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Date: January 24, 2009
Refer To: EP2009-0003

James P. Bearzi, Bureau Chief
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2905 Rodeo Park Drive East, Building 1
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Subject: Submittal of the Completion Report for Regional Aquifer Well R-42

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the Completion Report for Regional Aquifer Well R-42.

If you have any questions, please contact Mark Everett at (505) 667-5931 (meverett@lanl.gov) or Nancy Werdel at (505) 665-3619 (nwerdel@doeal.gov).

Sincerely,

Bruce G Schappell for MJG

Michael J. Graham, Associate Director
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Sincerely,

David R. Gregory, Project Director
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30155

MG/DG/PH/ME:sm

Enclosures: 1) Two hard copies with electronic files - Completion Report for Regional Aquifer Well R-42 (LA-UR-09-0217)

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LA-UR-09-0217
January 2009
EP2009-0003

Completion Report for Regional Aquifer Well R-42

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

LA-UR-09-0217
EP2009-0003

Completion Report for Regional Aquifer Well R-42

January 2009

Responsible project leader:

Printed Name	Signature	Title	Organization	Date
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EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, and aquifer testing of Los Alamos National Laboratory (the Laboratory) regional aquifer well R-42, located in Mortandad Canyon, Technical Area 05 (TA-05), Los Alamos County, New Mexico. This report was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent. The well was installed at the direction of the New Mexico Environment Department (NMED) as an upgradient well to R-28 to monitor groundwater quality and contaminant movement toward well R-28 (which has consistently shown the highest concentration of chromium in the regional aquifer at the Laboratory).

The R-42 borehole was drilled using dual-rotary air-drilling methods. Drilling fluid additives used included potable water and foam. Foam-assisted drilling was used only in the vadose zone; no drilling-fluid additives other than small amounts of potable water added to the air below 790 ft depth, which is 128 ft above the top of regional saturation. Additive-free drilling provides minimal impacts to the groundwater and aquifer materials. The borehole was successfully completed to total depth using casing-advance drilling methods.

Well R-42 was completed as a single-screen well with a screen within the upper part of the pumiceous sediments within the Santa Fe Group, which is the regional aquifer. The R-42 well is intended to further define the nature and extent of contamination from Mortandad and Sandia Canyon sources and to address key uncertainties in the conceptual model for contaminant fate and transport of known chromium contamination in the vicinity of well R-28. A dedicated submersible pump sampling system was installed in the R-42 well, and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

The well was completed in accordance with an NMED-approved well design. The well was thoroughly developed and all target water-quality parameters were achieved. Hydrogeologic testing indicated that monitoring well R-42 is highly productive and will perform effectively to meet the planned objectives.

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Acronyms and Abbreviations

µS/cm	microsiemen per centimeter
amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
DO	dissolved oxygen
EES	Environmental and Earth Sciences Group
ENV-MAQ	Environmental Stewardship–Meterology and Air Quality
EP	Environmental Programs
ICPOES	inductively coupled (argon) plasma optical emissison spectroscopy
ICPMS	inductively coupled (argon) mass spectrometry
I.D.	inside diameter
IDW	investigation-derived waste
IWD	integrated work document
LANL	Los Alamos National Laboratory
mV	millivolt
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxygen-reduction potential
PVC	polyvinyl chloride
Qal	Quaternary alluvium
Qbo	Quaternary Otowi Member of the Bandelier Tuff
Qbog	Quaternary Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
RPF	Records Processing Facility
SOP	standard operating procedure
SWL	static water level
TA	technical area
Tb 4	Tertiary Cerros del Rio basalt
TD	total depth
TOC	total organic carbon
Tpf	Tertiary Puye formation
Tsfu	Tertiary Santa Fe Group undifferentiated
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development, and related activities for monitoring well R-42 and was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent (the Consent Order). Well R-42 was drilled and completed from June 2008 to September 2008 at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Water Stewardship Program. Aquifer testing was conducted in November 2008, and results are presented in this completion report.

The R-42 project site is located in Mortandad Canyon upgradient of well R-28 within Technical Area 05 (TA-05), Los Alamos County, New Mexico (Figure 1.0-1). The purpose of the R-42 monitoring well is to provide hydrogeologic- and groundwater-quality data from the regional aquifer to achieve data quality objectives consistent with the Groundwater Protection Program for the Laboratory and the Consent Order, in addition to the New Mexico Environment Department- (NMED-) approved "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon" (LANL 2007, 099607). Specifically, well R-42 is intended to further define the nature and extent of contamination from Mortandad and Sandia Canyon sources and to address key uncertainties in the conceptual model for contaminant fate and transport of known chromium contamination in the vicinity of well R-28. Well R-42 will help define source and flowpath immediately upgradient of R-28.

The primary objective of the drilling activities was to drill and install a single-screened regional aquifer monitoring well in the uppermost part of the regional groundwater system. The water table at R-42 is within the upper part of Miocene pumiceous sediments characterized by abundant vitrc-aphyric rhyolitic pumice beneath the Puye Formation. This unit is highly transmissive in many aquifer tests (especially at R-28), and it contains groundwater with elevated chromium concentrations at R-28. Proximal upgradient position and location within a common transmissive unit make this location a critical sampling point for understanding contaminant movement toward well R-28.

The R-42 borehole was drilled to a total depth (TD) of 1047.5 ft below ground surface (bgs). A monitoring well was installed with a screened interval between 931.8 and 952.9 ft bgs. The depth to water after well installation and well development was 918.8 ft bgs. Postinstallation activities included well development, pump testing, surface completion, dedicated sampling system installation, site restoration, and geodetic surveying. Ongoing activities include 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 all activities associated with the R-42 project, as well as supporting figures, tables, and appendixes.

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 were prepared to guide the implementation of the scope of work for R-42, "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon" (LANL 2007, 099607), "Integrated Work Document for Regional and Intermediate Aquifer

Well Drilling" (LANL 2007, 100972), "Storm Water Pollution Prevention Plan Addendum" (LANL 2006, 092600), "Waste Characterization Strategy Form for Chromium Wells (R-42, SCI-2/R-43) and Corehole Installation" (LANL 2008, 101914).

2.2 Site Preparation

Site preparation was performed between June 19 and 29, 2008, and included clearing and grading a drill pad and access road; excavating and lining a cuttings containment pit; and installing berms, silt fencing, and straw waddles to control stormwater run-on and runoff and prevent erosion. The drill pad area was approximately 200 ft × 150 ft and was covered with base course. The access road was 1600 ft long and was covered with base course. The cuttings pit measured approximately 60 ft × 40 ft with a depth of 8 ft. Radiation control technicians (RCTs) from the Laboratory's Radiation Protection Group-1 performed radiological screening of the site and construction equipment as required.

Office and supply trailers, generators, and general field equipment were moved on-site during mobilization of drilling equipment. Potable water for drilling was trucked to the site by the drilling subcontractor from a Los Alamos County fire hydrant located near municipal well house PM-5. Safety barriers and signs were installed around the borehole-cuttings containment pit and along the perimeter of the work area.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and provides a chronological summary of field activities conducted at monitoring well R-42.

3.1 Drilling Approach

The drilling methodology and selection of equipment and drill-casing sizes were designed to ensure successful completion of well R-42. This approach retained the ability to case off perched groundwater and reach TD with sufficiently sized casing to meet the required 2-in. minimum annular thickness of the filter pack. Further, it was anticipated that if perched groundwater was encountered at R-42, the perched zone would be isolated and sealed off with either casing or by cementing to avoid commingling perched groundwater with the regional aquifer.

Dual-rotary air-drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-42 borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. The Foremost DR-24HD drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, one deck-mounted 900 ft^3/min air compressor, and general drilling equipment. Auxiliary equipment included two Sullair 1150 ft^3/min trailer-mounted air compressors. Two sizes of flush-welded mild carbon-steel casing were used on the R-42 project: 16-in.-inside diameter (I.D.) and 12-in.-I.D. The dual-rotary technique at R-42 used filtered air and fluid-assisted air to evacuate cuttings from the borehole. Cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD to characterize the hydrostratigraphy of rock units encountered in the borehole.

Drilling fluids used in the vadose zone included municipal water and a mixture of municipal water with Baroid AQF-2 foaming agent. The fluids were used to cool the bits and lift cuttings from the borehole. Estimated cumulative total of drilling fluids introduced into the borehole and the total fluids recovered are presented in Table 3.1-1. No additives other than municipal water were used for drilling within the lower 128 ft of the vadose zone or within the regional aquifer.

3.2 Chronology of Drilling Activities

Drilling equipment and supplies were mobilized to the site between June 28 and 29, 2008. On June 30, 2008, the R-42 borehole was initiated with dual-rotary methods using 16-in. casing and a 15-in. conventional hammer bit. The 16-in. casing was advanced through the alluvium, the Otowi Member of the Bandelier Tuff, and the upper Puye Formation sediments and landed on July 10, 2008, at 419.4 ft bgs, 4.4 ft into the top of the Cerros del Rio basalt. On July 11, 2008, drilling then continued below the Cerros del Rio basalt using open-hole drilling methods with a 15-in. hammer bit.

Difficulties were encountered at approximately 540 ft bgs, and the 15-in. hammer bit was removed for examination due to lost circulation and poor penetration rates. The internal foot valve in the hammer was malfunctioning and needed to be replaced. The 15-in. hammer bit foot valve was replaced on July 12, 2008, and open-hole drilling continued to approximately 777 ft bgs. At approximately 680 ft bgs, drilling conditions changed with rapid penetration rates, indicating the contact with the lower Puye Formation. Open-hole drilling conditions between 680 and 777 ft bgs were normal and fast because of the soft formation. The decision was made to switch over to 12-in. casing advance at 777 ft bgs because open-hole drilling was not feasible in the poorly consolidated Puye sediments. On July 13 and 14, 2008, the Laboratory's downhole video camera and geophysical tools were run in the borehole to investigate potential perched groundwater in the Puye Formation. On July 14, 2008, several discrete trickles of perched groundwater were identified from 685.9 to 690 ft bgs. The cumulative flow of the observed perched water between 685.9 to 690 ft bgs was estimated to be 1 gpm or less based on visual observation. Perched groundwater accumulation was observed in the bottom of the hole. A pump rig was brought on-site to aid in collecting a groundwater sample from the perched zone. A groundwater sample was collected with a bailer from standing water from 771 to 775 ft bgs and submitted for anion and cation analyses.

On July 14, 2008, the drive shoe was cut off the 16-in. casing, and the perched water zone was sealed using 12-in. casing and bentonite chip seal. On July 15, 2008, a 10-ft thick hydrated bentonite chip seal was installed from 774.9 to 764.2 ft bgs and hydrated with potable water. The 12-in. casing was advanced into the bentonite chip seal to a depth of 778 ft bgs.

Drilling continued using 12-in. casing (using an 11 7/8-in. tricone bit with conventional dual-rotary methods) through the Puye Formation and into sands and gravels of the Santa Fe Group sediments. No drilling additives other than potable water were used below 790 ft bgs. On July 17, 2008, evidence of groundwater was first encountered at 894.5 ft bgs and again at 913 ft bgs. Groundwater samples were collected from these two depths by airlifting the groundwater through the drill string. Drilling operations halted the injection of potable water and circulated only air for approximately 10 min at each of these intervals. Water continued to be observed in the discharge.

Drilling with 12-in. casing advance continued to 970 ft bgs. Collection of additional groundwater samples was attempted at 935 to 950 ft bgs, 960 ft bgs, and 970 ft bgs; however, the formation did not yield enough water for off-site analyses. The decision was made to halt drilling and monitor water levels with an electronic sounder to determine the static water level (SWL) in the borehole and identify the top of the regional aquifer. The SWL was measured at approximately 920 ft bgs. On July 17, 2008, the Laboratory decided to drill an additional 60 ft into the regional aquifer with 12-in. casing advance. Before drilling, a groundwater-screening sample was collected at 970 ft bgs. Additional groundwater-screening samples were collected every 20 ft until TD was reached at 1029ft bgs.

On July 18, 2008, the drilling tools were removed from the borehole, and the Laboratory's gamma tool and camera were run through the 12-in. casing to verify the SWL. The 12-in. casing was lifted 5 ft to help the groundwater equilibrate to a static level more quickly in the hole. The top of the groundwater table

was recorded at 945 ft bgs. After the Laboratory's geophysical tools were run, the casing was pushed back to the bottom of the borehole (1029 ft bgs) and the drilling tools were tripped back in to clean out the hole. Slough was encountered in the 12-in. casing at approximately 980 ft bgs and was cleaned out multiple times back to TD. Formation material continued to heave inside the 12-in. casing, reaching a level of 978 ft (50 ft inside the 12-ft casing). In attempts to clean out the borehole and control the heaving sediments, the borehole was flooded several times with potable water; however, formation sands and sediments continued to heave 10–15 ft up inside the casing. On July 19, 2008, the drilling tools were tripped back out of the borehole in preparation for geophysical logging by Schlumberger. Schlumberger logged the borehole on July 19 and 20, 2008. Formation heave was encountered during the last logging run at 972 ft bgs, which prevented the final log from reaching TD of the borehole.

The Laboratory approved the final well design for R-42 on July 23, 2008. At that time, formation material had surged 56.5 ft up into the 12-in. casing. Before cutting the casing (as discussed below), the tools were tripped back into the borehole and it was cleaned out to 1029.5 ft bgs.

On July 24, 2008, the crew began tripping out the tool string in preparation for cutting the 12-in. casing. While tripping out of the hole, the heaving sands and sediments continued to enter into the 12-in. casing. Formation material rose in the cased hole from 1027 to 994 ft bgs. Into the borehole, 1500 gal. of water was introduced in an attempt to force the formation material out of the 12-in. casing and to regain control of the formation; this attempt was not successful. Well construction activities were stalled until a solution to the heaving problem could be identified. The decision was made to attempt to advance the borehole an additional 20 ft and into undisturbed formation to case off the heaving zone and regain control of the formation so well construction could be accomplished.

On July 25, 2008, the R-42 borehole was advanced to 1047.5 ft bgs and flooded with 2500 gal. of potable water to control formation heave. At the end of the shift, the hole was tagged inside the 12-in. casing at 1039 ft bgs, indicating that the heaving of formation material had slowed. On July 26, 2008, the borehole was tagged at 1028.5 ft bgs. Although the formation heaved slightly overnight, the decision was made to trip out the tool string, cut the 12-in. casing, and begin well construction. An attempt was made to cut the 12-in. casing at 990 ft bgs, but the casing cutter malfunctioned and ultimately broke. On July 27, 2008, the drill string was tripped back in and the hole was cleaned out to 1000 ft bgs. On July 28, 2008, the casing cutter parts were delivered and the casing cutter was repaired. The tool string was tripped out and the casing cutter tripped back in the hole. The 12-in. casing string and drive shoe were successfully cut at 988 ft bgs. A total of 59.5 ft of 12-in. casing and the drive shoe remain in the borehole (988 to 1047.5 ft bgs). The 12-in. casing string was strategically cut to leave a long piece in place to isolate the worst heaving interval. This strategy proved successful, and no formation difficulties were experienced above the cut at 988 ft bgs. Once the 12-in. casing was cut, well installation began.

The field crew generally worked two 12-h shifts per day, 7 d/wk. Most of the drilling and well construction activities were conducted on 24-h workdays. Final well construction and development activities were conducted on single 12-h day shifts. Operations suffered numerous lightning delays throughout the duration of the project. Some technical delays were incurred because of the unexpected heaving formation material encountered in the sediments of the Santa Fe Group in the lower portion of the borehole. Mechanical delays due to a broken foot valve in the hammer bit and a broken casing cutter also affected progress.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities at well R-42. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-42 borehole at 5-ft intervals from ground surface to the TD of 1047.5 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected from the discharge hose, placed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected from ground surface to 1047.5 ft bgs and placed in chip trays along with unsieved (whole rock) cuttings. RCTs screened all cuttings before removal from the site.

Most drill cuttings collection methods used at R-42 did not retain a majority of the finest fraction (silt and clay) of the drill cuttings because the high-velocity compressed air required for non-mud-rotary methods made catching samples difficult. Site geologists manually collected samples with a wire mesh basket directly from the discharge hose and discharge velocities forced most of the fines through the basket. In addition, bucket samples were collected at various intervals to capture total formation material: 580–585 ft, 870–875 ft, 890–895 ft, 910–915 ft, 950–955 ft, 990–995 ft, and 1010–1015 ft. Recovery of the coarser fraction of the cuttings samples was excellent in nearly 100% of the borehole. The borehole lithologic log for R-42 is presented in Appendix A.

4.2 Water Sampling

Groundwater-screening samples were collected from the drilling discharge hose at 20-ft intervals from the top of regional aquifer to the TD of 1047.5 ft bgs in the R-42 borehole. Typically upon reaching the bottom of a 20-ft run of casing, the driller stopped water circulation (if injecting water) and circulated air to clean out the borehole. As the discharge cleared, water samples were collected directly from the discharge hose. Not all depth intervals below the top of the regional groundwater table could be captured at the end of each casing run due to lack of water production. Alternatively, some water samples were collected upon start-up of the next casing run after the borehole filled with water.

Perched groundwater samples were collected by bailing or by air-lifting a water sample through the drill string. Two perched groundwater samples (771–775 ft bgs) were collected and analyzed. Additionally, two samples (894 and 913 ft bgs) of indeterminate origin (introduced potable water?) were collected and analyzed.

Regional groundwater samples were also collected at regular intervals (one sample every 2 h) during well development and aquifer testing. The groundwater samples were collected from the surface discharge port on the submersible development pump riser pipe and submitted for analyses.

All groundwater samples were submitted to the Laboratory's Earth and Environmental Sciences groundwater chemistry laboratory for analysis of anions, cations, total organic carbon (TOC) and (for some samples) nitrates, tritium, and chromium. Sampling documentation and containers were provided by the Laboratory and processed through the Laboratory's Sample Management Office. Groundwater analytical results and details of groundwater chemistry at R-42 are presented in Appendix B. Table 4.2-1 presents a summary of all groundwater samples collected during drilling and well development activities.

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-42 is presented below. The Laboratory's geology task leader and site geologists examined cuttings and geophysical logs to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, water-level measurements, and geophysical logs were used to characterize groundwater occurrences encountered at R-42.

5.1 Stratigraphy

The stratigraphy for the R-42 borehole is presented below in order of youngest to oldest geologic units. Lithologic descriptions are based on cuttings samples collected from the discharge hose. Cuttings and borehole geophysical logs were used to identify geologic contacts. Figure 5.1-1 illustrates the stratigraphy at R-42. A detailed lithologic log is presented in Appendix A.

Quaternary Alluvium, Qal (0–70 ft bgs)

Quaternary alluvium consisting of unconsolidated silty sand to sandy silt with pebbles and gravels of tuffaceous sediments was encountered from 0 to 70 ft bgs. No evidence of alluvial groundwater was observed.

Otowi Member of the Bandelier Tuff, Qbo (70–367 ft bgs)

The Otowi Member of the Bandelier Tuff is present in R-42 from 70 to 367 ft bgs. The Otowi Member is a glassy, lithic-bearing, pumiceous, poorly welded ash-flow tuff. It contains reddish gray to gray, subangular to subrounded, intermediate composition volcanic rocks up to 16 mm in diameter and vitric pale yellow to white pumice lapilli with conspicuous phenocrysts of quartz and sanidine. Halos of iron staining occur around pumice.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (367–383 ft bgs)

The Guaje Pumice Bed is present from 367 to 383 ft bgs. The pumice bed contains abundant pumice fragments (up to 95%) with subordinate amounts of volcanic lithics, quartz and sanidine phenocrysts, and fine ash.

Upper Puye Formation, Tpf (383–393 ft bgs)

The upper Puye Formation, from 383 to 393 ft bgs, consists of volcaniclastic sandy silt to silty sand with pebble and gravel deposits. Gravels consist of intermediate composition volcanic rock fragments, volcaniclastic sandstones, pumice clasts, and conspicuous felsic and mafic mineral grains. The formation ranges from yellowish gray to light brown.

Basaltic Colluvium (393-415 ft bgs)

At approximately 393 ft bgs, the upper Puye Formation transitions downward into brown volcaniclastic sediments with 70%–100% basalt clasts. These basalt clasts appear to be derived from the underlying Cerros del Rio basalt.

