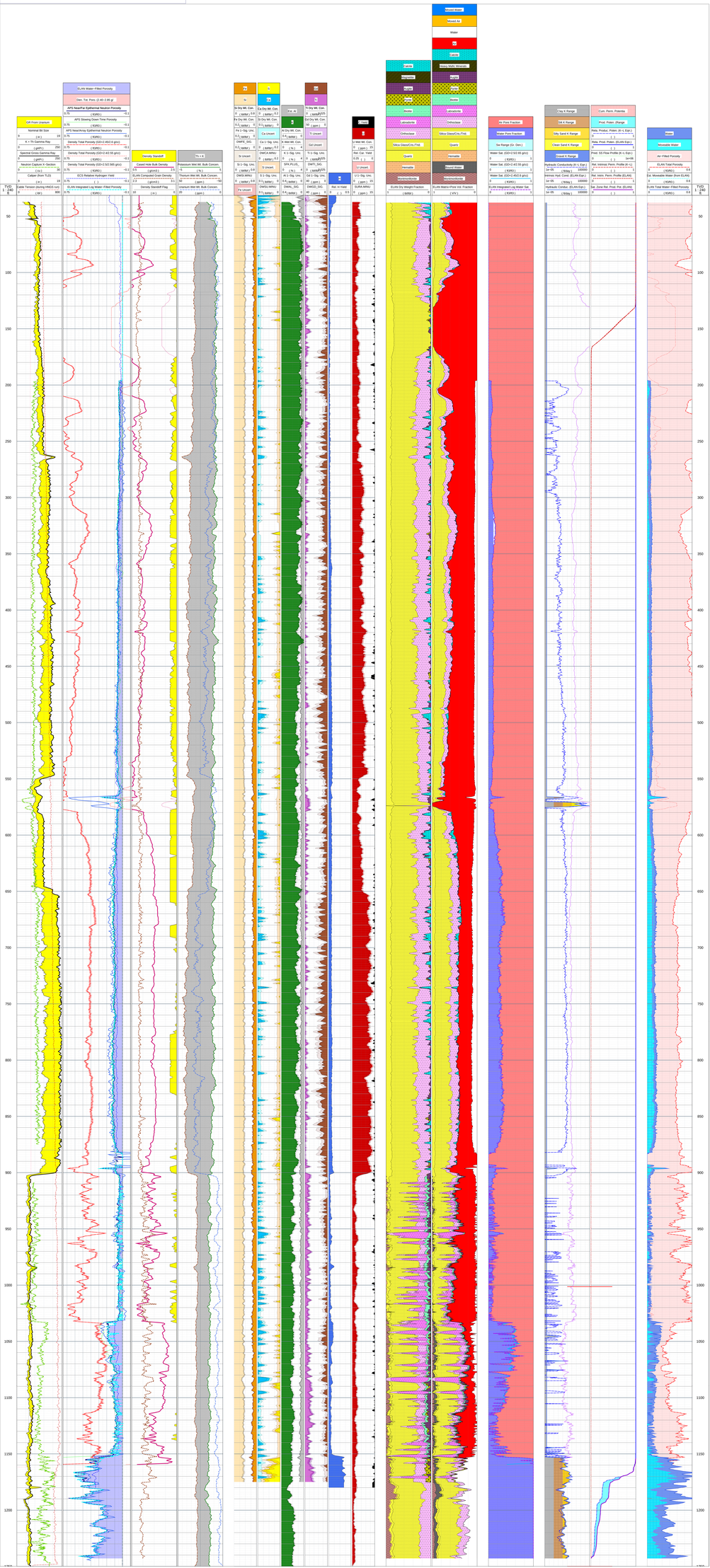
OP Vers. 17C0-154 Process Date May-2010 Center: SWS Tucson Baseline: GF4.2 Log Analyst N. Clayton

Mud and Borehole Measurements:

Rm @ Measured Temperature: NA	BHT: NA	Bitsize: 11.625 in
Rmf @ Measured Temperature: NA	Type Fluid in Hole: WatJel	FGM:
Rmc @ Measured Temperature: NA	Mud density: 8.34 lb/ingal	FGM:

Remarks:

Depth reference is ground surface.
Well contained one or more strings of casing above 1190 ft during logging.
Well water level at 1154 ft during logging.
ELAN* integrated log anal. performed without porosity or water saturation constraints.
Interpretation should account for well conditions.



Attachment 2 – Color Print of ELAN Optimized Mineral and Pore Volume Model Results for Well R-29

Schlumberger

ELAN* Geophysical Log Integrated Analysis

Optimized Mineral + Pore Volume Model

COMPANY:	North Wind Inc. (LANL Drilling Services Contractor)
WELL:	R−29
FIELD:	TA−49 (LANL)
State:	New Mexico
COUNTRY:	U.S.

Date Processed:	May−2010	Date Logged:	27−Feb−2010
Job Number:		Processed at:	SWS Tucson
Well Location:			
Latitude:		Longitude:	
Elevations:	KB:	DF: 1525.52m	GL: 1524m

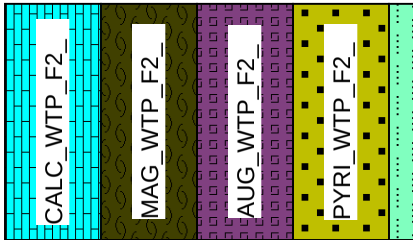
Depth ref. is ground surface. Results are affected by cased hole conditions.

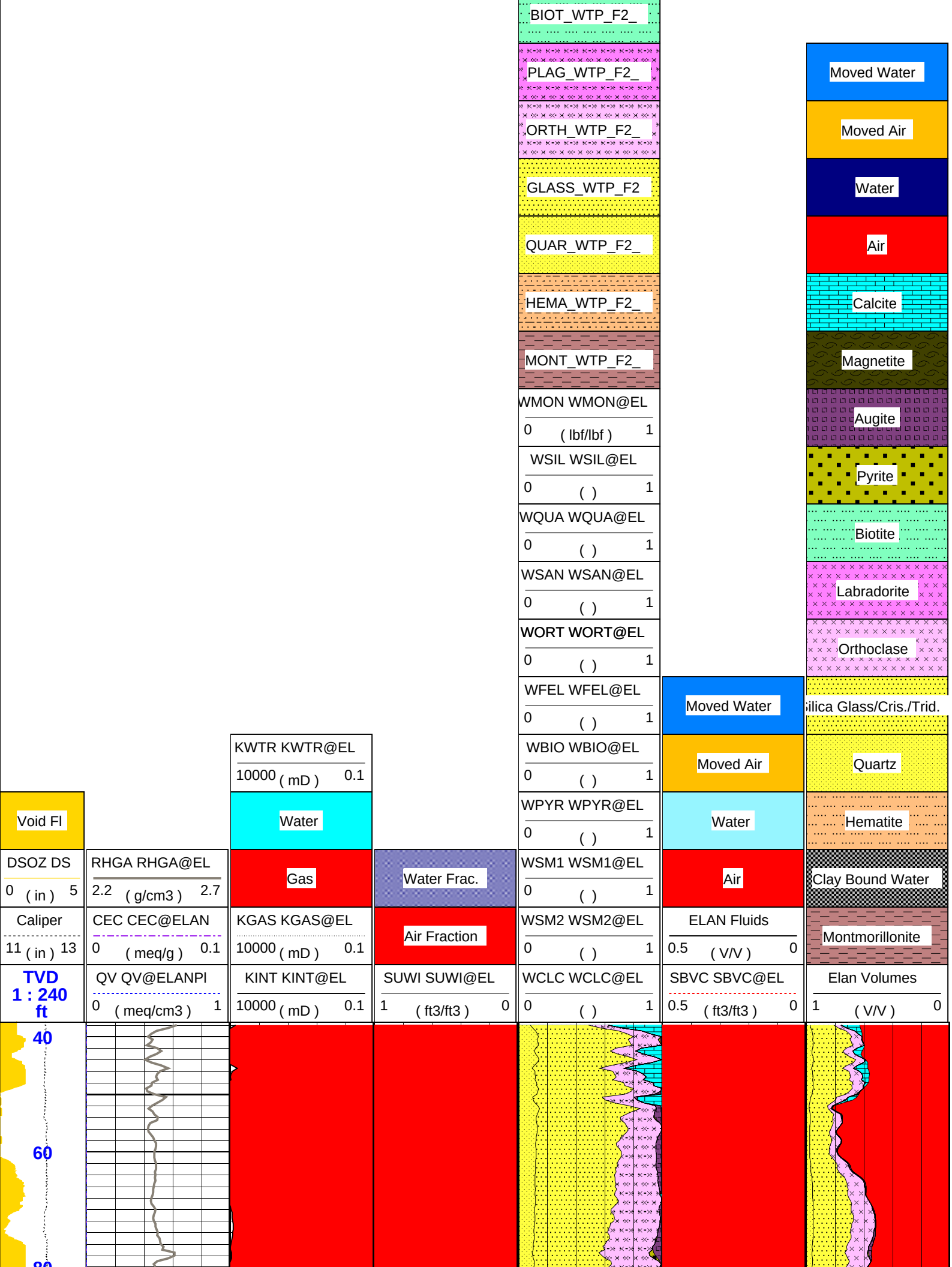
FOLD HERE

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

All interpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any interpretation, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretations made by any of our officers, agents or employees. These interpretations are also subject to Clause 4 of our General Terms and Conditions as set out in our current Price Schedule.