Cerros del Rio Basalt, Tb4 (415–680 ft bgs)

Cerros del Rio basalt, from 415 to 680 ft bgs, consists of multiple lava flows of vesicular to massive porphyritic basalt with an aphanitic groundmass. Trace to minor olivine and plagioclase phenocrysts and local clay and clay-filled vesicles are evident. Basalt ranges from dark to medium gray to dark reddish gray.

Lower Puye Formation, Tpf (680–900 ft bgs)

The lower Puye Formation consists of poorly sorted volcaniclastic sediments with white clay, silt, sand, gravels, and cobbles. Gravel and cobbles consist of intermediate composition lavas, with conspicuous felsic and mafic phenocrysts, siltstones, sandstones, and conglomerates. The formation ranges from pinkish white to medium gray.

Santa Fe Group, Undivided, Tsfu (900–1047.5 ft bgs)

The Miocene Santa Fe Group is present from 900 ft to TD at 1047.5 ft bgs and consists of (1) upper light tan, generally fine-grained pumiceous sediments (900 to 991 ft) and (2) lower brown riverine deposits (991 to 1047.5 ft). The pumiceous deposits include sands, silts and minor gravels made up of pumice, and other mixed felsic to intermediate volcanic detritus. The upper part of the riverine deposits (991 to 1020 ft) consists of siltstone with fine sand and clay made up primarily of volcanic detritus and up to 15% rounded Precambrian quartzite clasts. Below 1020 ft, the riverine deposits consist of coarse gravel with silt and sand made up of rounded intermediate to felsic volcanic detritus and 5%–10% Precambrian quartz, quartzite, and granite clasts.

5.2 Groundwater

Regional groundwater was believed to be encountered at R-42 during drilling at approximately 913 ft bgs in the Santa Fe Group on July 17, 2008. An SWL of 920.4 ft bgs was measured in the borehole on July 17, 2008. Groundwater-screening samples (section 4.2) were collected during drilling and well development. After well installation and development, the SWL was measured at 918.8 ft bgs. A discussion of groundwater chemistry is presented in Appendix B. Aquifer testing data and interpretation for R-42 are presented in Appendix C. Another show of water occurred during drilling at 894.5 ft bgs, which was initially suspected to be the regional aquifer occurring at a shallower than predicted depth. Water was produced from this zone at a rate of 5 to 10 gpm and a sample was collected. However, this saturated zone could not be further confirmed or characterized through water-level monitoring or borehole geophysics.

Several discrete trickles of perched groundwater were identified from 685.9 to 690 ft bgs. The flow of water entering the borehole between 685.9 to 690 ft bgs was visually estimated at 1 gpm or less. The water accumulated in the bottom of the borehole and a groundwater sample was collected for anion and cation analyses (Appendix B).

6.0 BOREHOLE LOGGING

Several video logs and a limited suite of cased-hole geophysical logs were collected during the R-42 drilling project using Laboratory-owned equipment. An additional suite of geophysical logs was collected by Schlumberger Wireline Services. A summary of video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

Video logs were run in the uncased borehole to check for the presence of perched groundwater in the Cerros del Rio basalt on July 13 and 14, 2008. Perched water was observed in the video logs in the Puye Formation a short distance below the Cerros del Rio basalt. Several other video logs were run in the borehole to verify conditions. An additional video log was collected in the completed well for inspection.

The July 14, 2008, video log from the borehole is presented on a digital video disc as part of Appendix D included with this document. Table 6.0-1 details individual video logging runs.

6.2 Geophysical Logging

A suite of Schlumberger geophysical logs was run inside the drill casing on July 19 and 20, 2008. At the time of logging, the terminations of the two casing strings in the R-42 borehole were located at the following depths: 16-in. casing at 419.4 ft bgs and the 12-in. casing at 1028.5 ft bgs. The geophysical suite included Triple Detector Lithodensity Tool, Accelerator Porosity Sonde, Natural and Spectral Gamma Logs, and Elemental Capture Sonde. Interpretation and details of the logging will be presented on CD in the Geophysical Logging Report as part of Appendix E.

Additionally, several natural gamma ray and induction tool logs were run in the R-42 borehole and the completed well using the Laboratory's geophysical equipment. Details of the logging operations are presented in Table 6.0-1. The results of the geophysical logging will be presented on plots in Appendix D.

7.0 WELL INSTALLATION

R-42 well casing and annular fill were installed between July 30, 2008, and August 27, 2008.

7.1 Well Design

The R-42 well was designed in accordance with the NMED Consent Order. NMED approved the well design before installation. The well was designed with a single screen interval to monitor groundwater quality in the upper part of the regional aquifer within Santa Fe Group sediments.

7.2 Well Construction

The R-42 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-outside diameter (O.D.) type A304 stainless-steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. External couplings (also type A304 stainless steel fabricated to ASTM A312 standards) were used to connect individual casing and screen sections. The screen sections were 12.3 ft long with 10-ft lengths of 5.0-in.-I.D. rod-based 0.020-in. slot wire-wrapped well screen. The coupled unions between threaded sections were approximately 0.7 ft long. The casing and screen were factory-cleaned and steam-cleaned on-site before installation. A 2-in.-I.D. steel-threaded/coupled tremie pipe was used to deliver all backfill and annular fill materials during well construction. A side-discharging cap was installed on the tremie pipe for installation of liquid backfill materials (high solids bentonite grout and cement grout).

A nominal 20-ft screened interval was used for R-42 with the top of the screen set at 931.8 ft bgs. A 20.6-ft stainless-steel sump was placed below the well screen. The dual-rotary drill rig was used for most of the well construction activities. A Semco work-over rig was brought on-site for final well construction activities. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Problems associated with the Santa Fe Group sediments included severe heaving sands and sediments encountered during the initial phase of well construction. Extending the hole 20 ft beyond the proposed TD into undisturbed formation and flooding, the borehole with potable water resolved the problems. As a result of the formation difficulties, the 12-in. casing string and drive shoe was cut at 988 ft bgs, leaving a 59.5-ft section of 12-in. casing in the bottom of the borehole. Once the casing was cut, the process of extracting drill casing and installing the well began.

After the well casing was assembled and lowered into the borehole, installation of annular backfill materials was started. This activity had two components: installing materials and retracting the drill casing. As the annular fill was emplaced, the drill casing was retracted and removed. The well-casing string was hung under full tension throughout well construction. The well installation proceeded normally and few difficulties were encountered. The bottom of the borehole was filled with 10/20 sand from 976.6 to 1047.5 ft bgs. Some sloughing occurred in this interval. The lower bentonite seal was installed around the well sump from 957.8 to 967.6 ft bgs. The primary filter pack of 10/20 silica sand was placed across the screened interval from 926.9 to 957.8 ft bgs. R-42 is screened from 931.8 to 952.9 ft bgs. During and after installation of the primary filter pack, the work-over rig was used to surge the screened interval with a surge block to promote settling and compaction of the filter pack. A fine-grained transition-sand collar of 20/40 silica sand was placed above the primary filter pack from 924.8 to 926.9 ft bgs. After placement of the fine sand collar, a bentonite chip seal was installed from 901.9 to 924.8 ft bgs. A high-solids bentonite grout was then installed from 687.3 to 901.9 ft bgs and another bentonite chip seal was placed from 400.3 to 687.3 ft bgs. The surface seal composed of 96% cement and 4% bentonite was installed from 3 to 400.3 ft bgs. Figure 7.2-1 depicts final depths and volumes used in each interval. Table 7.2-1 details volumes of materials used during well construction.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation, the well was developed and aquifer pumping tests were conducted. A dedicated submersible pump system banded with two transducer tubes was installed after pump testing. The wellhead and surface pad are completed and a geodetic survey of the wellhead was performed. Site restoration activities were completed following final disposition of contained drill cuttings, and groundwater is determined in accordance with the NMED-approved waste decision trees and regulatory requirements.

8.1 Well Development

Well development was conducted between September 2 and September 6, 2008. Initially, the screened interval was bailed and swabbed to remove formation fines in the filter pack and sump. Bailing and swabbing continued until water clarity visibly improved. Final development was then performed with a submersible pump. The swabbing tool was a 4.5-in.-O.D. 1-in.-thick nylon disc attached to a weighted steel rod. The swabbing tool was lowered by wireline and drawn repeatedly in both directions across the screened interval. Each interval of swabbing was followed by an interval of bailing to remove fines. After bailing and swabbing, a 5-hp, 4-in.-Grundfos submersible pump was installed in the well for the final stage of well development.

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxygen-reduction potential (ORP), and specific conductance parameters were measured. In addition, water samples for TOC analysis were collected. The required values for TOC and turbidity to determine adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTUs), respectively. The TOC measurement at the end of R-42 well development was less than 0.5 ppm and the final turbidity value was 4.9 NTUs. The lowest turbidity measurement during development was 2.3 NTUs.

Approximately 4448 gal. of groundwater was purged at R-42 during initial development activities. Total removed during development and testing was 17,995.5 gal. Table 8.1-1 presents the volume of water removed during well development and the corresponding water-quality parameters. Discussion of analytical results is presented in Appendix B.

8.1.1 Field Parameters

Results for field parameters consisting of pH, temperature, DO, ORP, specific conductance, and turbidity are provided in Table 8.1-1 and in Appendix B. Field parameters were measured at well R-42 by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This condition probably resulted in a slight variation of field parameters during well development and during the pumping test, most notably, temperature, pH, and DO. Measurements of pH and temperature varied from 7.86 to 8.12 and from 19.1°C to 25.4°C, respectively, at well R-42. Percent saturation of DO varied from 45.4 to approximately 100. Regional aquifer groundwater is relatively oxidizing at well R-42 based on DO and ORP measurements, with ORP varying from –78.9 to 175.7 millivolts (mV), with most of the ORP readings greater than +100 mV. Specific conductance ranged from 383 to 418 microsiemens per centimeter (μS/cm). Values of turbidity measured at R-42 ranged from 0.2 to 859 NTUs for the nonfiltered groundwater samples. Ten of the 35 turbidity measurements recorded during well development exceeded 5 NTUs.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-42 between November 12 and November 15, 2008. Several short-duration tests with short-duration recovery periods were performed on the first day of testing followed by a 36-h background data collection period. A 24-h pumping test followed by a 24-h recovery period completed the testing. The same 5-hp Grundfos pump used during well development was used to perform the aquifer tests. The results of the R-42 aquifer test are presented in Appendix C.

8.3 Dedicated Sampling System Installation

A dedicated 3-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump and an In-Situ Level Troll 500 transducer was installed in R-42 following the aquifer tests. Pump riser pipe consisted of threaded and coupled 1-in.-diameter stainless steel. Two 1-in.-diameter polyvinyl chloride (PVC) tubes were installed along with and banded to the pump riser. One tube was for the dedicated pressure transducer and the other for manual water-level measurements. The tubes were 1.0-in.-I.D. flush-threaded schedule 40 PVC pipe. Each PVC tube has a 6-in. long 0.010-in. screen-slot interval at the bottom of the tube with a threaded bottom cap. Postinstallation construction and sampling system component installation details for R-42 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for R-42.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-42 wellhead. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 10-in.-I.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. Base course was graded around the edges of the pad. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

Geodetic survey data for the stainless-steel well casing top cap, 10.-in. protective casing, brass pin, and ground surface at R-42, were collected on November 5, 2008. The survey data are presented in Figure 8.3-1b and Table 8.5-1. Geodetic surveys were conducted using a Trimble 5700 differential global positioning system. The survey data were collected by a licensed surveyor and conform to Laboratory

Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929.

8.6 Waste Management and Site Restoration

Waste generation and characterization for the R-42 project include a small quantity of contact waste, decontamination fluids, drill cuttings, discharged drilling water, cement slurry, and purged groundwater. R-42 waste characterization samples of drill cuttings, purge water, and cement slurry were collected from September 8, 2008, to November 14, 2008. A summary of the waste samples collected for the R-42 well is presented in Table 8.6-1.

Fluids, cuttings, cement slurry, and contact waste produced during drilling and development were containerized and sampled in accordance with the “Waste Characterization Strategy Form for Chromium Wells (R-42, SCI-2/R-43) and Corehole Installation” (LANL 2008, 101914).

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 (WSCF) and the EP Directorate Standard Operating Procedure (SOP) 010.0, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criterion for land application, the water will be evaluated for treatment and disposal at one of the Laboratory’s six wastewater treatment facilities. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the waste 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 Environmental Protection Division Resource Conservation Recovery Act SOP 011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criterion for land application, they will be removed from the pit and disposed of at an authorized facility. The cement slurry waste stream will be managed as industrial nonhazardous waste, pending analytical review. Disposal of this concrete slurry will take place at an authorized disposal facility. Characterization of contact waste will be based upon acceptable knowledge, pending the results of the waste samples collected from the drill cuttings, purge water, and cement slurry.

Site restoration activities will include removing water from the cuttings containment pit and land-applying it on-site (if applicable), removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area. Cuttings will be managed in accordance with SOP-011.0, referenced above. The site will be reseeded with a native seed mix consisting of Indian rice grass, mountain broam, blue stem, sand drop, and slender wheat grass seed. The Laboratory-approved seed mix will be applied at the required rate of 20 lb/acre; Biosol fertilizer will be applied at a rate of 80 lb/acre.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-42 were performed as specified in the “Drilling Work Plan for Regional Aquifer Well R-42” (TerranearPMC 2008, 103940).

10.0 ACKNOWLEDGMENTS

P. Longmire of Los Alamos National Laboratory contributed the geochemistry section of this report (Appendix B).

Boart Longyear drilled the R-42 borehole and installed the well.

S.G. Western, Inc. prepared the site for drilling activities.

Southwest Mountain Survey performed the geodetic survey.

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

11.0 REFERENCES

The following list includes all documents cited in the main text of this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers 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; the U.S. Department of Energy–Los Alamos Site Office; 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), November 2007. "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon," Los Alamos National Laboratory document LA-UR-07-7579, Los Alamos, New Mexico. (LANL 2007, 099607)

LANL (Los Alamos National Laboratory), May 2008. "Waste Characterization Strategy Form for the Chromium Wells (R-42 and SCI-2/R-43) Regional Groundwater Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2008, 101914)

TerranearPMC, June 2008. "Drilling Plan for Regional Aquifer Well R-42," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2008, 103940)

11.1 Map Data Sources for R-42 Completion Report Location Map

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

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

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

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

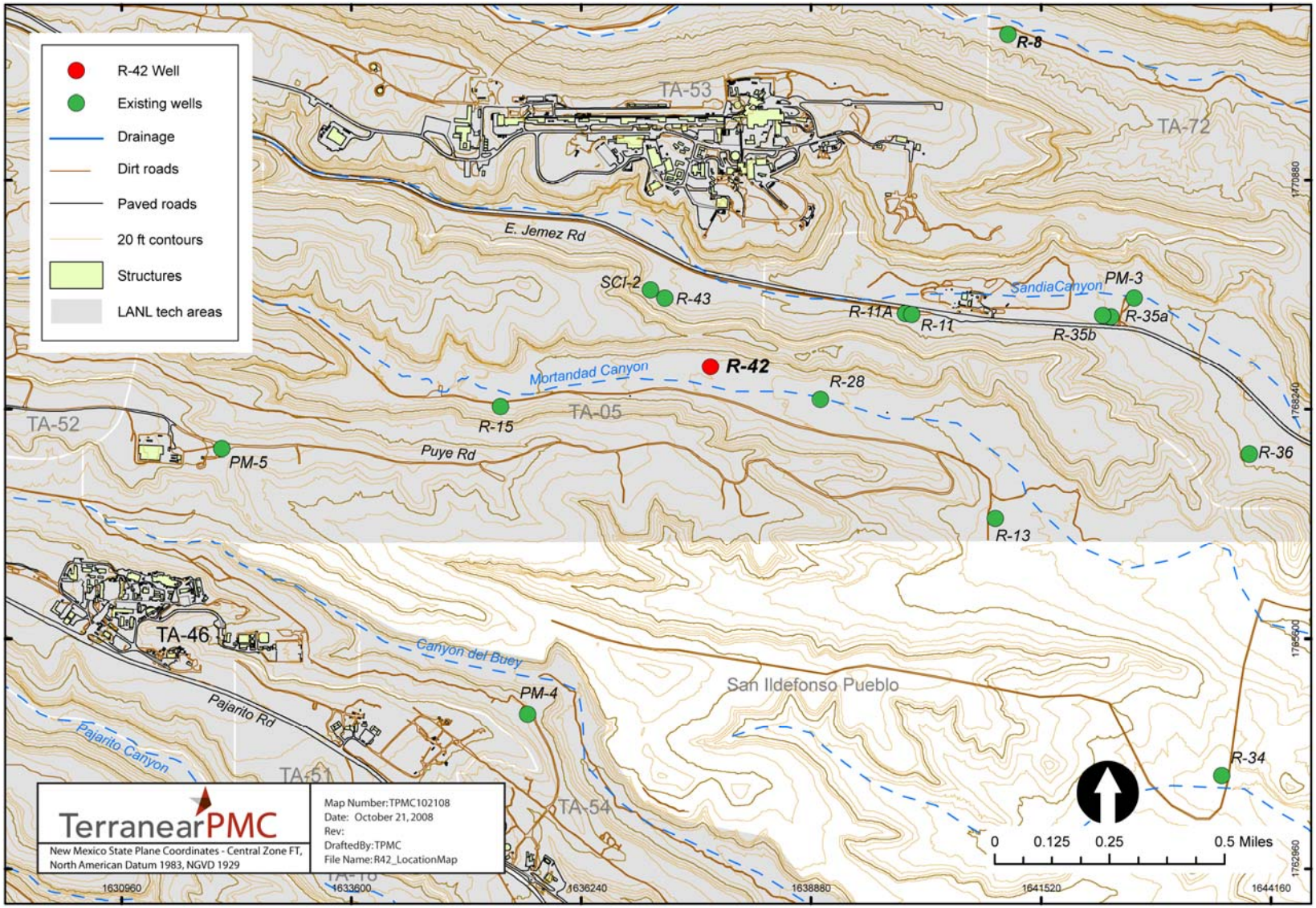

Figure 1.0-1 **Location of regional aquifer well R-42 with respect to municipal supply well PM-5 and additional surrounding regional wells**

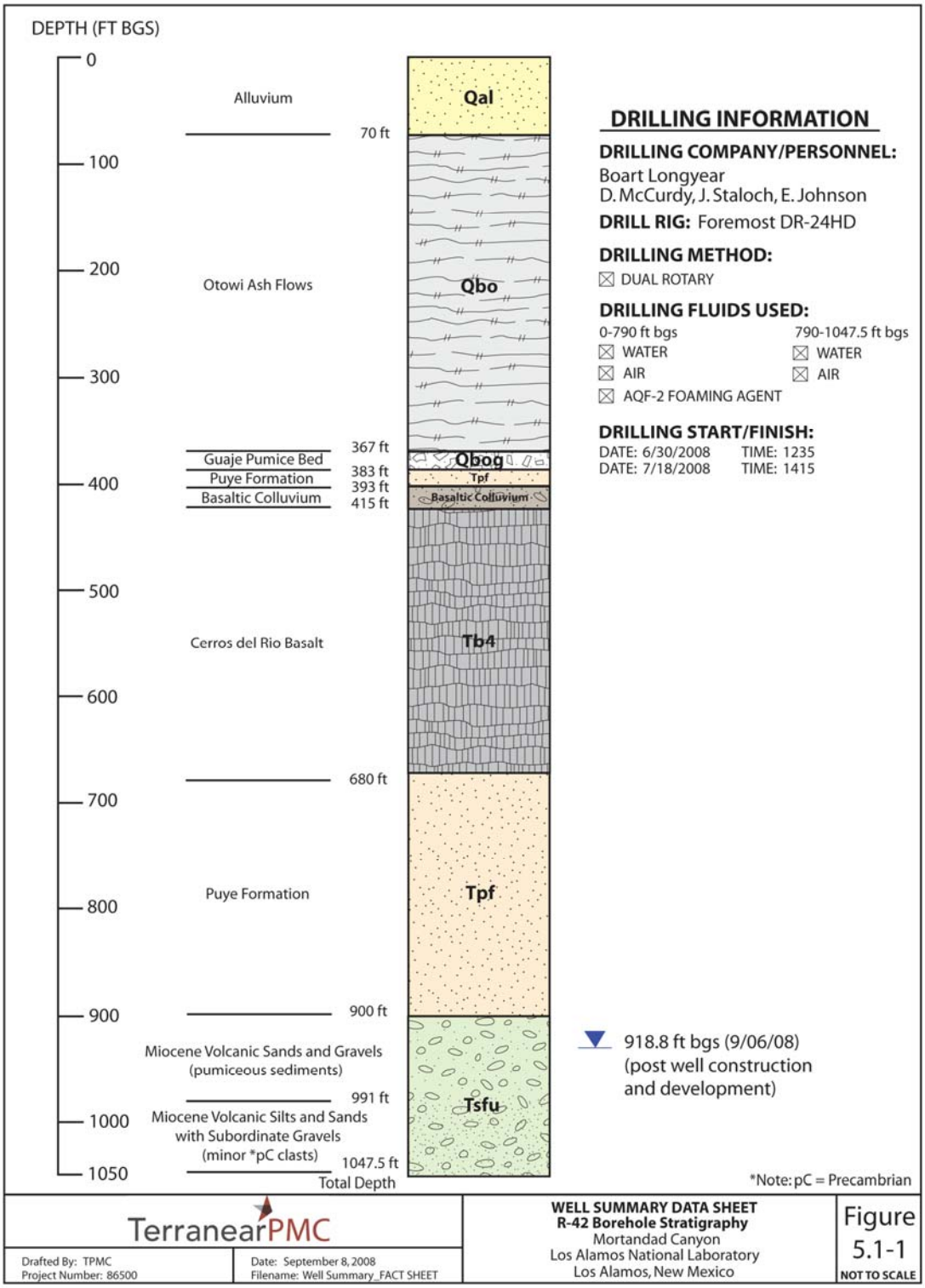

Figure 5.1-1 R-42 borehole stratigraphy

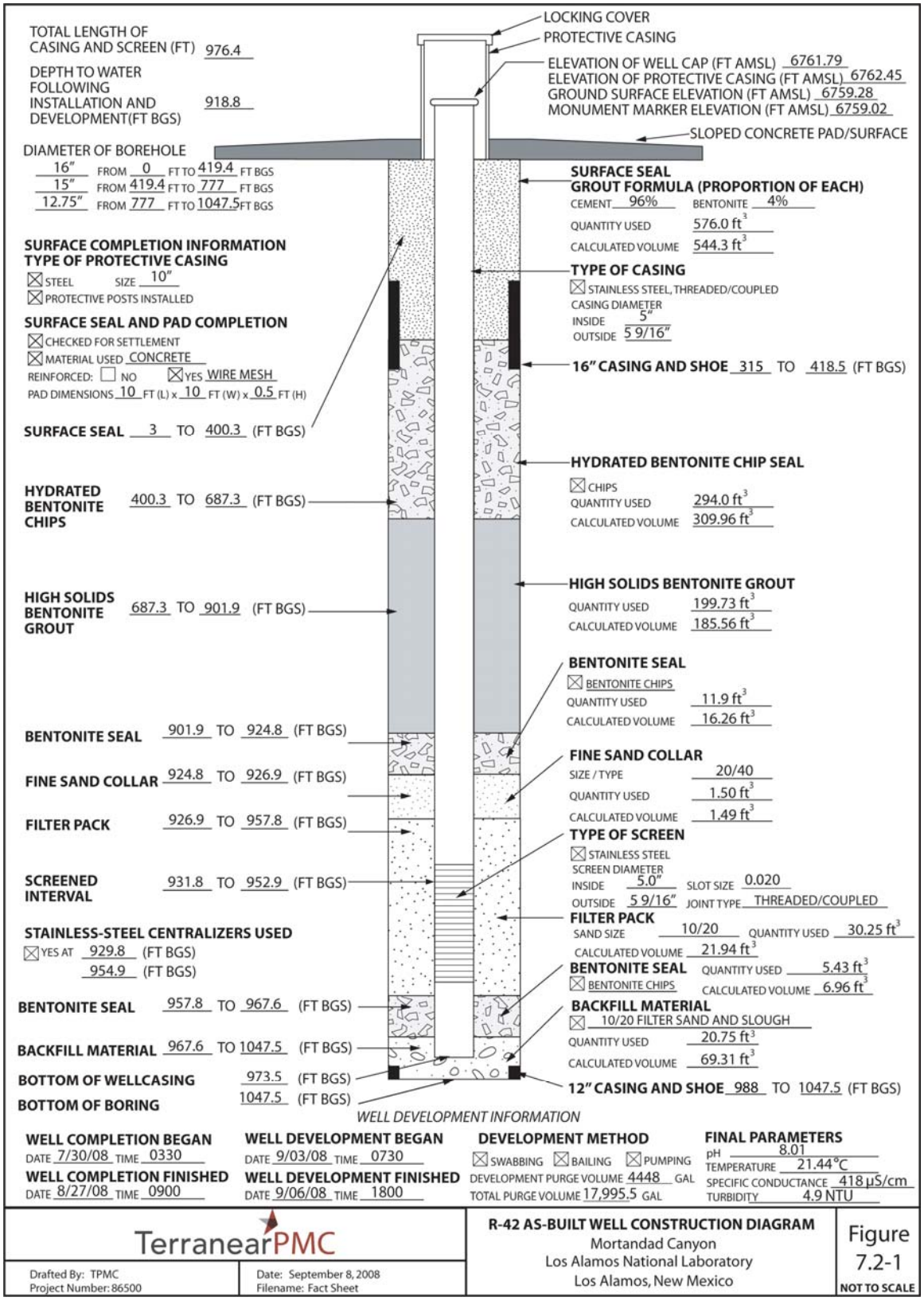

Figure 7.2-1 R-42 as-built well construction diagram

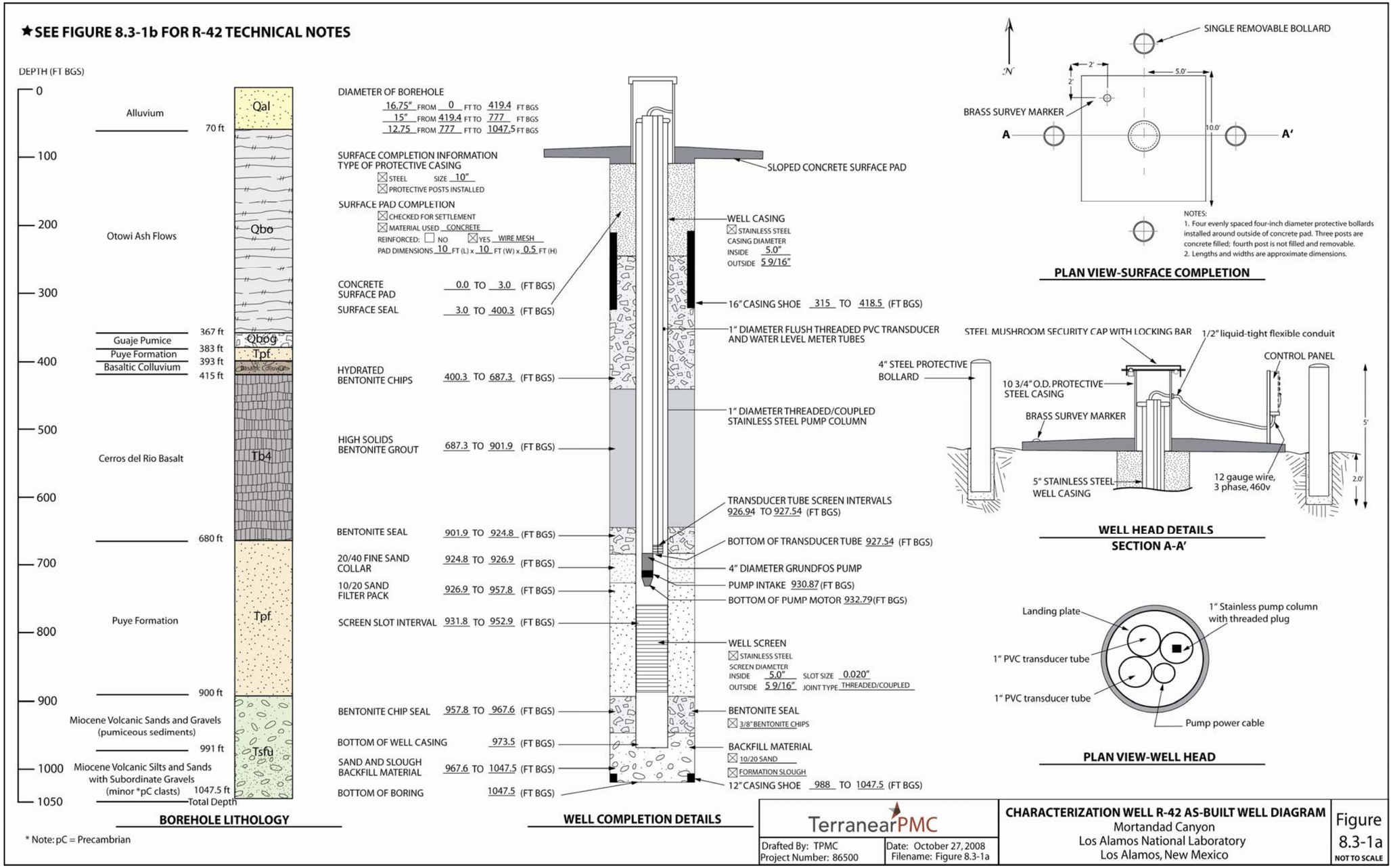

Figure 8.3-1a As-built schematic for regional well R-42

R-42 TECHNICAL NOTES: [1]

SURVEY INFORMATION[2]

Brass Marker

Northing:	1768775.7330
Easting:	1637709.9575
Elevation:	6759.02

Well Casing (top of stainless steel)

Northing:	1768770.2588
Easting:	1637713.6341
Elevation:	6761.79

BOREHOLE GEOPHYSICAL LOGS

LANL Natural Gamma Ray, LANL Induction Tool
Schlumberger Compensated Neutron, Three Detector Litho-Density, Natural Gamma Ray, and Elemental Capture Sonde

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam

MILESTONE DATES

Drilling

Start:	06/30/2008
Finished:	07/18/2008

Well Completion

Start:	07/30/2008
Finished:	08/27/2008

Well Development

Start:	09/03/2008
Finished:	09/06/2008

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 4,448 gallons

Parameter Measurments (Final)

pH:	8.01
Temperature:	21.44 °C
Specific Conductance:	418 µS/cm
Turbidity:	4.9 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Water Produced:	13,547.5 gallons
Average Flow Rate:	5.2 gpm
Performed on:	11/12–15/2008

DEDICATED SAMPLING SYSTEM

Pump
Grundfos, Type: 5S30-820 CBM
Model: 96023161-P10931004
3 U.S. gpm, intake at 930.8 ft bgs
Environmental Retrofit

Motor
Franklin Electric, model: 2343268602,
3HP, 3-phase

Pump Column
1-inch, schedule 40, 304 stainless steel,
threaded/coupled, check valves every 240 ft

Transducer Tubes
1-inch, schedule 40 PVC, flush threaded,
0.010-inch screen at 927-927.5 ft bgs

Transducer
In-Situ, Level Troll 500, 15 psi vented

NOTES:
1) Additional information available in "Final Completion Report, Characterization Well R-42, Los Alamos National Laboratory, Los Alamos, New Mexico, November 2008.
2) Coordinates based on New Mexico State Plane Grid Coordinates, Central Zone (NAD83); Elevation expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

TerranearPMC	R-42 TECHNICAL NOTES	Figure
Drafted By: TPMC Project Number: 86500 Date: November 20, 2008 Filename: Figure 8.3-1b	Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	8.3-1b NOT TO SCALE

Figure 8.3-1b As-built technical notes for R-42

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

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
Drilling					
6/30/2008	1200	1200	8	8	na[a]
7/01/2008	1500	2700	10	18	na
7/02/2008	2000	4700	9	27	na
7/03/2008	0	4700	0	27	na
7/08/2008	400	5100	10	37	na
7/09/2008	1200	6300	25	62	na
7/10/2008	3200	8500	55	117	na
7/11/2008	600	9100	30	147	na
7/12/2008	7200	16300	60	207	na
7/13/2008	1200	17500	40	247	na
7/14/2008	0	17500	0	247	na
7/15/2008	200	17700	10	257	na
7/16/2008	700	18400	25	282	na
7/17/2008	0	18400	0	282	na
7/18/2008	0	18400	0	282	na
7/19/2008	0	18400	0	282	na
7/20/2008	0	18400	0	282	na
Well Construction					
7/22/2008	0	18400	n/a[b]	n/a	na
7/23/2008	0	18400	n/a	n/a	na
7/24/2008	1500	19900	n/a	n/a	na
7/25/2008	2500	22400	n/a	n/a	na
7/26/2008	0	22400	n/a	n/a	na
7/27/2008	0	22400	n/a	n/a	na
7/28/2008	0	22400	n/a	n/a	na
7/29/2008	0	22400	n/a	n/a	na
7/30/2008	0	22400	n/a	n/a	na
7/31/2008	1000	23400	n/a	n/a	na
8/01/2008	3800	27200	n/a	n/a	na
8/02/2008	2600	29800	n/a	n/a	na
8/03/2008	5700	35500	n/a	n/a	na
8/04/2008	500	36000	n/a	n/a	na
8/05/2008	1350	37350	n/a	n/a	na
8/06/2008	540	37890	n/a	n/a	na

Table 3.1-1 (Continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
8/07/2008	100	37990	n/a	n/a	na
8/08/2008	0	37990	n/a	n/a	na
8/09/2008	0	37990	n/a	n/a	na
8/10/2008	0	37990	n/a	n/a	na
8/11/2008	0	37990	n/a	n/a	na
8/12/2008	0	37990	n/a	n/a	na
8/13/2008	0	37990	n/a	n/a	na
8/14/2008	820	38810	n/a	n/a	na
8/15/2008	2830	41640	n/a	n/a	na
8/16/2008	0	41640	n/a	n/a	na
8/17/2008	1090	42730	n/a	n/a	na
8/18/2008	240	42970	n/a	n/a	na
8/19/2008	0	42970	n/a	n/a	na
8/20/2008	0	42970	n/a	n/a	na
8/21/2008	115	43085	n/a	n/a	na
8/22/2008	175	43260	n/a	n/a	na
8/23/2008	270	43530	n/a	n/a	na
8/24/2008	675	44205	n/a	n/a	na
8/25/2008	0	44205	n/a	n/a	na
8/26/2008	570	44775	n/a	n/a	na
8/27/2008	330	45105	n/a	n/a	na
Total Volume (gal.)					
R-42	45105				32484

[a] na = Not available.

[b] n/a = Not applicable. Foam use and pit use discontinued after drilling activities; therefore, no additional fluids were produced.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-42

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type
Drilling				
R-42	GW42-08-14095	7/14/2008	771–775	Potential perched groundwater
R-42	GW42-08-14096	7/17/2008	894	Potential perched groundwater
R-42	GW42-08-14097	7/17/2008	913	Groundwater
R-42	GW42-08-14098	7/17/2008	970	Groundwater
R-42	GW42-08-14099	7/17/2008	990–995	Groundwater
R-42	GW42-08-14100	7/17/2008	1020–1029	Groundwater
Well Development				
R-42	GW42-08-14109	9/03/2008	932	Groundwater
R-42	GW42-08-14110	9/05/2008	955.4	Groundwater
R-42	GW42-08-14111	9/05/2008	955.41	Groundwater
R-42	GW42-08-14112	9/05/2008	949.41	Groundwater
R-42	GW42-08-14113	9/05/2008	941.41	Groundwater
R-42	GW42-08-14114	9/05/2008	933.41	Groundwater
R-42	GW42-08-14115	9/06/2008	931.41	Groundwater
R-42	GW42-08-14116	9/06/2008	931.41	Groundwater
R-42	GW42-08-14117	9/06/2008	966.20	Groundwater
R-42	GW42-08-14118	9/06/2008	966.20	Groundwater
Aquifer Pump Test				
R-42	GW42-09-999	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1000	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1001	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1002	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1003	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1004	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1005	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1006	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1007	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1008	11/15/2008	931.8–952.9	Groundwater
R-42	GW42-09-1009	11/15/2008	931.8–952.9	Groundwater
R-42	GW42-09-1010	11/15/2008	931.8–952.9	Groundwater
R-42	GW42-09-1011	11/15/2008	931.8–952.9	Groundwater
R-42	GW42-09-1014	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1015	11/14/2008	931.8–952.9	Groundwater
R-42	GW42-09-1016	11/15/2008	931.8–952.9	Groundwater

Table 6.0-1
R-42 Video and Geophysical Logging Runs

Date	Depth (ft bgs)	Description
7/13/2008	0–769	Laboratory video run to view basalt/Puye contact and potential perched water in Puye Formation
7/14/2008	0–771	Laboratory video and induction log run to view basalt/Puye contact and potential perched water in Puye Formation
7/18/2008	0–1029.5	Laboratory gamma tools run through 12-in. casing to TD at 1029.5 ft bgs
7/19/2008 and 7/20/2008	0–1023	Schlumberger complete geophysical suite, including Triple Detector Lithodensity Tool, Accelerator Porosity Sonde, Compensated Neutron Tool, Hostile Natural Gamma Spectroscopy, Elemental Capture Spectroscopy, and cased hole formation resistivity.

Table 7.2-1
R-42 Annular Fill Materials

Material	Volume
Surface seal: cement slurry	576.0 ft^3
Bentonite seal: bentonite chips	294.0 ft^3
Bentonite seal: high solids bentonite grout	199.73 ft^3
Upper annular seal: bentonite chips	11.9 ft^3
Fine sand collar: 20/40 silica sand	1.5 ft^3
Primary filter: 10/20 silica sand	30.25 ft^3
Lower annular seal: bentonite chips	5.43 ft^3
Backfill material: 10/20 silica sand and slough	20.75 ft^3
Potable water used in the regional aquifer (drilling and well construction)	45,105 gal.

Table 8.1-1
Well Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-42

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
9/05/2008	8.04	21.34	~100	170.0	0.383	859.0	4	4
	8.14	23.04	80.9	171.7	0.383	638.7	135	139
	8.12	23.78	81.1	167.8	0.389	733.9	120	259
	8.07	23.76	80.7	168.3	0.391	673.8	140	399
	8.09	23.80	79.6	167.4	0.393	9.4	140	539
	8.05	23.95	80.1	168.0	0.389	7.3	140	679
	8.04	23.99	79.8	168.4	0.398	2.7	140	819
	8.04	24.66	78.9	169.0	0.399	2.3	140	959
	8.02	23.68	80.2	173.3	0.402	1.6	140	1099
	8.01	24.03	80.0	175.7	0.404	0.7	140	1239
	8.00	23.79	80.7	181.9	0.402	1.5	140	1379
	8.01	23.62	80.5	175.6	0.407	1.1	140	1519
	7.99	23.32	79.6	174.9	0.407	0.2	140	1659
	8.00	23.75	79.1	175.7	0.409	2.2	140	1799
	7.99	23.29	79.4	174.6	0.407	2.7	140	1939
	8.01	23.21	79.2	171.1	0.409	1.4	140	2079
9/06/08	7.86	19.06	45.4	–78.9	0.397	145.1	164	2243
	7.95	22.21	56.5	10.1	0.408	6.9	130	2373
	8.12	22.96	60.3	63.1	0.412	5.9	130	2503
	8.09	23.25	60.8	78.6	0.412	4.8	130	2633
	8.08	23.65	65.8	91.2	0.412	4.5	130	2763
	8.05	24.11	65.8	103.2	0.413	4.2	125	2888
	8.04	24.28	68.7	112.0	0.413	4.3	120	3008
	8.03	24.48	67.1	115.9	0.414	5.1	120	3128
	8.03	25.36	70.8	121.5	0.416	4.7	120	3248
	8.03	25.39	71.7	125.7	0.412	4.3	120	3368
	8.12	24.92	62.2	134.6	0.405	29.1	120	3488
	8.04	23.63	71.1	138.6	0.414	4.4	120	3608
	8.02	23.60	72.8	144.8	0.415	3.4	120	3728
	8.01	23.63	73.0	151.2	0.416	2.7	120	3848
	8.02	23.42	73.9	151.9	0.406	2.3	120	3968
	8.01	23.10	72.7	152.7	0.417	2.7	120	4088
	8.01	22.98	74.8	158.8	0.410	2.4	120	4208
	8.02	23.20	71.9	163.2	0.417	2.3	120	4328
	8.01	21.44	72.8	169.8	0.418	4.9	120	4448

Table 8.1-1 (Continued)

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pump Test Volumes								
11/12/08	n/r*	n/r	n/r	n/r	n/r	n/r	413	4861
11/14/08	8.22	17.68	12.1	–251.3	0.414	187.8	270	5131
	8.11	20.86	57.5	31.9	0.434	0.6	468	5599
	8.04	21.04	65.3	54.9	0.434	0.3	624	6223
	8.04	21.04	66.6	55.8	0.434	0.1	624	6847
	8.05	20.89	68.4	60.8	0.435	0.2	624	7471
	8.06	20.68	68.8	64.8	0.436	0.0	624	8095
	8.07	20.54	68.7	71.1	0.436	0.0	624	8719
	8.08	20.61	70.8	72.3	0.436	0.0	624	9343
	8.07	20.61	71.8	82.0	0.436	0.0	624	9967
11/15/08	8.08	20.50	72.0	87.1	0.437	0.0	624	10591
	8.08	20.46	70.7	92.7	0.437	0.0	624	11215
	8.07	20.46	71.4	94.0	0.437	0.0	624	11839
	8.07	20.68	72.5	95.1	0.438	0.0	572	12411
Postaquifer Pump Test Purge Volumes								
11/16/08	n/r	n/r	n/r	n/r	n/r	n/r	5589.6	17995.5

Note: Cumulative purge volumes calculated using average pump discharge rate of 5.2 gpm.