R−29 [Fun_2]

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GLASS_WTP_F2
QUAR_WTP_F2_
HEMA_WTP_F2_
MONT_WTP_F2_
Moved Water
Moved Air
Water
Air
Calcite
Magnetite
Augite
Pyrite
Biotite
Labradorite
Orthoclase
Silica Glass/Cris./Trid.
Quartz
Hematite
Clay Bound Water
Montmorillonite
WMON WMON@EL
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WSIL WSIL@EL
0 ( ) 1
WQUA WQUA@EL
0 ( ) 1
WSAN WSAN@EL
0 ( ) 1
WORT WORT@EL
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WPYR WPYR@EL
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WSM1 WSM1@EL
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WSM2 WSM2@EL
0 ( ) 1
WCLC WCLC@EL
0 ( ) 1
KWTR KWTR@EL
10000 (mD) 0.1
Water
Gas
KGAS KGAS@EL
10000 (mD) 0.1
KINT KINT@EL
10000 (mD) 0.1
Water Frac.
Air Fraction
SUWI SUWI@EL
1 (ft3/ft3) 0
Moved Water
Moved Air
Water
Air
ELAN Fluids
0.5 (V/V) 0
SBVC SBVC@EL
0.5 (ft3/ft3) 0
Elan Volumes
1 (V/V) 0
Void Fl
DSOZ DS
0 (in) 5
Caliper
11 (in) 13
TVD
1 : 240
ft
RHGA RHGA@EL
2.2 (g/cm3) 2.7
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60
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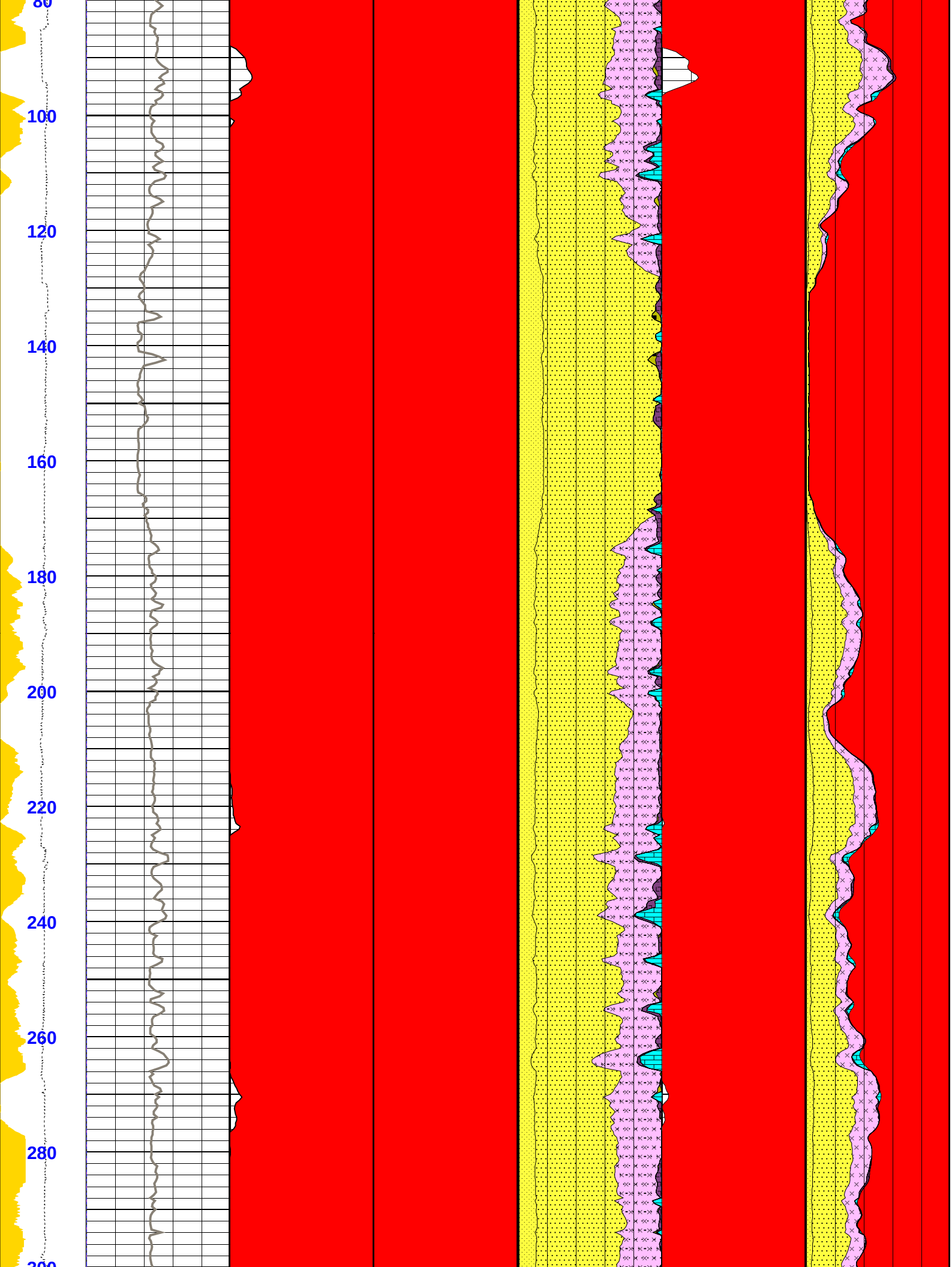
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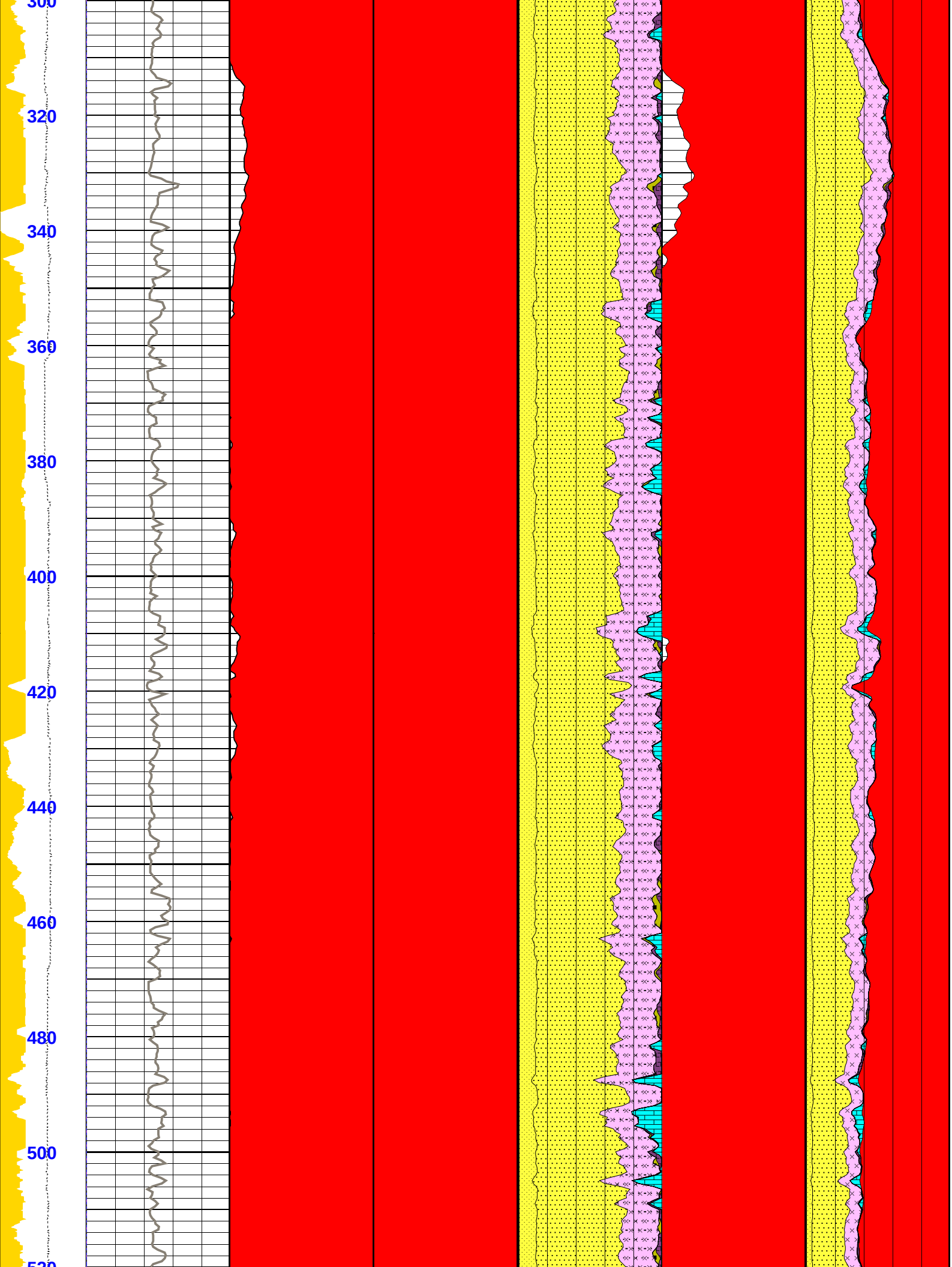