* n/r = Not recorded.

Table 8.5-1
R-42 Survey Coordinates

North	East	Elevation (ft amsl)	Identification
1768775.7330	1637709.9575	6759.02	R-42 brass pin embedded in pad
1768772.4834	1637715.2387	6759.28	R-42 ground surface near pad
1768770.1228	1637713.7024	6762.45	R-42 top of 10-in. protective casing
1768770.2588	1637713.6341	6761.79	R-42 top of stainless-steel well casing

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

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-42

Location ID	Sample ID	Date Collected	Description	Sample Type
WST-600902	GW42-08-14277	9/08/08	Cuttings Pit Solids	Drill Cuttings
WST-600902	GW42-08-14276	9/08/08	Cuttings Pit Solids	Drill Cuttings
WST-600902	GW42-08-14288	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	GW42-08-14289	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	GW42-08-14290	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	GW42-08-14291	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	RC05-08-15255	10/30/08	Well Development Purge Fluids	Purge Water
WST-600902	RC05-08-15256	10/30/08	Well Development Purge Fluids	Purge Water
WST-600902	RC05-08-15257	10/30/08	Well Development Purge Fluids	Purge Water
WST-600902	RC05-08-15258	10/30/08	Well Development Purge Fluids	Purge Water
R-42	RC05-09-1268	10/30/08	Decontamination Fluids	Decontamination Water
R-42	RC05-09-1269	10/30/08	Decontamination Fluids	Decontamination Water
R-42	RC05-09-1270	10/30/08	Decontamination Fluids	Decontamination Water
R-42	RC05-09-1271	10/30/08	Decontamination Fluids	Decontamination Water

Appendix A

Well R-42 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-42	**TECHNICAL AREA (TA): 05**	**PAGE: 1 of 5**
DRILLING COMPANY: Boart Longyear	**START DATE/TIME:** 6/30/08: 1235	**END DATE/TIME:** 7/17/08: 2030
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR-24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION:		**TOTAL DEPTH:** 1047.5 ft below ground surface (bgs)
DRILLERS: D. McCurdy/J. Staloch	**SITE GEOLOGIST:** J.R. Lawrence	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
0–70	**ALLUVIUM:** Unconsolidated Tuffaceous Sediments—pale red (10R 6/2) to light gray (5YR 7/1), silty sand to sandy silt with few pebbles and gravels, trace clay, unconsolidated, G/S/F = 2%–5%/10%–30%/60%–90%, 3–25-mm pebbles of volcanic rock lithics in silt matrix with fine to coarse-grained sand composed of quartz and sanidine	Qal	Alluvium 0–70 ft bgs, 70 ft thick Qal/Qbo contact at 70 ft bgs based on gamma log and clasts of Tshirege Member in cuttings to at least 70 ft
70–80	**OTOWI MEMBER OF THE BANDELIER TUFF:** Weathered Tuff—orange (5YR 7/6) to pink (5YR 8/3), moderately to poorly welded, mostly ash, with little quartz and sanidine phenocrysts and trace volcanic lithics (mostly dacite)	Qbo	Distinct color change, presence of iron oxide, sample appears fresh, pumice appear weathered Otowi Member Bandelier Tuff (70–369 ft bgs), 299 ft thick
80–145	Tuff—pale orange (5YR 7/6) to white (10YR 8/1), poorly to moderately welded, lithic- and pumice-rich, 25%–30% pumice fragments (weathered to fibrous, vitric), lithics 10%–15% (mostly dacite up to 30 mm), 10%–15% phenocrysts of quartz and sanidine, 15%–50% ash matrix, some iron-staining around pumice		
145–200	Tuff—very pale brown (10YR 8/4), lithic- and pumice-rich, poorly welded, 15%–30% pumice (mostly fibrous vitric, up to 15 mm), 8%–30% lithics (mostly dacite, some andesite and flow-banded rhyolite up to 16 mm), 10%–15% phenocrysts (mostly quartz, some sanidine), 15%–50% ashy matrix, iron staining		
200–345	Tuff—reddish yellow (5YR 6/8) to orange brown (5YR 7/8), more ashy than above, lithic- and pumice-rich, poorly welded, 15%–50% pumice (mostly fibrous, vitric, up to 15 mm), lithics 8%–30% (mostly gray dacite, trace andesite and rhyolite), phenocrysts 10%–15% (mostly quartz, some sanidine), ashy matrix		Pumice are iron stained
345–367	Tuff—reddish yellow (5YR 6/6) to pale orange tan (5YR 7/6), lithic-poor, pumice rich, poorly welded, mostly ash and pumice >50% (mostly fibrous, vitric), <5% lithics (mostly dacite and andesite), phenocrysts 10%–15% (mostly quartz, some sanidine), some iron staining		Decrease in lithics Estimated Qbo/Qbog contact at 367 ft bgs

Borehole Lithologic Log (continued)

BOREHOLE ID: R-42	**TA-05**	**PAGE: 2 of 5**

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
367–383	**GUAJE PUMICE BED:** Pumice Bed—white (5YR 8/1), nonwelded, pumice fragments 80%–95% (white, vitric, fibrous, up to 22 mm), 5%–20% lithics (dacites, andesites, rhyolites, up to 20 mm), 5%–10% quartz and sanidine crystals >5% fine ash	Qbog	Guaje Pumice (367–383 ft bgs), 16 ft thick
383–415	**PUYE FORMATION:** Volcaniclastic Sediments—pink (5YR 7/4), sandy silt to silty sand with pebbles and gravel, gravel component increases with depth, G/S/F = 20%–70%/15%–50%/20%–35%, sand is composed of basalt chips, siltstone, and sandstone, gravels are subrounded clasts of basalt and sandstone, at depth composition of gravels is 100% silt coated basalt chips	Tpf	Base of Guaje Pumice Bed and estimated top of Puye Formation at 383 ft bgs Puye Formation, upper part above Cerros del Rio basalt (383–415 ft bgs), 32 ft thick Section from 393 to 415 ft entirely basaltic detritus; possible flow rubble zone
415–495	**CERROS DEL RIO BASALT:** Basalt—dark to medium gray (GLEY 4/1 to GLEY 4/0), 100% basalt (massive to weakly vesicular, porphyritic with aphanitic groundmass, 3%–5% phenocrysts (clinopyroxene, minor olivine, minor feldspar), cumulophyric	Tb4	Cerros del Rio Basalt (est. 415–680 ft bgs), 265 ft thick Limonitic iron oxides on some fracture surfaces
495–535	Basalt—light medium gray (GLEY1 6/0) to dark gray (GLEY1 4/0), 50%–85% light medium gray basalt chips, 15%–50% dark gray olivine-bearing basalt, (massive, porphyritic with aphanitic groundmass), 10%–15% silt and clay 3%–5% phenocrysts (olivine, brown subhedral clinopyroxene, rare plagioclase)		Olivines strongly altered to iddingsite
535–590	Basalt—light gray (GLEY1 6/0), 100% basalt (nonvesicular, porphyritic with aphanitic groundmass, cumulophyric, groundmass weak to moderately altered and bleached, 3%–5% phenocrysts (green olivine and clinopyroxene)		
590–595	Basalt—very dark gray (GLEY1 3/0) to dark reddish gray (2.5 YR 4/1), 50% massive olivine basalt, 50% dark reddish brown strongly vesicular basalt with strong iron-oxide staining, amygdaloidal white clay, strongly weathered appearance		Strong vesicularity suggests Tb4 flow unit top; apparent contact at 592.5 ft bgs

Borehole Lithologic Log (continued)

BOREHOLE ID: R-42	**TA-05**	**PAGE: 3 of 5**

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
595–676	Basalt—varicolored very dark gray (GLEY1 3/0) to dark reddish gray (2.5 YR 4/1) to white (10YR 8/1), 80%–90% basalt (vesicular to weakly vesicular, porphyritic with aphanitic groundmass), 1%–3% phenocrysts (clinopyroxene and olivine), 10%–20% white clay filling vesicles	Tb4	
676–680	Basaltic detritus—sediments and tephra of Cerros del Rio	Tb4 clastic	Based on gamma, density, and ECS geophysical logs
680–695	**PUYE FORMATION:** Volcaniclastic Sediments—light gray (GLEY1 7/10), sand with gravels and pebbles, mixed varieties of volcanic rocks, 80% mixed volcanic lithics, 10%–15% sandstone fragments, 7%–10% white clay	Tpf	Puye Formation Puye Formation lower part (680–900 ft bgs), 220 ft thick Overall Puye Formation encompassing Cerros del Rio (383–900 ft bgs), 517 ft thick
695–730	Volcaniclastic Sediments—pinkish white (5YR 8/2), gravel with sand and silt, dominantly dacite detritus, 85%–95% light gray to pink hornblende dacite, 10%–15% basalt, 2%–3% sandstone fragments		
730–780	Volcaniclastic Sediments—light gray (GLEY1 7/0), coarse gravel with sand, subrounded detrital clasts composed mostly of gray and pinkish gray dacite, 90%–95% dacite (up to 18 mm), 5%–10% pink and black quartz-bearing rhyolite vitrophyre		
780–795	Volcaniclastic Sediments—brownish gray (10YR 5/2), pebbley gravel with sand and silt, detrital dacites, 80% light gray hornblende dacite, 15% dacite vitrophyre, 5% pumice		
795–820	Volcaniclastic Sediments—pinkish white (5YR 8/2), gravel with sand and minor clay, dacite detritus, 97% dacite, 3% indurated sandstones		
820–845	Volcaniclastic Sediments—pinkish gray (5YR 7/2), gravel with sand and clay, dacite detritus, up to 25% silt and clay matrix, detrital clasts mostly dacite, some quartz bearing rhyodacite		
845–875	Volcaniclastic Sediments—pinkish gray (5YR 6/2), coarse gravel with sand, dacite detritus, composed mostly of light gray biotite-dacite, minor pinkish quartz rhyolite, abundant free quartz crystals, silty matrix		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-42	**TA-05**	**PAGE: 4 of 5**

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
875–900	Volcaniclastic Sediments—gray (GLEY1 6/0), coarse gravel with sand, dacite detritus, 100% white to light gray hornblende-dacite clasts (up to 20 mm)	Tpf	Puye Formation continued
900–920	**MIOCENE VOLCANIC SANDS AND GRAVELS:** Pumiceous Sediments—pink tan (5YR 8/3) to light gray (GLEY1 7/10) gravel with pebbles, sand and silt, 40%–75% white vitric aphyric pumices, 25%–60% mixed volcanic clasts (dacite, andesite, basalt and biotite-rhyolite), silty matrix	Tsfu	Santa Fe Group contact at 900 ft bgs
920–945	Pumiceous Sediments—pale yellow tan (10YR 8/3) and light gray (GLEY1 7/0) gravel with sand and abundant silt, pumice and mixed volcanic detritus, 40%–50% white pumice, 40%–50% mixed volcanic rocks, 15%–20% silt		
945–970	Pumiceous Sediments—pale yellowish brown (10 YR 7/3), gravel with pebbles and sand, 90%–95% white pumice fragments (up to 15 mm), 5%–10% light gray dacites, trace sandstone fragments		Note: Sharp increase in % pumice
970–991	Pumiceous Sediments—very pale brown (10YR 7/4), siltstone and mudstone with trace sand and fine gravel, predominantly pumice detritus, 50%–95% silt, pumice and dacite gravels		
991-1020	**MIOCENE VOLCANIC AND PRECAMBRIAN PLUTONIC/METAMORPHIC SILTS AND SANDS:** Volcaniclastic Sediments—very pale brown (10YR 7/4), siltstone with fine sand and clay, predominately volcanic detritus, 50%–90% silt and clay, 10%–20% sand, 20%–30% lithic clasts of indurated fine-grained sandstone, dacite, rhyolite, and andesite, minor to 15% rounded Precambrian quartz clasts		Sharp change in composition of detritus; first appearance of Precambrian quartzite clasts
1020–1047.5	Volcaniclastic Sediments—very pale brown (10YR 7/4) coarse gravel with silt and sand, mixed volcanic and minor Precambrian detrital material, 70%–80% rounded volcanic clasts (dacite, rhyolite, andesite), 5%–10% Precambrian quartzite (varicolored), 10%–20% silt matrix, trace sandstone lithics		
1047.5	Total Depth		

ABBREVIATIONS

5YR 8/1 = Munsell soil color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g.,1) are expressed. Hue indicates soil color's relation to red, yellow, green, blue, and purple. Value indicates soil color's lightness. Chroma indicates soil color's strength.
F = Fines.
F = fines (<62 μm).
G = Gravel (2 to 75 mm).
N = Neutrals.
Qal = Quaternary Alluvium.
Qbo = Otowi Member of Bandelier Tuff.
Qbog = Guaje Pumice Bed.
S = Sand (2 mm to 62 μm).
Tb4 = Cerros del Rio Basalt.
Tpf = Puye Formation.
Tsfu = Santa Fe Group.
YR = Yellow red.

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-42

Seven groundwater-screening samples were collected at borehole R-42 during drilling: two above the regional water table (from 771 to 775 ft below ground surface [bgs]) and five within the regional aquifer (from 894 to 1029 ft bgs). A total of 10 groundwater-screening samples were collected at well R-42 during well development. The samples were collected from the screen interval of 932 to 966 ft bgs within the regional aquifer. The filtered samples were analyzed for total organic carbon (TOC), cations, anions, perchlorate, and metals. A total of 4448 gal. of groundwater was pumped from well R-42 during development and sample collection.

B-1.1 Field Preparation and Analytical Techniques

Chemical analyses of groundwater-screening samples were performed at Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 6 (EES-6). Groundwater samples were filtered (0.45-µm membranes) before preservation and chemical analyses. Samples were acidified at the EES-6 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified in the U.S. Environmental Protection Agency (EPA) SW-846 manual. Ion chromatography was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Instrument detection limits for perchlorate were 0.002 and 0.005 ppm. Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was used for analyses of calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS). The precision limits (analytical error) for major ions and trace elements were generally less than ±7% using ICPOES and ICPMS. Charge balance errors for total cations and anions were generally less than ±9% for complete analyses of the above inorganic chemicals. The negative cation-anion charge balance values indicate excess anions for the filtered samples. Total carbonate alkalinity was measured using standard titration techniques.

B-1.2 Field Parameters

Table B-1.2-1 provides results of field parameters, consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during well development. Measurements of pH and temperature varied from 7.86 to 8.12 and from 19.1°C to 25.4°C, respectively, at well R-42. Percent saturation of DO varied from 45.4 to approximately 100, suggesting that DO was measured between 3 and 7 mg/L at the well. This assumes that 6.61 mg/L of DO represents complete (100%) saturation at 6000 ft and 25°C. Regional aquifer groundwater is relatively oxidizing at well R-42 based on DO and ORP measurements, with ORP varying from –78.9 to 175.7 millivolts (mV) (Table B-1.2-1), with most of the ORP readings greater than +100 mV. Elevated above-background concentrations of total dissolved chromium of 0.100 ppm and higher also support relatively oxidizing conditions at well R-42. Specific conductance ranged from 383 to 418 microsiemens per centimeter (µS/cm). Values of turbidity measured at R-42 ranged from 0.2 to 859 nephelometric turbidity units (NTUs) for the nonfiltered groundwater samples. Ten of the 35 turbidity measurements recorded during well development exceeded 5 NTUs (Table B-1.2-1).

B-1.3 Analytical Results for Groundwater-Screening Samples

Table B-1.3-1 provides analytical results for groundwater-screening samples collected at well R-42 during drilling and well development. Calcium and sodium are the dominant cations in groundwater pumped from well R-42. Dissolved concentrations of calcium and sodium in filtered samples ranged from 24.2 to 39.4 ppm (24.2 to 39.4 mg/L) and from 15.4 to 29.4 ppm, respectively. Concentrations of chloride and fluoride in filtered samples ranged from 26.7 to 34.0 ppm and from 0.33 to 0.45 ppm, respectively, during development of well R-42. Dissolved concentrations of nitrate(N) and sulfate ranged from 4.12 to 5.53 ppm and from 42.5 to 58.8 ppm, respectively, at the well. Dissolved concentrations of chloride, nitrate(N), and sulfate at well R-42 exceeded Laboratory background within the regional aquifer (LANL 2007, 095817). Maximum background concentrations for dissolved chloride, nitrate plus nitrite(N), and sulfate in the regional aquifer are 5.95 mg/L, 1.05 mg/L, and 8.63 mg/L, respectively (LANL 2007, 095817). Concentrations of TOC ranged from 0.82 to 1.19 mgC/L at well R-42 (Table B-1.3-1). Concentrations of perchlorate were less than detection (<0.002 and 0.005 ppm) at well R-42.

Dissolved concentrations of iron and manganese ranged from 0.01 to 0.06 ppm (10 to 60 μg/L) and from 0.023 to 0.135 ppm, respectively, in groundwater-screening samples collected at well R-42 (Table B-1.3-1). Dissolved concentrations of iron and manganese are less than the maximum background values for these two trace metals (excluding one sample analyzed for manganese) in the regional aquifer (iron: 0.147 mg/L and manganese: 0.124 mg/L) (LANL 2007, 095817). Detectable concentrations of molybdenum in filtered samples ranged from 0.001 to 0.006 ppm (Table B-1.3-1). Dissolved concentrations of zinc ranged from 0.001 to 0.012 ppm in groundwater-screening samples collected at R-42, with no samples exceeding the maximum background concentration of this trace metal in filtered samples (Table B-1.3-1). Background mean, median, and maximum concentrations of zinc in filtered samples are 3.08 μg/L, 1.45 μg/L, and 32.0 μg/L, respectively, for the regional aquifer (LANL 2007, 095817). Dissolved concentrations of boron ranging from 0.018 to 0.056 ppm at well R-42 typically are less than the Laboratory maximum background value of 51.6 μg/L for the regional aquifer (LANL 2007, 095817). Total dissolved concentrations of chromium ranged from 0.146 to 0.513 ppm (146 to 513 ppb or μg/L) at well R-42 (Table B-1.3-1). Background mean, median, and maximum concentrations of total dissolved chromium are 3.07 μg/L, 3.05 μg/L, and 7.20 μg/L, respectively, for the regional aquifer (LANL 2007, 095817).