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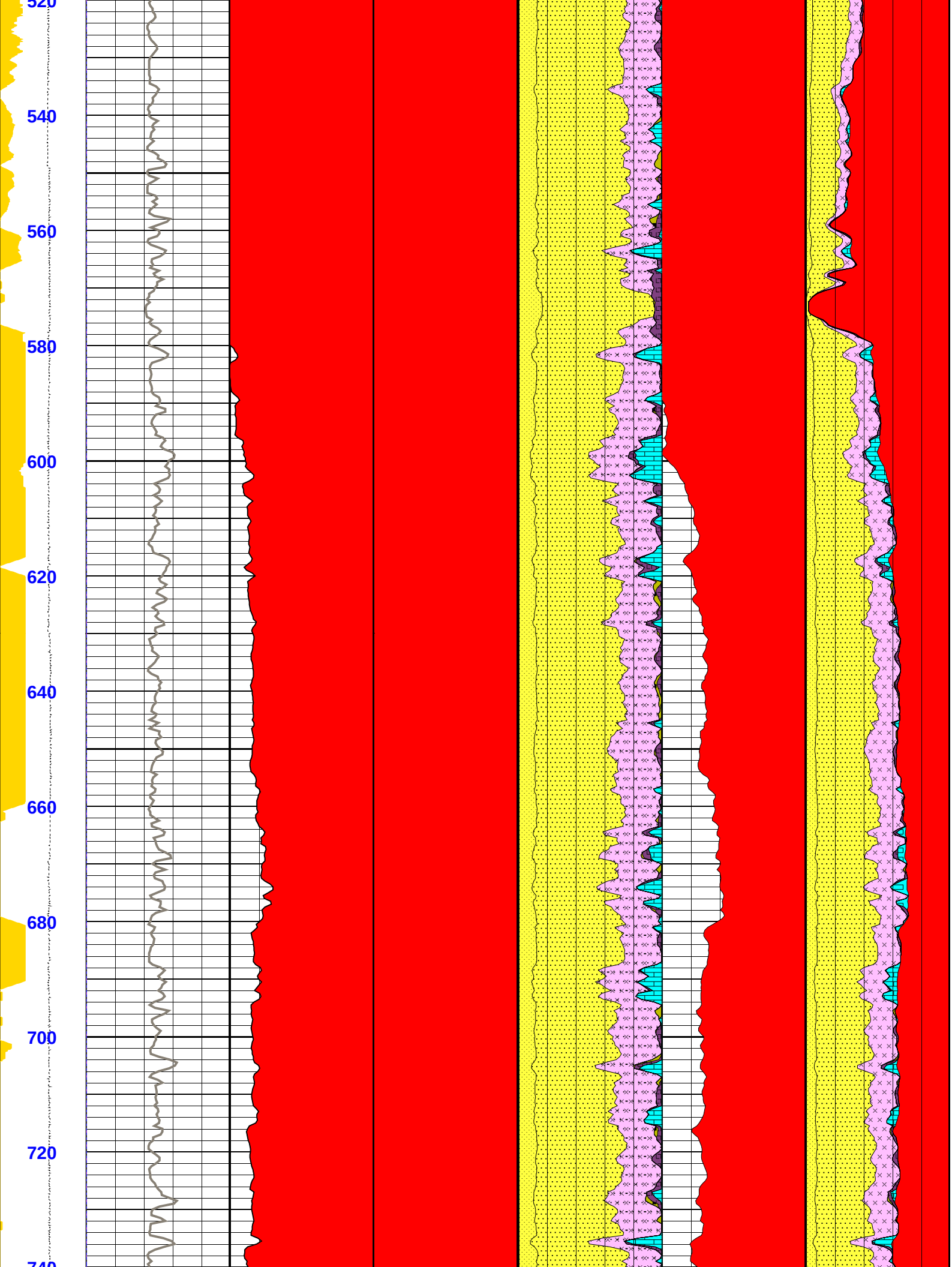
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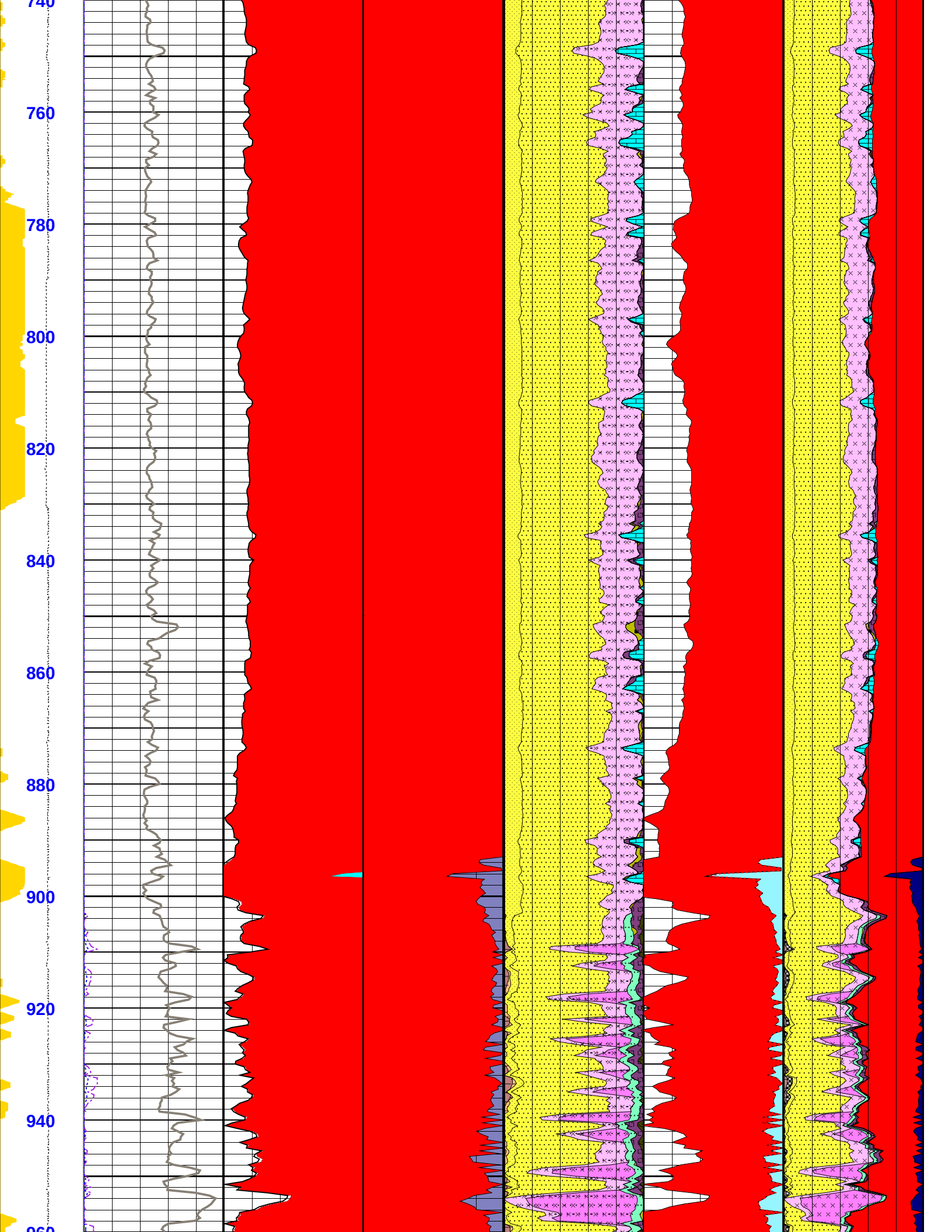
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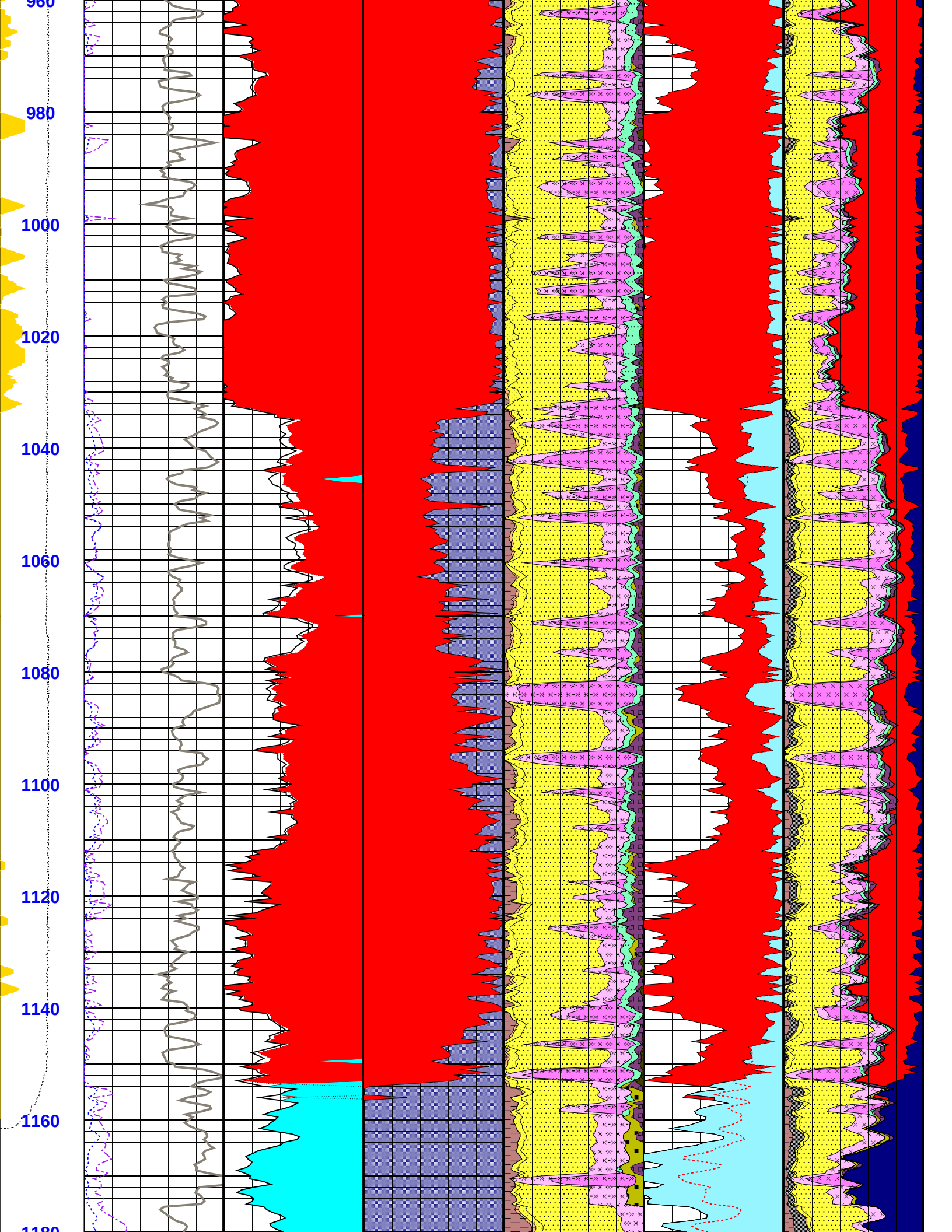
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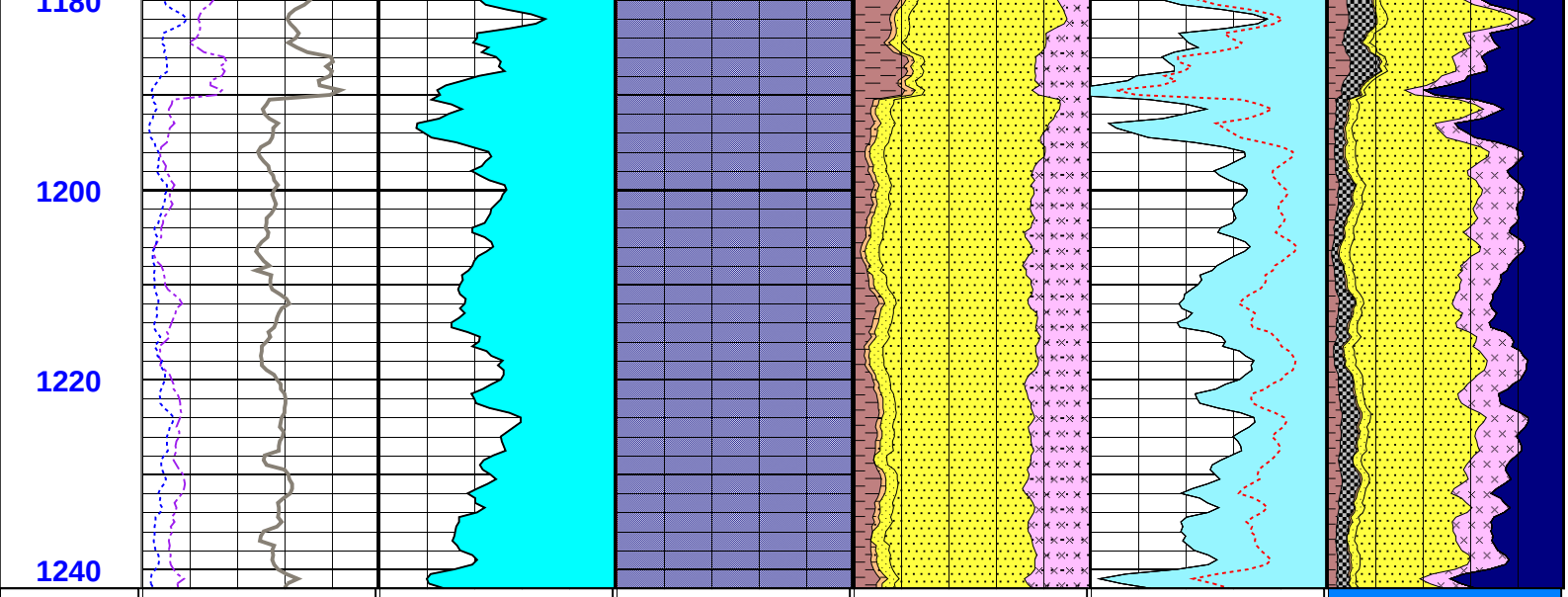
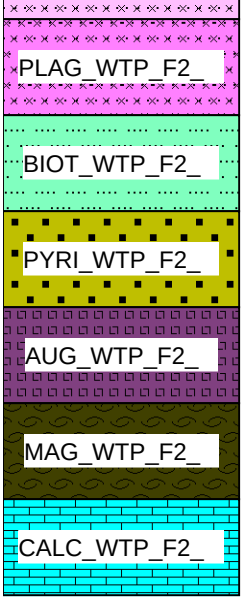
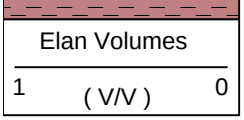