B-2.0 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 number. This information is also included in text citations. ER ID numbers 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 New Mexico Environment Department Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; EPA, 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), 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
Well Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-42

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
9/05/2008	8.04	21.34	~100	170.0	383	859.0	4	4
	8.14	23.04	80.9	171.7	383	638.7	135	139
	8.12	23.78	81.1	167.8	389	733.9	120	259
	8.07	23.76	80.7	168.3	391	673.8	140	399
	8.09	23.80	79.6	167.4	393	9.4	140	539
	8.05	23.95	80.1	168.0	389	7.3	140	679
	8.04	23.99	79.8	168.4	398	2.7	140	819
	8.04	24.66	78.9	169.0	399	2.3	140	959
	8.02	23.68	80.2	173.3	402	1.6	140	1099
	8.01	24.03	80.0	175.7	404	0.7	140	1239
	8.00	23.79	80.7	181.9	402	1.5	140	1379
	8.01	23.62	80.5	175.6	407	1.1	140	1519
	7.99	23.32	79.6	174.9	407	0.2	140	1659
	8.00	23.75	79.1	175.7	409	2.2	140	1799
	7.99	23.29	79.4	174.6	407	2.7	140	1939
	8.01	23.21	79.2	171.1	409	1.4	140	2079
9/06/08	7.86	19.06	45.4	–78.9	397	145.1	164	2243
	7.95	22.21	56.5	10.1	408	6.9	130	2373
	8.12	22.96	60.3	63.1	412	5.9	130	2503
	8.09	23.25	60.8	78.6	412	4.8	130	2633
	8.08	23.65	65.8	91.2	412	4.5	130	2763
	8.05	24.11	65.8	103.2	413	4.2	125	2888
	8.04	24.28	68.7	112.0	413	4.3	120	3008
	8.03	24.48	67.1	115.9	414	5.1	120	3128
	8.03	25.36	70.8	121.5	416	4.7	120	3248
	8.03	25.39	71.7	125.7	412	4.3	120	3368
	8.12	24.92	62.2	134.6	405	29.1	120	3488
	8.04	23.63	71.1	138.6	414	4.4	120	3608
	8.02	23.60	72.8	144.8	415	3.4	120	3728
	8.01	23.63	73.0	151.2	416	2.7	120	3848
	8.02	23.42	73.9	151.9	406	2.3	120	3968
	8.01	23.10	72.7	152.7	417	2.7	120	4088
	8.01	22.98	74.8	158.8	410	2.4	120	4208
	8.02	23.20	71.9	163.2	417	2.3	120	4328
	8.01	21.44	72.8	169.8	418	4.9	120	4448

Note: Cumulative purge volumes calculated using average pump discharge rate of 17.2 gpm.

Table B-1.3-1
Analytical Results for Groundwater-Screening Samples Collected at Well R-42

Sample ID	Aquifer	Sample Type	Activity	Date Received	ER/RRES-WQH	Depth (ft)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	08-1554	771–775	0.001	U[a]	0.321	0.001	0.0009	0.0000	0.059	0.000	0.044	0.000	0.001	U
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	08-1554	771–775	0.001	U	0.304	0.001	0.0008	0.0000	0.047	0.000	0.043	0.000	0.001	U
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	08-1577	894	0.001	U	0.685	0.001	0.0006	0.0000	0.039	0.000	0.052	0.001	0.001	U
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	08-1577	913	0.001	U	0.008	0.001	0.0004	0.0000	0.032	0.000	0.059	0.001	0.001	U
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	08-1577	970	0.001	U	0.009	0.000	0.0005	0.0000	0.029	0.000	0.073	0.003	0.001	U
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	08-1577	990–955	0.001	U	0.006	0.000	0.0005	0.0000	0.032	0.001	0.099	0.000	0.001	U
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	08-1577	1020–1029	0.001	U	0.054	0.009	0.0006	0.0000	0.030	0.000	0.070	0.001	0.001	U
GW42-08-14109	Regional	Well	Development	9/8/2008	08-1556	932	0.001	U	0.005	0.000	0.0010	0.0000	0.026	0.000	0.056	0.000	0.001	U
GW42-08-14110	Regional	Well	Development	9/8/2008	08-1556	955.4	0.001	U	0.005	0.000	0.0010	0.0001	0.020	0.001	0.062	0.000	0.001	U
GW42-08-14111	Regional	Well	Development	9/8/2008	08-1556	955.41	0.001	U	0.004	0.000	0.0008	0.0000	0.018	0.000	0.063	0.000	0.001	U
GW42-08-14112	Regional	Well	Development	9/8/2008	08-1556	949.41	0.001	U	0.006	0.000	0.0007	0.0000	0.056	0.001	0.065	0.001	0.001	U
GW42-08-14113	Regional	Well	Development	9/8/2008	08-1556	941.41	0.001	U	0.005	0.000	0.0008	0.0000	0.035	0.000	0.067	0.001	0.001	U
GW42-08-14114	Regional	Well	Development	9/8/2008	08-1556	933.41	0.001	U	0.005	0.000	0.0006	0.0000	0.029	0.001	0.058	0.000	0.001	U
GW42-08-14115	Regional	Well	Development	9/8/2008	08-1556	931.41	0.001	U	0.005	0.000	0.0006	0.0000	0.026	0.000	0.060	0.000	0.001	U
GW42-08-14116	Regional	Well	Development	9/8/2008	08-1556	931.41	0.001	U	0.005	0.000	0.0006	0.0001	0.024	0.001	0.059	0.000	0.001	U
GW42-08-14117	Regional	Well	Development	9/8/2008	08-1556	966.2	0.001	U	0.005	0.000	0.0007	0.0000	0.023	0.001	0.064	0.000	0.001	U
GW42-08-14118	Regional	Well	Development	9/8/2008	08-1857	966.2	0.001	U	0.005	0.000	0.0007	0.0000	0.021	0.000	0.064	0.001	0.001	U

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Br^- (ppm)	TOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl^- (ppm)	ClO_4^- (ppm)	ClO_4^- (U)	Co rslt (ppm)	stdev (Co)	Alk-CO_3 rslt (ppm)	ALK-CO_3 (U)	Cr rslt (ppm)	stdev (Cr)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	0.43	Not measured	25.4	0.1	0.001	U	37.5	n/a[b]	n/a	0.001	U	0.8	U	0.021	0.000
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	0.41	Not measured	25.0	0.1	0.001	U	37.2	0.005	U	0.001	U	0.8	U	0.021	0.000
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	0.05	Not measured	14.3	0.1	0.001	U	10.1	0.002	U	0.001	U	0.8	U	0.007	0.000
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	0.08	Not measured	23.6	0.1	0.001	U	19.3	0.005	U	0.001	U	0.8	U	0.009	0.000
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	0.20	Not measured	35.8	0.4	0.001	U	42.6	0.005	U	0.001	U	0.8	U	0.005	0.000
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	0.25	Not measured	43.5	0.1	0.001	U	46.9	0.005	U	0.001	U	0.8	U	0.006	0.000
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	0.14	Not measured	27.3	0.2	0.001	U	25.4	0.005	U	0.001	U	0.8	U	0.004	0.001
GW42-08-14109	Regional	Well	Development	9/8/2008	0.13	1.19	24.2	0.1	0.001	U	26.7	0.002	U	0.001	0.001	0.8	U	0.158	0.001
GW42-08-14110	Regional	Well	Development	9/8/2008	0.15	1.05	31.3	0.3	0.001	U	29.2	0.002	U	0.001	U	0.8	U	0.459	0.003
GW42-08-14111	Regional	Well	Development	9/8/2008	0.14	0.90	35.3	0.3	0.001	U	33.4	0.002	U	0.001	U	0.8	U	0.492	0.002
GW42-08-14112	Regional	Well	Development	9/8/2008	0.16	0.90	37.9	0.1	0.001	U	31.8	0.002	U	0.001	U	0.8	U	0.509	0.001
GW42-08-14113	Regional	Well	Development	9/8/2008	0.16	0.84	38.6	0.2	0.001	U	32.6	0.002	U	0.001	U	0.8	U	0.513	0.010
GW42-08-14114	Regional	Well	Development	9/8/2008	0.17	0.89	38.8	0.1	0.001	U	33.2	0.005	U	0.001	U	0.8	U	0.238	0.001
GW42-08-14115	Regional	Well	Development	9/8/2008	0.17	0.84	37.9	0.2	0.001	U	33.3	0.005	U	0.001	U	0.8	U	0.177	0.002
GW42-08-14116	Regional	Well	Development	9/8/2008	0.16	0.88	37.9	0.1	0.001	U	33.7	0.002	U	0.001	U	0.8	U	0.146	0.000
GW42-08-14117	Regional	Well	Development	9/8/2008	0.18	0.82	38.9	0.2	0.001	U	33.7	0.002	U	0.001	U	0.8	U	0.265	0.001
GW42-08-14118	Regional	Well	Development	9/8/2008	0.17	0.96	39.4	0.2	0.001	U	34.0	0.002	U	0.001	U	0.8	U	0.274	0.002

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F^-(ppm)	Fe rslt (ppm)	stdev (Fe)	Alk-CO_3+HCO_3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	0.001	U	0.003	0.000	0.73	0.50	0.00	142	0.00011	0.00001	3.28	0.01	0.052	0.001
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	0.001	U	0.003	0.000	0.76	0.50	0.00	145	0.00009	0.00000	3.35	0.01	0.050	0.002
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	0.001	U	0.003	0.000	0.70	0.38	0.00	107	0.00014	0.00001	4.12	0.01	0.054	0.005
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	0.001	U	0.001	0.000	0.63	0.01	U	138	0.00005	U	4.66	0.03	0.089	0.001
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	0.001	U	0.001	U	0.69	0.01	U	98.2	0.00010	0.00000	5.61	0.01	0.110	0.000
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	0.001	0.001	0.001	U	0.60	0.01	U	105	0.00007	0.00000	6.16	0.02	0.120	0.000
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	0.001	U	0.001	0.000	0.79	0.01	0.00	112	0.00014	0.00000	5.19	0.03	0.085	0.012
GW42-08-14109	Regional	Well	Development	9/8/2008	0.001	U	0.002	0.000	0.45	0.03	0.00	92.0	0.00007	0.00000	1.25	0.00	0.033	0.000
GW42-08-14110	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.34	0.01	0.00	79.8	0.00005	0.00001	2.65	0.02	0.033	0.000
GW42-08-14111	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.34	0.01	U	75.1	0.00005	U	2.09	0.01	0.033	0.000
GW42-08-14112	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.03	0.00	73.8	0.00005	U	2.11	0.01	0.036	0.000
GW42-08-14113	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.03	0.00	73.4	0.00005	U	2.05	0.01	0.035	0.001
GW42-08-14114	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	74.2	0.00005	U	2.07	0.01	0.036	0.000
GW42-08-14115	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	73.1	0.00005	U	2.07	0.01	0.036	0.000
GW42-08-14116	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	73.0	0.00005	U	2.02	0.01	0.035	0.000
GW42-08-14117	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	72.3	0.00005	U	2.05	0.01	0.035	0.000
GW42-08-14118	Regional	Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.06	0.00	72.5	0.00005	U	2.03	0.01	0.035	0.000

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)	stdev (Na)	Ni rslt (ppm)	stdev (Ni)	NO_2 (ppm)	NO_2-N rslt	NO_2-N (U)	NO_3 (ppm)	NO_3-N rslt
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	7.13	0.02	0.104	0.001	0.093	0.001	52.6	0.2	0.006	0.000	0.01	0.003	U	5.53	1.25
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	6.91	0.03	0.103	0.001	0.086	0.001	50.4	0.3	0.006	0.000	0.01	0.003	U	5.55	1.25
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	3.36	0.02	0.069	0.007	0.179	0.002	21.3	0.1	0.001	0.000	0.23	0.07	[b]	2.20	0.50
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	6.10	0.05	0.455	0.002	0.113	0.001	30.7	0.0	0.003	0.000	0.12	0.04	[b]	1.14	0.26
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	10.7	0.2	0.316	0.002	0.235	0.004	26.3	0.1	0.009	0.000	3.16	0.96	[b]	13.9	3.15
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	13.4	0.1	0.376	0.002	0.209	0.001	28.5	0.3	0.011	0.000	4.12	1.25	[b]	11.1	2.51
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	8.76	0.13	0.323	0.002	0.180	0.001	21.8	0.1	0.004	0.000	0.69	0.21	[b]	1.31	0.30
GW42-08-14109	Regional	Well	Development	9/8/2008	7.28	0.02	0.135	0.000	0.006	0.000	29.4	0.1	0.008	0.000	0.01	0.003	U	18.2	4.12
GW42-08-14110	Regional	Well	Development	9/8/2008	8.97	0.06	0.080	0.000	0.003	0.000	21.2	0.0	0.008	0.000	0.01	0.003	U	20.9	4.71
GW42-08-14111	Regional	Well	Development	9/8/2008	9.89	0.07	0.038	0.000	0.002	0.000	17.8	0.0	0.009	0.000	0.01	0.003	U	22.1	4.99
GW42-08-14112	Regional	Well	Development	9/8/2008	10.5	0.2	0.028	0.000	0.001	0.000	15.8	0.2	0.009	0.000	0.01	0.003	U	23.2	5.23
GW42-08-14113	Regional	Well	Development	9/8/2008	10.8	0.1	0.025	0.000	0.001	0.000	15.3	0.2	0.010	0.000	0.01	0.003	U	23.7	5.35
GW42-08-14114	Regional	Well	Development	9/8/2008	11.0	0.1	0.032	0.000	0.001	0.000	15.9	0.1	0.009	0.001	0.01	0.003	U	23.5	5.32
GW42-08-14115	Regional	Well	Development	9/8/2008	10.9	0.1	0.029	0.000	0.002	0.000	17.0	0.1	0.009	0.001	0.01	0.003	U	23.3	5.27
GW42-08-14116	Regional	Well	Development	9/8/2008	10.7	0.1	0.029	0.000	0.002	0.000	16.5	0.1	0.011	0.001	0.01	0.003	U	23.6	5.33
GW42-08-14117	Regional	Well	Development	9/8/2008	11.1	0.1	0.025	0.000	0.001	0.000	15.7	0.2	0.011	0.001	0.01	0.003	U	23.9	5.40
GW42-08-14118	Regional	Well	Development	9/8/2008	11.1	0.0	0.023	0.000	0.001	0.000	15.4	0.1	0.010	0.000	0.01	0.003	U	24.5	5.53

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	C_2O_4 rslt (ppm)	C_2O_4 (U)	Pb rslt (ppm)	stdev (Pb)	pH	PO_4^{3-} rslt (ppm)	PO_4^{3-} (U)	Rb rslt (ppm)	stdev (Rb)	S_2- rslt (ppm)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	0.16	SD[c]	0.0014	0.0001	7.83	0.01	U	0.007	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	0.17	SD	0.0014	0.0000	7.73	0.01	U	0.006	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	0.27	SD	0.0005	0.0000	7.85	0.01	U	0.007	0.000	Not measured	0.001	U	0.001	U
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	1.14	SD	0.0002	U	7.41	0.01	U	0.006	0.000	Not measured	0.001	U	0.001	U
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	0.43	SD	0.0002	U	7.64	0.01	U	0.009	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	0.01	U	0.0002	U	7.56	0.01	U	0.011	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	0.35	SD	0.0003	0.0000	7.86	0.01	U	0.009	0.000	Not measured	0.001	U	0.001	U
GW42-08-14109	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.99	0.01	U	0.002	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14110	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.92	0.01	U	0.006	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14111	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.60	0.01	U	0.004	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14112	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.76	0.01	U	0.004	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14113	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.75	0.01	U	0.004	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14114	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.73	0.01	U	0.004	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14115	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.70	0.01	U	0.004	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14116	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.65	0.01	U	0.004	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14117	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.59	0.01	U	0.004	0.000	Not measured	0.001	U	0.002	0.000
GW42-08-14118	Regional	Well	Development	9/8/2008	0.01	U	0.0002	U	7.66	0.01	U	0.004	0.000	Not measured	0.001	U	0.002	0.000

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Si rslt (ppm)	stdev (Si)	SiO_2 rslt (ppm)	stdev (SiO_2)	Sn rslt (ppm)	stdev (Sn)	SO_4^{2-} rslt (ppm)	Sr rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	24.6	0.2	52.6	0.4	0.001	U	41.2	0.124	0.001	0.001	U	0.056	0.000	0.001
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	24.1	0.1	51.5	0.2	0.001	U	40.9	0.120	0.000	0.001	U	0.057	0.000	0.001
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	21.9	0.1	46.8	0.2	0.001	U	11.4	0.054	0.002	0.001	U	0.010	0.000	0.001
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	9.35	0.04	20.0	0.1	0.001	U	23.8	0.085	0.000	0.001	U	0.002	U	0.001
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	16.5	0.1	35.4	0.1	0.001	U	63.3	0.133	0.001	0.001	U	0.002	U	0.001
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	19.8	0.0	42.3	0.0	0.001	U	85.0	0.162	0.002	0.001	U	0.002	U	0.001
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	19.9	0.1	42.7	0.2	0.001	U	49.4	0.105	0.001	0.001	U	0.003	0.000	0.001
GW42-08-14109	Regional	Well	Development	9/8/2008	27.5	0.2	58.8	0.4	0.001	U	42.5	0.139	0.001	0.001	U	0.002	U	0.001
GW42-08-14110	Regional	Well	Development	9/8/2008	32.1	0.1	68.6	0.2	0.001	U	47.7	0.150	0.003	0.001	U	0.002	U	0.001
GW42-08-14111	Regional	Well	Development	9/8/2008	33.6	0.1	71.8	0.2	0.001	U	56.9	0.139	0.001	0.001	U	0.002	U	0.001
GW42-08-14112	Regional	Well	Development	9/8/2008	34.1	0.2	73.1	0.5	0.001	U	53.8	0.142	0.001	0.001	U	0.002	U	0.001
GW42-08-14113	Regional	Well	Development	9/8/2008	34.2	0.4	73.2	0.8	0.001	U	55.8	0.143	0.001	0.001	U	0.002	U	0.001
GW42-08-14114	Regional	Well	Development	9/8/2008	32.9	0.1	70.5	0.2	0.001	U	56.9	0.148	0.002	0.001	U	0.002	U	0.001
GW42-08-14115	Regional	Well	Development	9/8/2008	33.1	0.1	70.9	0.3	0.001	U	57.3	0.145	0.001	0.001	U	0.002	U	0.001
GW42-08-14116	Regional	Well	Development	9/8/2008	32.3	0.3	69.1	0.6	0.001	U	58.1	0.142	0.000	0.001	U	0.002	U	0.001
GW42-08-14117	Regional	Well	Development	9/8/2008	33.8	0.2	72.3	0.5	0.001	U	58.3	0.143	0.001	0.001	U	0.002	U	0.001
GW42-08-14118	Regional	Well	Development	9/8/2008	33.6	0.2	71.9	0.5	0.001	U	58.8	0.144	0.002	0.001	U	0.002	U	0.001

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS[d] (ppm)	Cations	Anions	Balance
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	U	0.0044	0.0005	0.003	0.000	0.018	0.001	371	4.24	4.41	-0.02
GW42-08-14095	Perched	Borehole	Drilling	7/14/2008	U	0.0038	0.0001	0.002	0.000	0.017	0.001	369	4.11	4.44	-0.04
GW42-08-14096	Introduced Water?	Borehole	Drilling	7/21/2008	U	0.0015	0.0000	0.003	0.000	0.002	0.000	224	2.04	2.40	-0.08
GW42-08-14097	Introduced Water?	Borehole	Drilling	7/21/2008	U	0.0004	0.0000	0.002	0.000	0.003	0.000	270	3.17	3.39	-0.03
GW42-08-14098	Regional	Borehole	Drilling	7/21/2008	U	0.0015	0.0000	0.002	0.000	0.003	0.000	338	3.99	4.49	-0.06
GW42-08-14099	Regional	Borehole	Drilling	7/21/2008	U	0.0019	0.0001	0.002	0.000	0.003	0.000	389	4.70	5.15	-0.05
GW42-08-14100	Regional	Borehole	Drilling	7/21/2008	U	0.0018	0.0000	0.002	0.000	0.005	0.000	297	3.19	3.69	-0.07
GW42-08-14109	Regional	Well	Development	9/8/2008	U	0.0014	0.0000	0.001	U	0.012	0.000	302	3.13	3.49	-0.06
GW42-08-14110	Regional	Well	Development	9/8/2008	U	0.0012	0.0000	0.001	U	0.002	0.000	312	3.30	3.51	-0.03
GW42-08-14111	Regional	Well	Development	9/8/2008	U	0.0009	0.0000	0.001	U	0.004	0.000	327	3.42	3.76	-0.05
GW42-08-14112	Regional	Well	Development	9/8/2008	U	0.0008	0.0000	0.001	U	0.003	0.000	324	3.51	3.65	-0.02
GW42-08-14113	Regional	Well	Development	9/8/2008	U	0.0008	0.0000	0.001	U	0.003	0.000	328	3.54	3.71	-0.02
GW42-08-14114	Regional	Well	Development	9/8/2008	U	0.0008	0.0000	0.001	U	0.001	0.000	328	3.60	3.76	-0.02
GW42-08-14115	Regional	Well	Development	9/8/2008	U	0.0008	0.0001	0.001	U	0.002	0.000	328	3.59	3.75	-0.02
GW42-08-14116	Regional	Well	Development	9/8/2008	U	0.0009	0.0000	0.001	U	0.002	0.000	327	3.56	3.78	-0.03
GW42-08-14117	Regional	Well	Development	9/8/2008	U	0.0008	0.0000	0.001	U	0.002	0.000	330	3.60	3.78	-0.02
GW42-08-14118	Regional	Well	Development	9/8/2008	U	0.0008	0.0000	0.001	U	0.002	0.000	332	3.61	3.81	-0.03

[a] U = Undetected.
[b] n/a = Not available.
[c] SD = Sample detected.
[d] TDS = Total dissolved solids.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests at well R-42 located in Mortandad Canyon within the existing chromium plume beneath the canyon. The tests were conducted in conjunction with testing of cross-gradient well R-43 located in Sandia Canyon near the edge of the chromium plume. The primary objective of the analysis was to determine the hydraulic properties of the formation screened by R-42. A secondary objective was to look for a cross-connection between R-42 and surrounding wells, including R-43.

Testing consisted primarily of constant-rate pumping tests. During the tests, water levels were monitored in the pumped well and both screen zones in R-43. In addition, water-level data were collected from regional wells R-11, R-13, R-15, R-28, and R-33.

Consistent with most of the R-well pumping tests conducted on the plateau, an inflatable packer system was used in R-42 to eliminate the effects of casing storage on the test data.

Conceptual Hydrogeology

R-42 is completed at the top of the regional aquifer within the Miocene pumiceous deposits. It is a single-screen completion with 21.1 ft of screen between 931.8 and 952.9 ft below ground surface (bgs). The static water level (SWL) measured at the onset of testing was 919.8 feet bgs. The estimated ground surface elevation at R-42 was 6759 ft above mean sea level (amsl), putting the groundwater elevation at about 5839 ft amsl.

The original R-42 borehole was advanced to a depth of 1047 ft where tight sediments were encountered. The deeper portion of the borehole was backfilled and the well was completed shallower. The aquifer penetrated by R-42 was considered to be unconfined, extending from the SWL of 919.8 ft to the tight sediments at 1047. Thus, the assumed aquifer thickness was approximately 127 ft. The actual properties of the sediments between the bottom of the well and 1047 ft were not known, so the assignment of an aquifer thickness of 127 ft was somewhat arbitrary and considered only an estimate.

Well R-43 is a dual-screen well completed at the top of the Miocene riverine sediments, with 20.7 ft of screen from 903.9 to 924.6 ft (screen 1) and 10 ft of screen from 969.1 to 979.1 ft (screen 2). At the time of testing R-42, the approximate groundwater elevations in R-43 screens 1 and 2 were 5837 and 5836 ft, respectively.

R-42 Testing

R-42 was tested from November 12 to November 16, 2008. Testing consisted of brief trial pumping on November 12, background data collection, and a 24-h constant-rate pumping test that was begun on November 14.

At the conclusion of formal testing, R-42 was purged an additional 15 h to complete the development process of removing a volume of water equivalent to what was lost to the regional aquifer during the drilling process. Purging was performed on November 16, followed by recovery until November 17. The water-level data recorded during the final development purging were retained for analysis.

After brief pumping to fill the drop pipe and adjust the discharge rate, two trial tests were conducted on November 12. Trial 1 was conducted for 30 min from 10:30 to 11:00 a.m. and was followed by 50 min of recovery until 11:50 a.m. During trial 1, a significant leak was detected in the drop pipe used to hang the pump, forcing removal of a number of joints of drop pipe and replacement of two pipe joints that had leaks.

The water that had leaked from the drop pipe during trial 1 was trapped above the inflatable packer and thus did not reenter the screen zone. Therefore, the metered flow at the surface underestimated the true formation pumping rate by the quantity of water that had leaked from the drop pipe. The effective pumping rate was estimated in two ways: (1) by observing the volume of water above the packer, based on head buildup data recorded after packer deflation, and (2) by applying the specific capacity of the well observed in subsequent pumping episodes. It was estimated that the leakage rate was 3.0 gpm. Adding this to the measured discharge rate of 3.4 gpm resulted in an estimated pumping rate of 6.4 gpm for trial 1.

A second trial test was conducted, but because of the delay caused by removing, examining, and replacing some of the drop pipe, the high-density data collection schedule programmed for trial 2 had expired. The actual data density achieved was not adequate to contribute to the pumping test interpretation. Therefore, the data from trial 2 were not analyzed.

At 8:00 a.m. on November 14, the 24-h pumping test was begun at a rate that was a little over 5 gpm. During the test, the discharge rate fluctuated erratically. Pumping continued until 8:00 a.m. on November 15. Following shutdown, recovery measurements were recorded for 23 h until 7:00 a.m. on November 16.

Final purge development began at 7:00 a.m. on November 16 and continued for 15 h until 10:00 p.m. Pumping was discontinued and recovery data were recorded until 8:00 a.m. on November 17. The purge rate averaged 6.2 gpm, although it was not constant.

Variations in Generator Output

During testing and purge development, the discharge rate from R-42 varied erratically. The generator that was used to power the pump showed slight variations in frequency output during the test, according to visual observations of the electrical meter on the generator control panel. Based on the bowl characteristics of the 4-in. submersible pump used for the testing, an output variation only a small fraction of a cycle per second would have been enough to account for the variation in flow rates measured during testing. It was assumed that this was the cause of the discharge rate fluctuations. There was no evidence of air being discharged in the water stream as had occurred in the R-43 tests, so it was unlikely that entrained air affected the pump operation.

C-2.0 BACKGROUND DATA

The background water-level data collected with running the pumping tests allowed the analyst to see what water-level fluctuations occur naturally in the aquifer and helped 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 between 90% and 100%. Barometric efficiency is defined as the ratio of water-level change divided by barometric pressure change, expressed as a percentage. In the initial pumping tests conducted on the early R-wells, downhole pressure was monitored using a *vented* pressure transducer. This equipment measures the *difference* between the total pressure applied to the transducer and the barometric pressure, this difference being the true height of water above the transducer.

Subsequent pumping tests, including R-42, have utilized *nonvented* transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated "apparent" hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an *increase* in barometric pressure of 1 unit causes a *decrease* in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 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.

The Environmental Division Meteorology and Air Quality (ENV-MAQ) obtained barometric pressure data from the Technical Area (TA-54) tower site. The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is approximately 6759 ft amsl. The SWL was about 920 ft below land surface, making the water table elevation roughly 5839 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-42.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{R42} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R42}}{T_{WELL}} \right) \right] \qquad \textbf{Equation C-1}$$

Where P_{WT} = barometric pressure at the water table inside R-42

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

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

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

E_{R42} = land surface elevation at R-42 site, in feet (6759 ft estimated)

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

E_{WT} = elevation of the water level in R-42, in feet (approximately 5839 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 38.6° Fahrenheit or 276.8° Kelvin)

T_{WELL} = air temperature inside R-42, in degrees Kelvin (assigned a value of 64.8° Fahrenheit or 291.4° Kelvin)

This formula is an adaptation of an equation ENV-MAQ 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 hydrographs to discern the correlation between the two.

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 that the effective height of the cone of depression is known with certainty. 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, 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

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 the R-42 pumping tests. As described below, antecedent drainage of a portion of the filter pack may have left air pockets in place that contributed to a casing-storagelike effect.

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-3**

Where,

$$W(u) = \int_u^\infty \frac{e^{-x}}{x} dx$$ **Equation C-4**

and

$$u = \frac{1.87 r^2 S}{Tt}$$ **Equation C-5**

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-6**

$$S = \frac{Tut}{2693r^2}$$ **Equation C-7**

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-8**

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-9**

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

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-10**

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. This was of paramount importance in the R-42 pumping tests because variable current output from the electric generator induced discharge rate fluctuations.

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

For fully penetrating wells, the Cooper–Jacob equation can be iterated to solve for the lower-bound hydraulic conductivity. However, the Cooper–Jacob equation (assuming full penetration) ignores the contribution to well yield from permeable sediments above and below the screened interval. To account

for this contribution, it is necessary to use a computation algorithm that includes the effects of partial penetration. One such approach was introduced by Brons and Marting (1961, 098235) and augmented by Bradbury and Rothchild (1985, 098234).

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

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right] \qquad \textbf{Equation C-11}$$

Where S_p = partial penetration correction, dimensionless

L = well screen length, in feet

b = aquifer thickness, in feet

r_w = radius of the pumping well, in feet

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:

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right) \qquad \textbf{Equation C-12}$$

Where K = hydraulic conductivity, in feet/day

Q = flow rate, in gallons per minute

T = transmissivity, in gallons per day per foot

t = time, in minutes

S_p = partial penetration correction, dimensionless

s = drawdown, in feet

b = aquifer thickness, in feet

r_w = radius of the pumping well, in feet

S = storage coefficient, dimensionless

To apply this procedure, a storage coefficient value must be assigned. Unconfined conditions were assumed for R-42. Storage coefficient values for unconfined conditions can be expected to range from about 0.01 to 0.25, depending on sediment makeup (Driscoll 1986, 104226) 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. An assumed value of 0.1 was used for R-42.

The analysis also requires assigning a value for the saturated aquifer thickness, *b*. For calculation purposes, the aquifer thickness of 127 ft cited above was used. The computed result is not particularly sensitive to the exact aquifer thickness because sediments far above or below the screen have little effect

on yield and drawdown response. Therefore, the calculation based on the assumed aquifer thickness value was deemed to be adequate.

Computing the lower-bound estimate of hydraulic conductivity can provide a useful frame of reference for evaluating the other pumping test calculations.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-42 tests were plotted along with barometric pressure to determine the barometric effect on water levels and to look for pumping response in the surrounding observation wells. R-42 screen and R-43 screens 1 and 2 were monitored using nonvented pressure transducers, while the remaining wells—R-11, R-13, R-15, R-28, and R-33—were monitored using vented transducers.

Figure C-7.0-1 shows aquifer pressure data from R-42 along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure at the water table in feet of water. The R-42 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-42 pumping tests are included on the figure for reference.

It is apparent that the swings in barometric pressure had little effect on the total aquifer pressure. This meant that if there had been no packer above the transducer, a given change in barometric pressure would have caused an opposite and nearly equal change in the water level in the well, such that the total pressure remained nearly unchanged. This implied a high barometric efficiency for R-42.

The background data recorded from November 12 to 14 showed a slight downward trend—a continuation of the trend observed the previous week during the testing of R-43. On November 10, continuous pumping of County supply well PM-4 was discontinued, allowing general groundwater levels in the area to rebound slightly (described below). Nevertheless, the R-42 water levels continued a downward trend, suggesting that the sediments screened in R-42 are more poorly hydraulically connected to the deep aquifer than other R-well screen zones. This response was consistent with observations made the previous week and a half during testing of R-43. At that time, continuous operation of PM-4 from late October to November 10 caused water levels in other regional wells to decline for the entire 10-d monitoring period from November 1 to 10. During that time, however, the response in R-42 was delayed in that water levels were observed to rise until November 3 before they began to decline in response to operation of PM-4. In summary, the data from both the R-43 and R-42 pumping tests showed a delayed response in R-42 to regional aquifer pumping compared with what was observed in other R-wells.

An alternative explanation to the idea of delayed response to operation of PM-4 is the possibility that the observed lag is a delayed response to large-scale atmospheric pressure fluctuations. Long-term monitoring of R-42 may shed light on this idea.

Figures C-7.0-2 and C-7.0-3 show apparent hydrographs for R-43 screens 1 and 2, respectively. The graphs were similar in that there was negligible change in total aquifer pressure in response to changes in barometric pressure. This implied a barometric efficiency near 100% for both screens 1 and 2 in R-43. The data collected during previous testing of R-43 were inconclusive with respect to determining the barometric efficiency of screen 2. The data in Figure C-7.0-3, however, showed conclusively that the zone is highly barometrically efficient.

Both Figures C-7.0-2 and C-7.0-3 showed tiny diurnal water-level fluctuations throughout the monitoring period (subtle “ripples” in the data plots). These appeared to be unrelated to barometric pressure changes and could not be correlated to cycling of the County supply wells. It is possible that these small water-level perturbations reflect earth tides.

There was no evidence of a response to pumping R-42 in either screen zone in R-43.

Figures C-7.0-4 through C-7.0-8 show comparisons of barometric pressure and hydrograph data from regional wells R-11, R-13, R-15, R-28, and R-33 screen 1, respectively. (Data from R-33 screen 2 showed daily fluctuations of 5 or 6 ft in response to operation of PM-5 and are not presented here.) For all hydrographs, the strong correlation between barometric pressure and water level was clear, showing near 100% barometric efficiencies. In each of these plots, there was a steady rise in water levels compared with the barometric pressure changes, presumably in response to discontinuing operation of PM-4 after November 10.

Examination of the data in Figures C-7.0-4 through C-7.0-8 showed that there was no apparent response to pumping R-42 in any of the monitored wells.

The data from R-33 screen 1 were replotted along with the run times for Los Alamos County supply well PM-5 as shown in Figure C-7.0-9.

Previous background data collection during the R-43 pumping tests revealed possible reverse water-level fluctuations in R-33 screen 1, also called the Noordbergum effect (Wolff 1970, 098242; Rodrigues 1983, 098239; Heish 1996, 098238), in response to operation of PM-5. This effect is occasionally seen in observation wells completed within aquitards or within aquifers adjacent to the pumped aquifer and separated from it by an aquitard. The data obtained during the R-42 test were examined for this effect.

Reverse water-level fluctuations are brought about by poroelastic effects and corresponding pore-pressure changes. When the main aquifer is pumped, it undergoes elastic deformation in response to the change in pore-water pressures, as well as the down thrust on the land surface at the wellhead associated with operating the pump. When the pumped aquifer becomes distorted, adjacent layers of aquitards and aquifers also are distorted. This creates transient pore-pressure changes within these units. At some locations, the pressures decline, while at other locations they rise (reverse water-level fluctuations). As time goes on, these pressure changes are relieved as water moves from high pressure areas to low pressure areas.

To check again for this response, the R-33 screen 1 hydrograph was examined along with the start and stop times for PM-5. As observed previously, a detailed analysis of the data showed that when PM-5 began pumping, the water level in R-33 screen 1 rose by an amount that was disproportionate compared with the barometric pressure change at that time. Likewise, when PM-5 pumping stopped, there was a similar disproportionate drop in the R-33 screen 1 water level. As an example, according to the hydrograph, when PM-5 began pumping just after midnight on November 12, the water level rise in R-33 screen 1 exceeded the corresponding barometric pressure change. When pumping stopped, the dip in the R-33 screen 1 water level again exceeded the corresponding barometric pressure change. Observations consistent with this idea were noted for virtually every cycling event at PM-5 shown in Figure C-7.0-9.

An alternative explanation for the observed response in screen 1 is the possibility that earth tides could have caused the fluctuations observed in the hydrograph. The diurnal pattern of the observed fluctuations is consistent with this idea.

A third possibility is that the observed pressure perturbations could be related to the elasticity of the pump and packer system installed in R-33. For example, when operation of PM-5 lowers or raises the water level in screen 2 at 5 or 6 ft, it is possible that the changing pressure beneath the inflatable packer could cause it to move, expand, contract, deform, etc., giving rise to the exaggerated amplitude of the small oscillations seen in the screen 1 hydrograph.

Finally, the observed response could be caused by a leak in the sampling system equipment, possibly through the screen 2 transducer drop tube. A 5-ft offset in screen 2 water levels has been noted consistently between post-pack-inflation levels and postsampling levels, with a corresponding tiny opposite water-level effect in screen 1. This anomaly and the apparent reverse water-level fluctuations in Figure C-7.0-9 could be related.

In summary, all monitored R-wells presented above showed near 100% barometric efficiency response. None of the wells showed any response to pumping R-42. All wells except R-42 showed water-level recovery in response to discontinuing pumping at PM-4. Levels in R-42 continued their antecedent downward trend from the previous pumping of PM-4, suggesting that the R-42 response was delayed and that the formation screened in R-42 is less well connected to the deep aquifer than the screen zones in the other wells. Finally, R-33 screen 1 showed subtle water-level oscillations coincident with operation of County well PM-5 that could have been caused by either the Noordbergum effect (reverse water-level fluctuations), fortuitously coincident earth tide response, or elastic deformation of components of the pump and packer sampling system.

C-8.0 R-42 DATA ANALYSIS

This section presents the data obtained from the R-42 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for trial 1, the 24-h constant-rate pumping test, and final purge development.

Trial 1

Figure C-8.0-1 shows a semilog plot of the trial 1 drawdown data. The initial drawdown spike was attributed to antecedent drainage of a portion of the drop pipe through leaky coupling joints at a substantial depth below ground surface (unrelated to the holes discovered in some of the shallow drop pipes). On startup, the pump operated against reduced head briefly until the void in the drop pipe filled. Against reduced head, the pump produced a greater discharge rate momentarily, resulting in exaggerated drawdown.

Note that the effective pumping water level was pulled below the top of the well screen (and below the top of the filter packed annulus as well). The presence of the inflatable packer above the pump ensured that air could not enter the screen zone from inside the well casing. (In fact, the submersible pump intake was positioned 2 ft above the top of the screen. The drawdown indicated on the graph was achieved by the pump pulling a vacuum beneath the packer.) However, there was a possibility that air could have accessed the filter pack and/or well screen through the formation outside the well. This created the possibility of entrained air in either the filter pack or screen/casing that could contribute an effect similar to casing storage.

The drawdown data trace was uneven, indicating discharge rate variations. The unsteady flow rate was probably attributable to nonuniform generator output as described above.

Figure C-8.0-2 shows a semilog plot of the trial 1 recovery data. The transmissivity value computed from the very early data was 390 gpd/ft. Based on the screen length of 21.1 ft, the computed hydraulic conductivity was 18.5 gpd/ft^2, or 2.5 ft/d. Based on the possibility of entrained air in the well or filter pack,

it was possible that the data could have been affected by a storagelike phenomenon similar to casing storage, caused by expansion and contraction of the hypothesized trapped air. If this were the case, the computed hydraulic conductivity value would be an underestimate of the true value. As described below, subsequent testing and analysis showed that this was the case.

As shown in Figure C-8.0-2, after less than a minute of recovery, the data curve flattened steadily. This was likely attributable to vertical expansion of the cone of depression (partial penetration effects) and possibly delayed yield. Other contributing factors also could have included changes (increases) in hydraulic conductivity laterally or vertically around the well.

Figure C-8.0-3 shows an expanded-scale plot of the late recovery data. The line of fit shown on the graph yielded a computed transmissivity value of 26,000 gpd/ft. Because the graph represented a limited recovery time, just 50 min, the extremely flat slope depicted on the graph could represent delayed yield rather than reflect true aquifer coefficients. Also, there was substantial scatter in the data set casting doubt on the reliability of the computed transmissivity value.

Packer Deflation

Following trial 1, the downhole packer was deflated so that the pump string could be lifted to remove and replace defective sections of drop pipe. This allowed the weight of the trapped water above the packer that had leaked through holes in the drop pipe to be delivered to the pressure transducer while the water drained back into the well and formation.

Figure C-8.0-4 shows the resulting head buildup and decay that occurred when the packer was deflated. Also shown on the graph are the computed “injection” rate of water moving from the well casing into the aquifer and the effective injection specific capacity (ratio of inflow rate to head buildup). After packer deflation, the head in the casing above the transducer increased more than 100 ft and then slowly declined. This information helped establish an estimate of the volume of water that had leaked from the drop pipe during trial 1, supporting determination of an estimated discharge rate for the trial 1 test.

Of interest in Figure C-8.0-4 is the depiction of the injection specific capacity. As shown on the graph, the injection specific capacity fell between 0.1 and 0.2 gpm/ft. In contrast, the pumping tests on R-42 produced specific capacities around 0.8 gpm/ft. This supports the generally accepted idea that injection rates tend to be less than extraction rates because of clogging at the borehole face that often occurs during injection, either with solids or air or dynamic changes that occur between the filter pack and borehole face when the flow direction is reversed. Numerous previous pumping tests in R-wells on the plateau utilized injection rather than pumping as the mechanism of stressing the aquifer. The data in Figure C-8.0-4 provide anecdotal evidence that, as suspected, those previous tests may have underestimated hydraulic conductivity in cases where calculations were based either on specific capacity performance or on slug test analysis.