TVD 1 : 240 ft	QV QV@ELANPl	KINT KINT@EL	SUWI SUWI@EL	WCLC WCLC@EL	SBVC SBVC@EL	Moved Water
	0 (meq/cm3) 1	10000 (mD) 0.1	1 (ft3/ft3) 0	0 ( ) 1	0.5 (ft3/ft3) 0	
Caliper	CEC CEC@ELAN	KGAS KGAS@EL	Air Fraction	WSM2 WSM2@EL	Moved Water	Moved Air
11 (in) 13	0 (meq/g) 0.1	10000 (mD) 0.1		0 ( ) 1		
DSOZ DS	RHGA RHGA@EL	Gas	Water Frac.	WSM1 WSM1@EL	Moved Air	Water
0 (in) 5	2.2 (g/cm3) 2.7			0 ( ) 1		
Void Fl		Water		WPYR WPYR@EL	Water	Air
				0 ( ) 1		
		KWTR KWTR@EL		WBIO WBIO@EL	Air	Calcite
		10000 (mD) 0.1		0 ( ) 1		
				WFEL WFEL@EL	ELAN Fluids	Magnetite
				0 ( ) 1	0.5 (V/V) 0	
				WORT WORT@EL		Augite
				0 ( ) 1		
				WSAN WSAN@EL		Pyrite
				0 ( ) 1		
				WQUA WQUA@EL		Biotite
				0 ( ) 1		
				WSIL WSIL@EL		Labradorite
				0 ( ) 1		
				WMON WMON@EL		Orthoclase
				0 (lbf/lbf) 1		
				MONT_WTP_F2_		ilica Glass/Cris./Trid.
				HEMA_WTP_F2_		Quartz
				QUAR_WTP_F2_		Hematite
				GLASS_WTP_F2		Clay Bound Water
				ORTH_WTP_F2_		Montmorillonite