C-8.1 R-42 24-H Constant-Rate Pumping Test

Figure C-8.1-1 shows a semilog plot of the drawdown data recorded during the 24-h constant-rate pumping test conducted at R-42. The early-time drawdown exceeded subsequent drawdown because of antecedent drainage of the drop pipe through leaky threaded joints, as described above. Consistent with this, on startup it took several seconds before water was produced from the discharge pipe at the surface. This was the time required to refill the void in the drop pipe.

Subsequent data showed varying drawdown throughout the test corresponding to changing discharge rates. Some examples of the measured discharge rates are identified on the graph. As stated above, the variable output of the electrical generator likely caused the flow rate fluctuations. The rate gradually increased to 5.5 gpm and stayed close to that level for the last several hours of the test.

Figure C-8.1-2 shows a semilog plot of the recovery data following the 24-h test. The transmissivity value computed from the early data was 450 gpd/ft making the hydraulic conductivity 21.3 gpd/ft^2, or 2.9 ft/d. In general, early recovery data respond according to the last pumping rate of the test, just before pump shutoff. Therefore, calculations shown in Figure C-8.1-2 used the final pumping rate of 5.5 gpm rather than the average rate of 5.2 gpm.

The curvature associated with the first few data points on the recovery graph mimicked what is seen when casing storage affects pumping test data. Care was taken to ensure that all air within the casing beneath the packer was allowed to escape before inflating the packer for the 24-h pumping test. This, coupled with the storagelike response in Figure C-8.1-2, implied a likelihood that air had become entrained in the filter pack. This could have occurred when the effective pumping water level was pulled into the well screen during trial 1. It also could have happened during initial development of the well weeks earlier. The likelihood of storage effects meant that the computed parameter values in Figure C-8.1-2 underestimated the true values.

After about 1 min, the late recovery data showed flattening associated with the combination of delayed yield and partial penetration, as well as perhaps other effects as described earlier. An expanded-scale plot of the late data was prepared as shown in Figure C-8.1-3.

The flattening of the curve followed by an increase in slope at late recovery time lent support to the idea that delayed yield of the unconfined aquifer had occurred. The transmissivity computed from the late data was 10,400 gpd/ft. Because late-recovery data respond according to the average pumping rate of the test, calculations shown in Figure C-8.1-3 were based on the average pumping rate of 5.2 gpm. Assigning the aquifer thickness of 127 ft yielded a hydraulic conductivity of 81.9 gpd/ft2, or 10.9 ft/d. Note that the computed transmissivity value was substantially less than the 26,000 gpd/ft computed from trial 1 (Figure C-8.0-3). This confirmed that the trial 1 analysis was based on delayed yield data, thus overestimating the transmissivity.

C-8.2 Development Purging

Following the recovery from the 24-h pumping test, purge development was performed on R-42 for 15 h followed by 10 h of recovery. Figure C-8.2-1 shows the drawdown data measured during the 15 h of purging the well.

As with other tests on R-42, the drawdown data shown in Figure C-8.2-1 were erratic, in response to variations in pumping rate. The pumping rate was roughly proportional to the observed drawdown so examining the drawdown curve provides insight into the magnitude of the variation in discharge rate. The average rate throughout the purging event was 6.2 gpm.

Figure C-8.2-2 shows recovery data recorded following pump shutdown when purging ceased. The early steep slope shown on the graph reflected the presumed casing-storagelike effect combined with the limited transmissivity of the screened interval. The intermediate portion of the curve became flat in response to a combination of vertical growth of the cone of depression and delayed yield. The late-time slope revealed a transmissivity of 8240 gpd/ft, making the hydraulic conductivity 64.9 gpd/ft^2, or 8.7 f/dt, in fair agreement with the value obtained from the 24-h pumping test.

C-8.3 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound conductivity value for R-42 for comparison to the pumping test values. In addition to specific capacity, other input values used in the calculations included the aquifer thickness of 127 ft (from the SWL to the bottom of the originally advanced borehole), a storage coefficient of 0.1 and a borehole radius of 0.51 ft. The calculations are somewhat insensitive to the assigned aquifer thickness, as long as the selected value is substantially greater than the screen length.

R-42 produced 5.5 gpm with a drawdown of 7.0 ft after 24 h of pumping for a specific capacity of 0.79 gpm/ft. Applying the Brons and Marting method (1961, 098235) to these inputs yielded a lower-bound hydraulic conductivity value for the screened interval of 32.5 gpd/ft^2, or 4.3 ft/d. This was greater than the values obtained from the early recovery data in Figures C-8.0-2 and C-8.1-2. This confirmed that those values were underestimates of aquifer properties, reinforcing the idea that the data on which they were based were storage affected.

The late data in Figures C-8.1-3 and C-8.2-2 yielded an average hydraulic conductivity of 9.8 ft/d, assuming an aquifer thickness of 127 ft. The lower-bound hydraulic conductivity value of 4.3 ft/d was consistent with these data, that is, the value did not exceed it. The discrepancy in the magnitude of these values could indicate that the well is a little less than 50% efficient, certainly a possibility.

On the other hand, if the well is highly efficient, the result could indicate that the average hydraulic conductivity of the overall aquifer is greater than that of the screened portion. Or alternatively, it could imply that the assumed aquifer thickness is incorrect.

C-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-42 in Mortandad Canyon. The tests were conducted to gain an understanding of the hydraulic characteristics of the aquifer. Additionally, several surrounding wells, including cross-gradient well R-43, were monitored to check for hydraulic cross connection to R-42. Numerous observations and conclusions were drawn for the tests as summarized below.

- Water-level data from R-42, R-43 screens 1 and 2, R-11, R-13, R-15, R-28, and R-33 screen 1 showed near 100% barometric efficiencies.
- There was a general water-level rise in all of the surrounding wells, in response to ceasing operation at PM-4. However, levels in R-42 continued to decline, showing a lag in response to PM-4, consistent with what was observed during the previous week and a half of R-43 pumping tests. This suggested that the sediments screened in R-42 may not be as effectively hydraulically connected to the deep aquifer as are the zones penetrated by the other wells.
- There was no observed response to pumping R-42 in any of the monitored wells.
- A defective (leaky) drop pipe used in initial testing allowed the annulus above the inflatable packer to fill with water more than 100 ft above the SWL. Upon packer deflation, the inflow rate of the water back into the aquifer occurred at a specific capacity ranging between 0.1 and 0.2 gpm/ft, compared with a pumping specific capacity of about 0.8 gpm/ft. This supported the idea that previous injection tests on the plateau some years ago may have significantly underestimated hydraulic conductivity values.
- During each test, the discharge rate varied erratically, apparently as a function of subtle variations in the output characteristics of the electric generator.

- During the initial trial test, antecedent drainage of a portion of the drop pipe allowed the pump to produce a high discharge rate briefly, pulling the effective pumping water level below the top of the well screen. This may have introduced air into the filter pack, causing subsequent casing-storagelike effects. Introduction of air into the filter pack also could have occurred during previous well development.
- Early recovery data underestimated the hydraulic conductivity, consistent with what occurs when the data are affected by casing storage. Further, visual appearance of the early recovery curve was consistent with casing storage phenomena.
- Intermediate data showed a subtle delayed yield effect.
- Late data showed an average transmissivity of about 9300 gpd/ft.
- The aquifer thickness was estimated at 127 ft, the distance between the SWL and the maximum depth of the original borehole where tight sediments were encountered. This thickness, combined with the transmissivity cited above, yielded an average hydraulic conductivity of 73 gpd/ft^2, or 9.8 ft/d.
- Specific capacity data yielded a lower-bound hydraulic conductivity of 4.3 ft/d, consistent with the above estimate (about 44%). The difference between the estimates could indicate a well efficiency on the order of 40% to 50% or that the screened interval has a lower hydraulic conductivity than the aquifer average.

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 number. This information is also included in text citations. ER ID numbers 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 New Mexico Environment Department 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.

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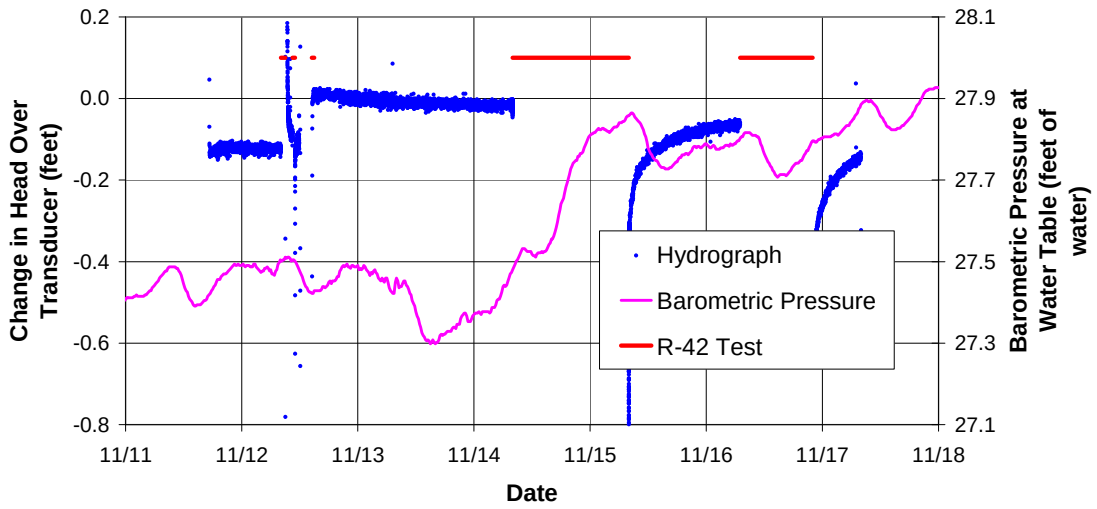


Figure C-7.0-1 Comparison of R-42 apparent hydrograph and adjusted TA-54 barometric pressure

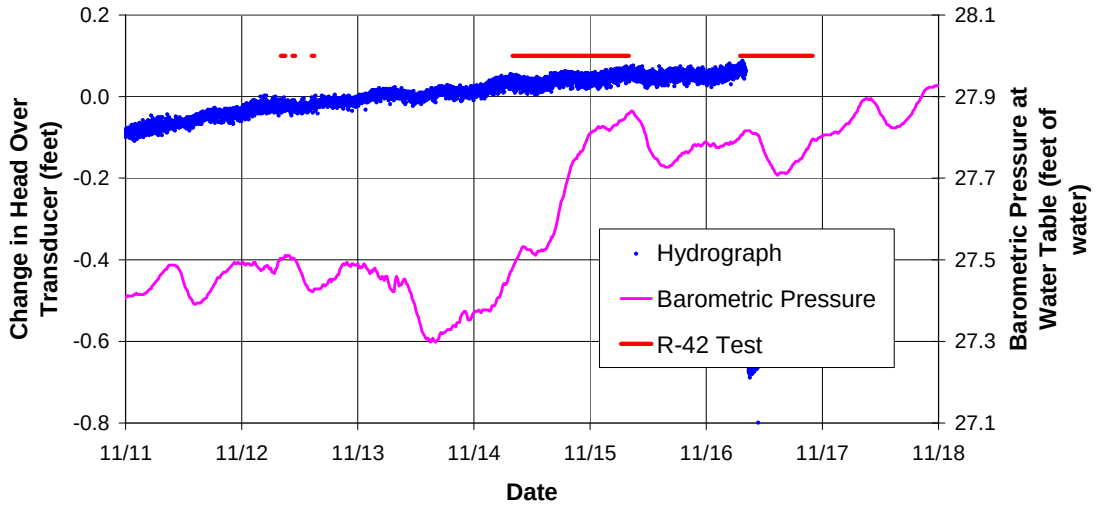


Figure C-7.0-2 Comparison of R-43 screen 1 apparent hydrograph and adjusted TA-54 barometric pressure

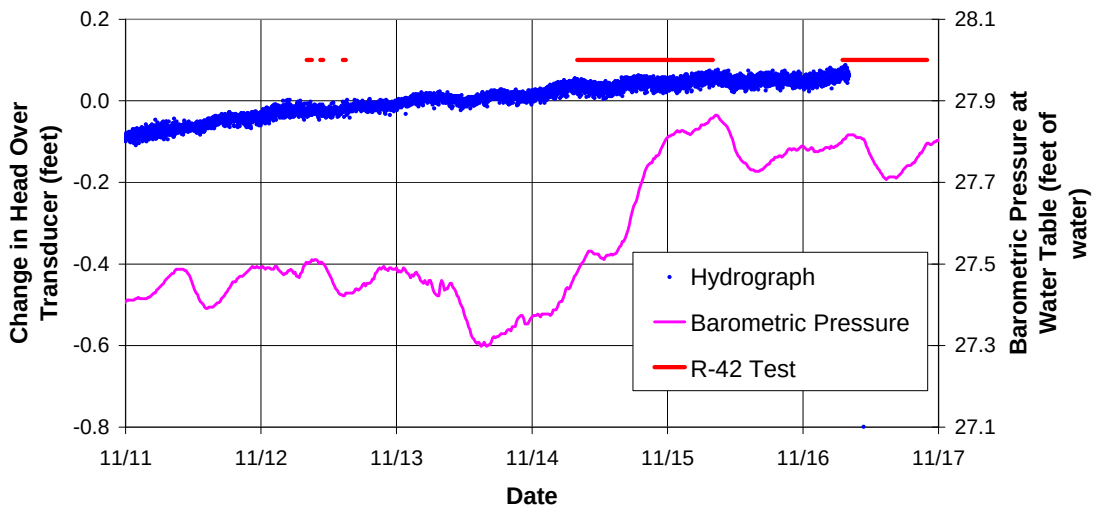


Figure C-7.0-3 Comparison of R-43 screen 2 apparent hydrograph and adjusted TA-54 barometric pressure

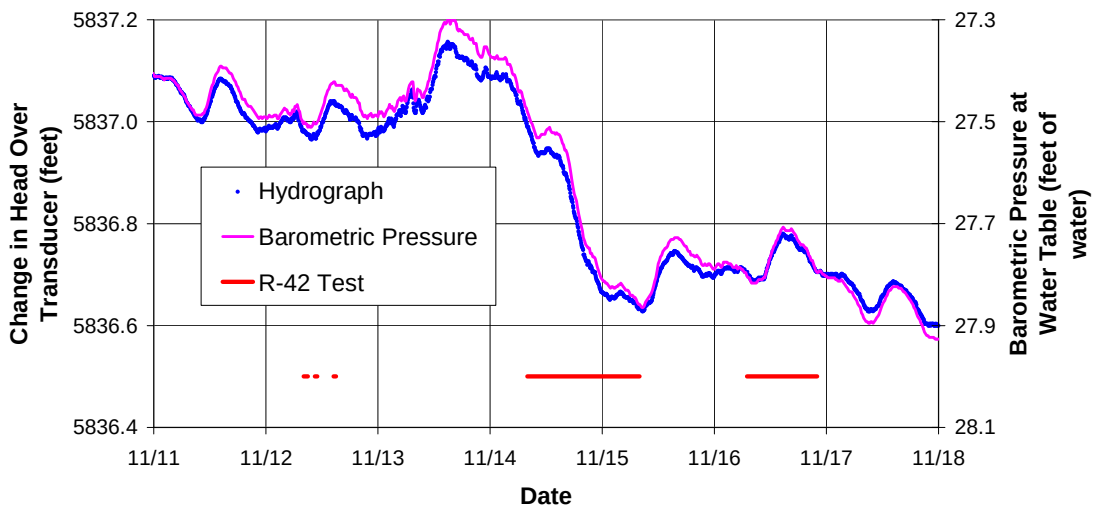


Figure C-7.0-4 Comparison of R-11 hydrograph and adjusted TA-54 barometric pressure

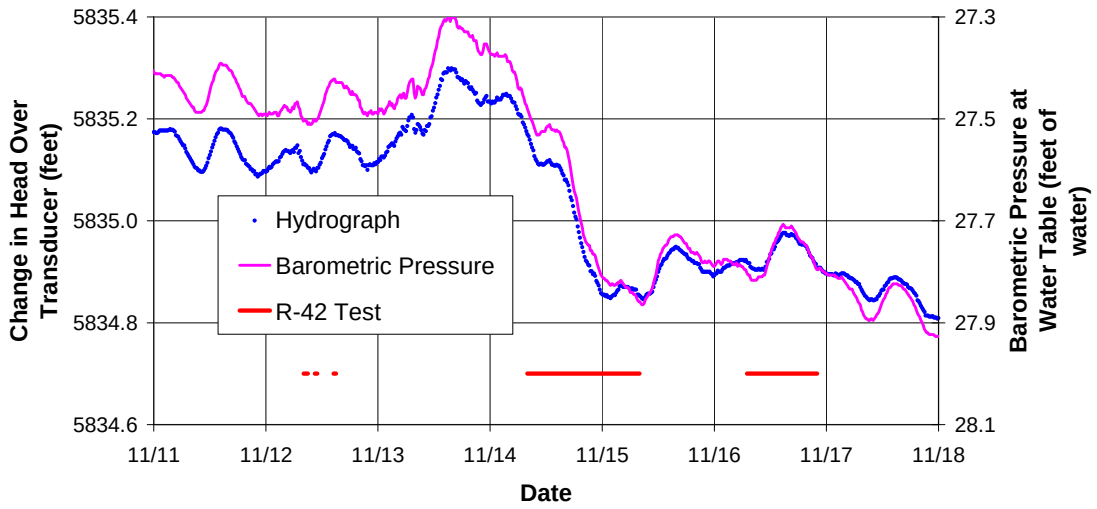


Figure C-7.0-5 Comparison of R-13 hydrograph and adjusted TA-54 barometric pressure

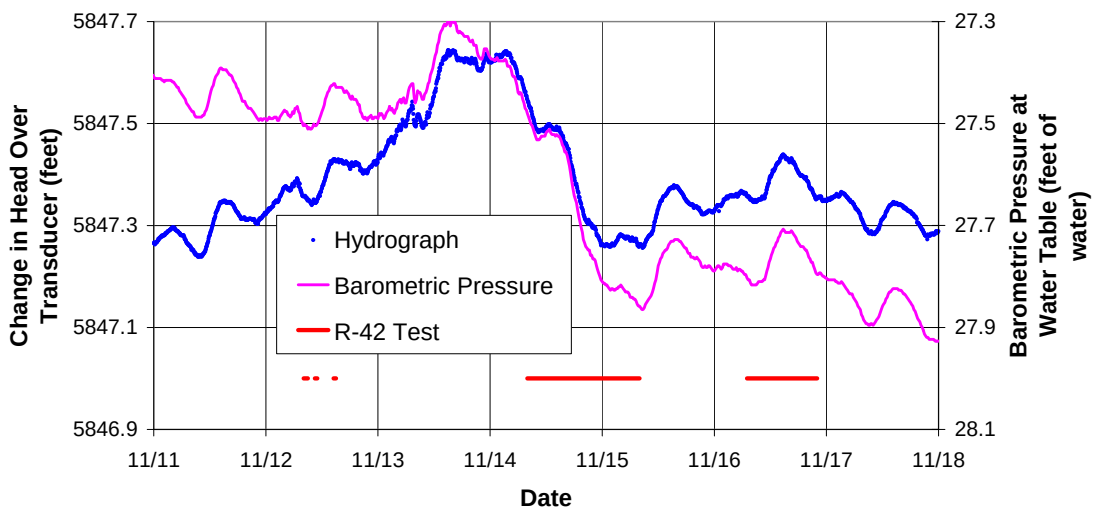


Figure C-7.0-6 Comparison of R-15 hydrograph and adjusted TA-54 barometric pressure