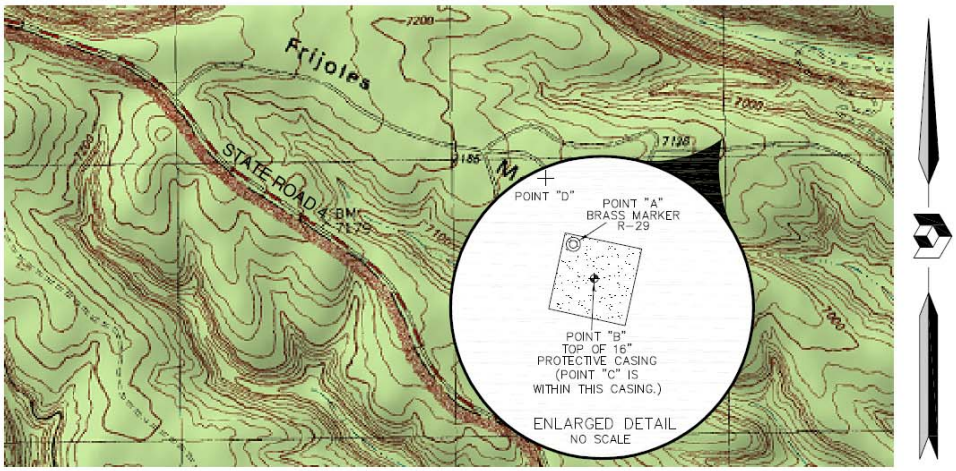

PLAG_WTP_F2_
BIOT_WTP_F2_
PYRI_WTP_F2_
AUG_WTP_F2_
MAG_WTP_F2_
CALC_WTP_F2_


Elan Volumes
1
(V/V)
0

Appendix F

Geodetic Survey

LANL MONITORING WELL LOCATION REPORT
DESIGNATED R-29
WITHIN TECHNICAL AREA 49
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS COUNTY, NEW MEXICO
JUNE, 2010



POINT	DESCRIPTION	EASTING (X)	NORTHING (Y)	ELEVATION
A	BRASS MARKER R-29	1626779.91	1755383.32	7100.75
B	TOP OF 16" PROTECTIVE CASING	1626782.59	1755378.94	7103.40
C	TOP OF 6" WELL	1626782.64	1755378.87	7102.91
D	GROUND	1626776.38	1755391.80	7100.34

Notes

1.) FIELD SURVEY COMPLETED ON JUNE 4, 2010.

2.) THIS AREA LIES WITHIN LOS ALAMOS NATIONAL LABORATORY PROPERTY IN TECHNICAL AREA 49, LOS ALAMOS COUNTY, NEW MEXICO.

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

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

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

AUTHORITY:
THIS MONITORING WELL LOCATION REPORT WAS PREPARED FROM A SURVEY DONE UNDER MY SUPERVISION ON THE 4TH DAY OF JUNE, 2010 AND FROM INSTRUCTION PROVIDED TO US BY NORTHWIND, INC.

LARRY W. MEDRANO, N.M.P.L.S. NO. 11993 *DATE* 07/14/2010

LARRY W. MEDRANO
NEW MEXICO
11993
REGISTERED PROFESSIONAL SURVEYOR

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