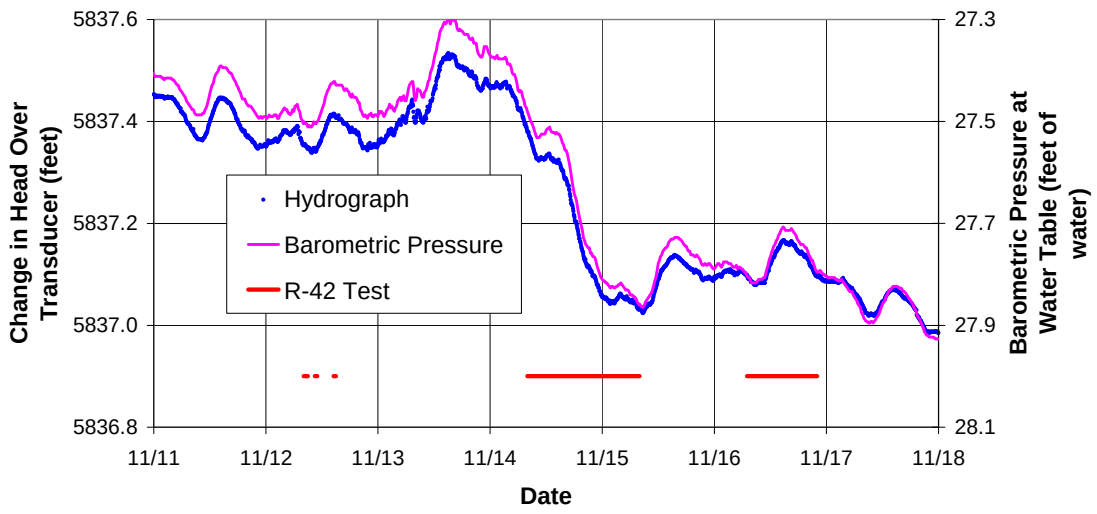


Figure C-7.0-7 Comparison of R-28 hydrograph and adjusted TA-54 barometric pressure

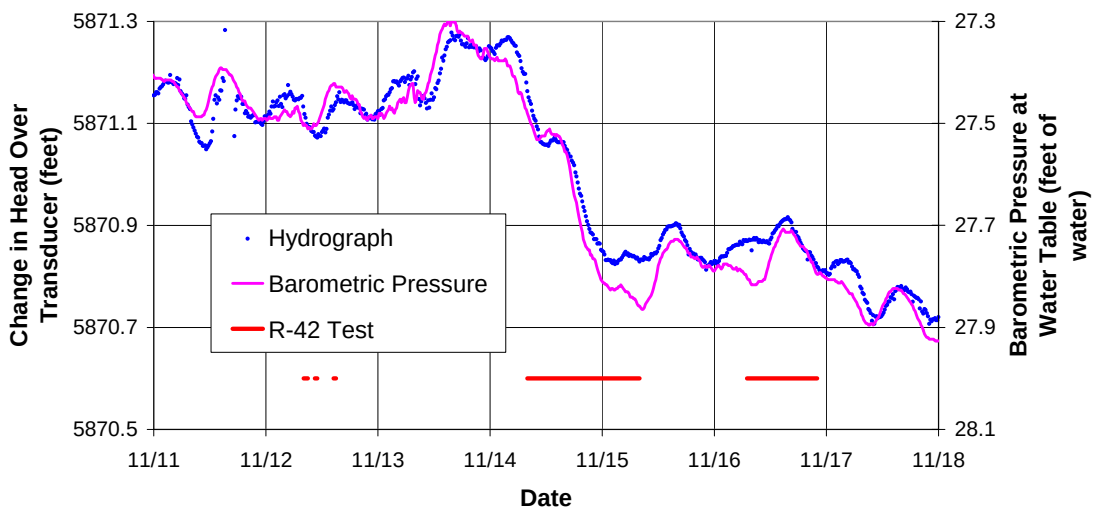


Figure C-7.0-8 Comparison of R-33 screen 1 hydrograph and adjusted TA-54 barometric pressure

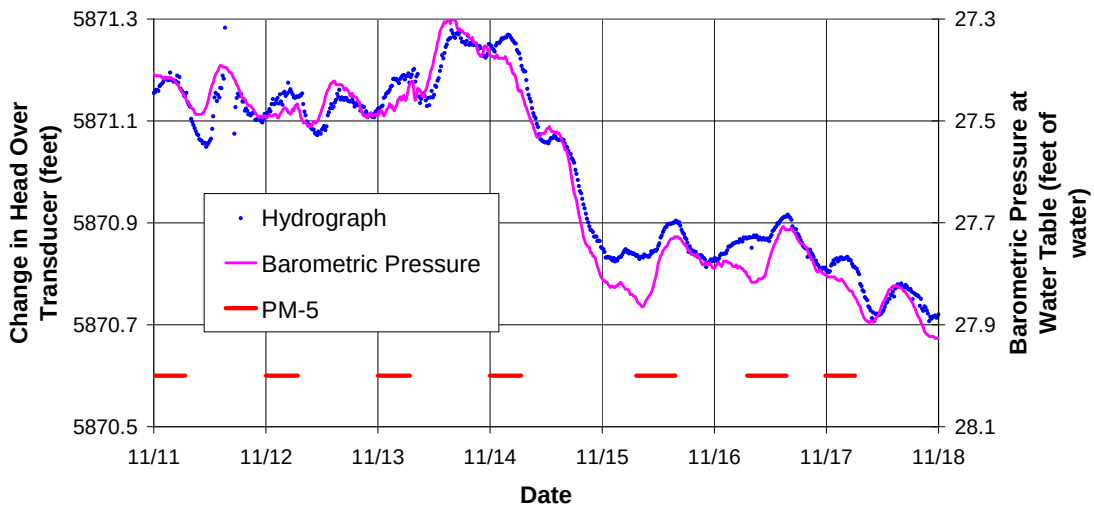


Figure C-7.0-9 Comparison of R-33 screen 1 hydrograph and PM-5 operation

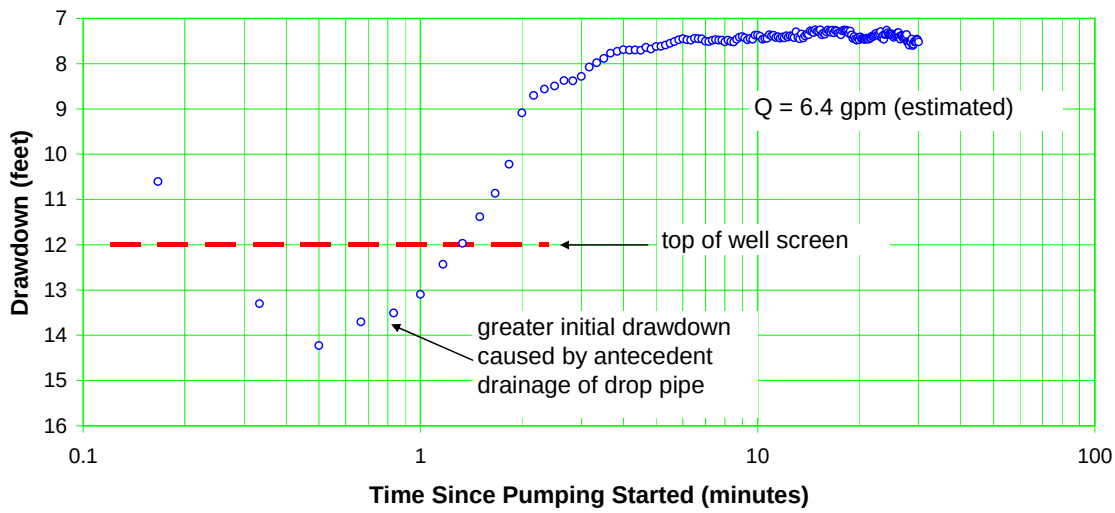


Figure C-8.0-1 Well R-42 trial 1 drawdown

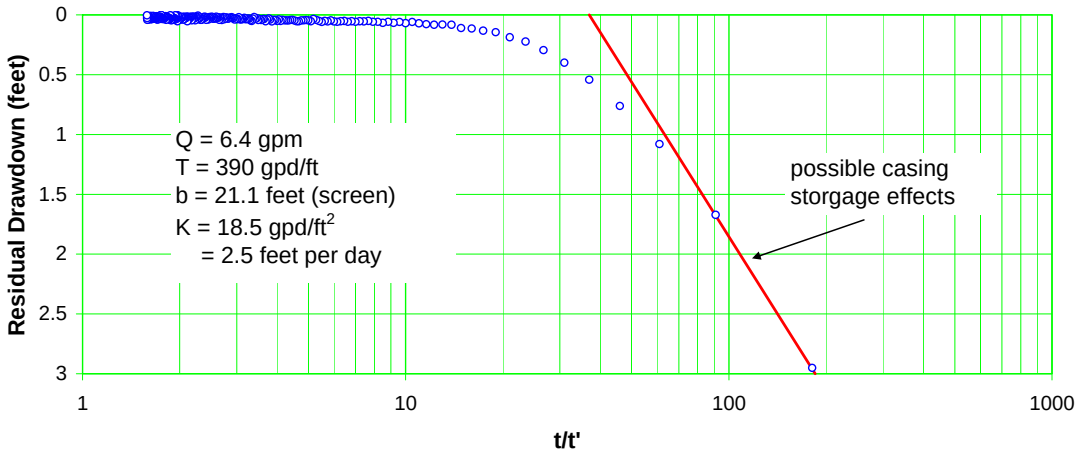


Figure C-8.0-2 Well R-42 trial 1 recovery

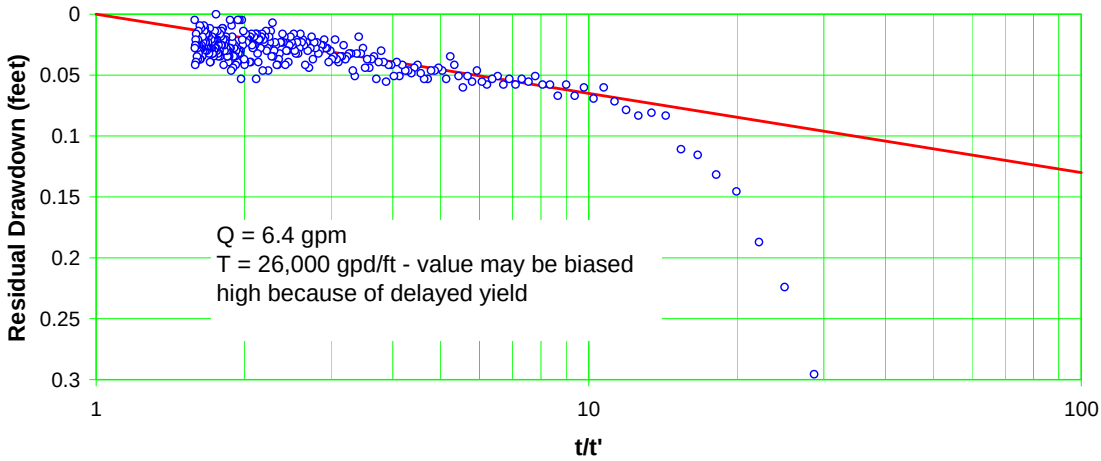


Figure C-8.0-3 Well R-42 trial 1 recovery—late data

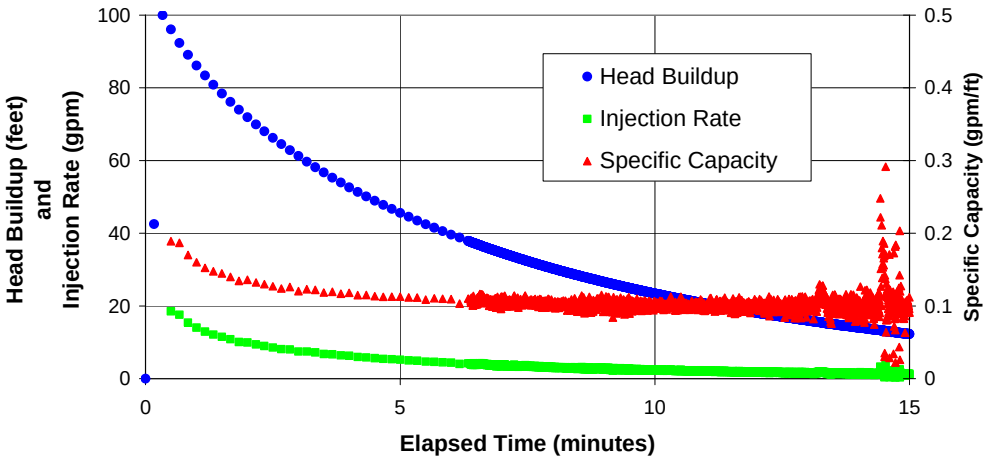


Figure C-8.0-4 Head buildup following trial 1 packer deflation

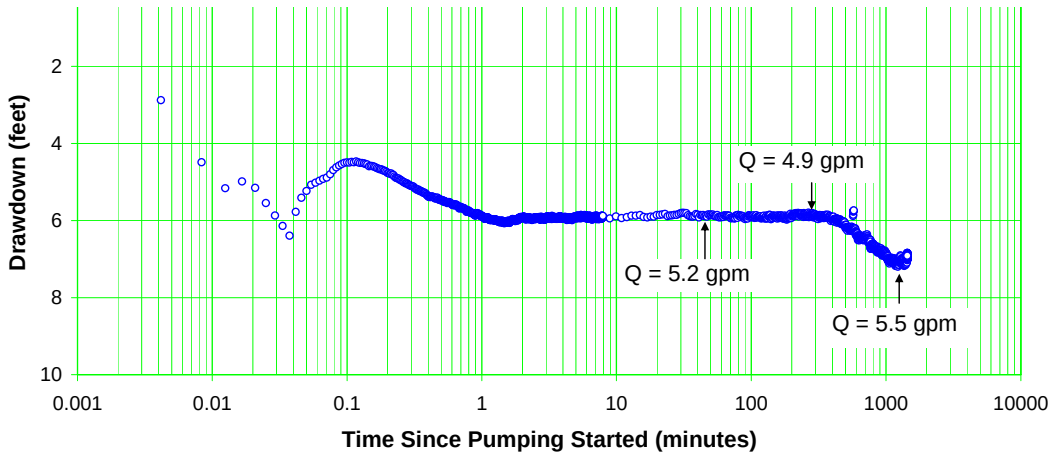


Figure C-8.1-1 Comparison of R-42 drawdown

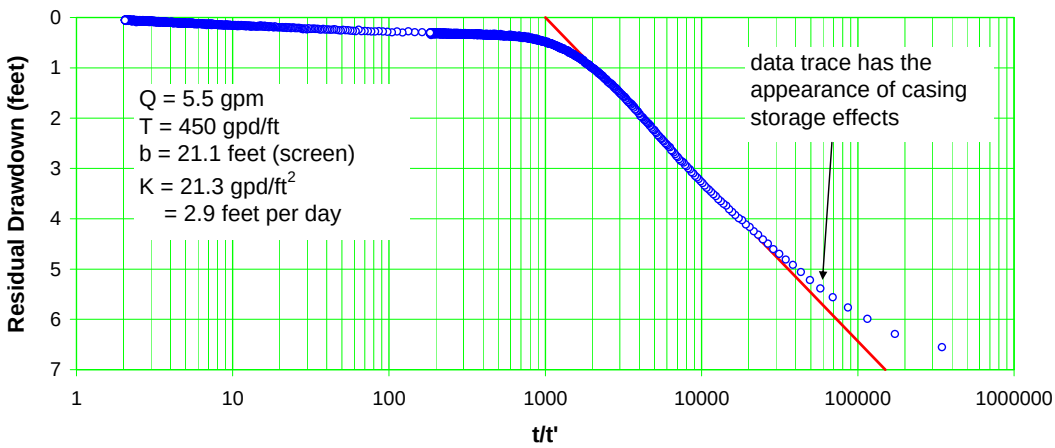


Figure C-8.1-2 Well R-42 recovery—early data

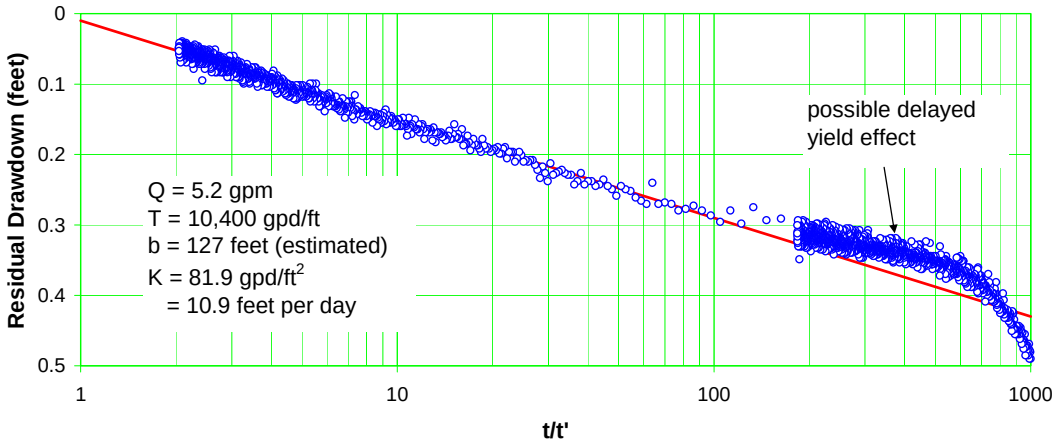


Figure C-8.1-3 Well R-42 recovery—late data

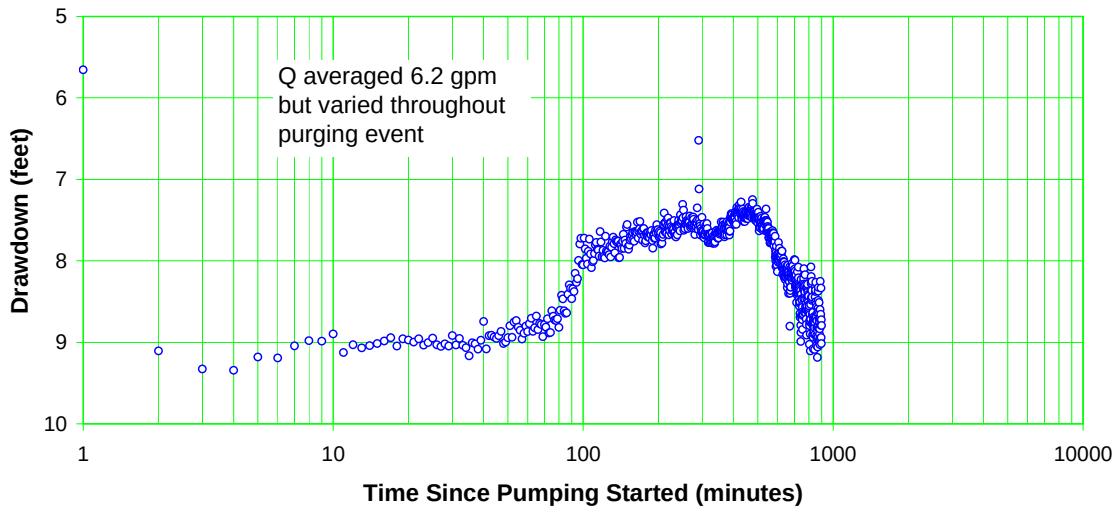


Figure C-8.2-1 Well R-42 purge drawdown

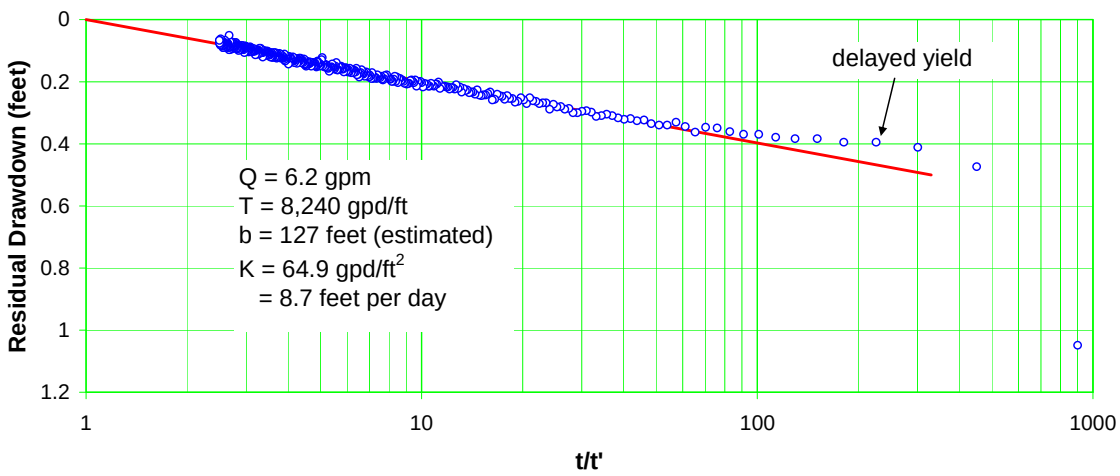


Figure C-8.2-2 Well R-42 purge recovery

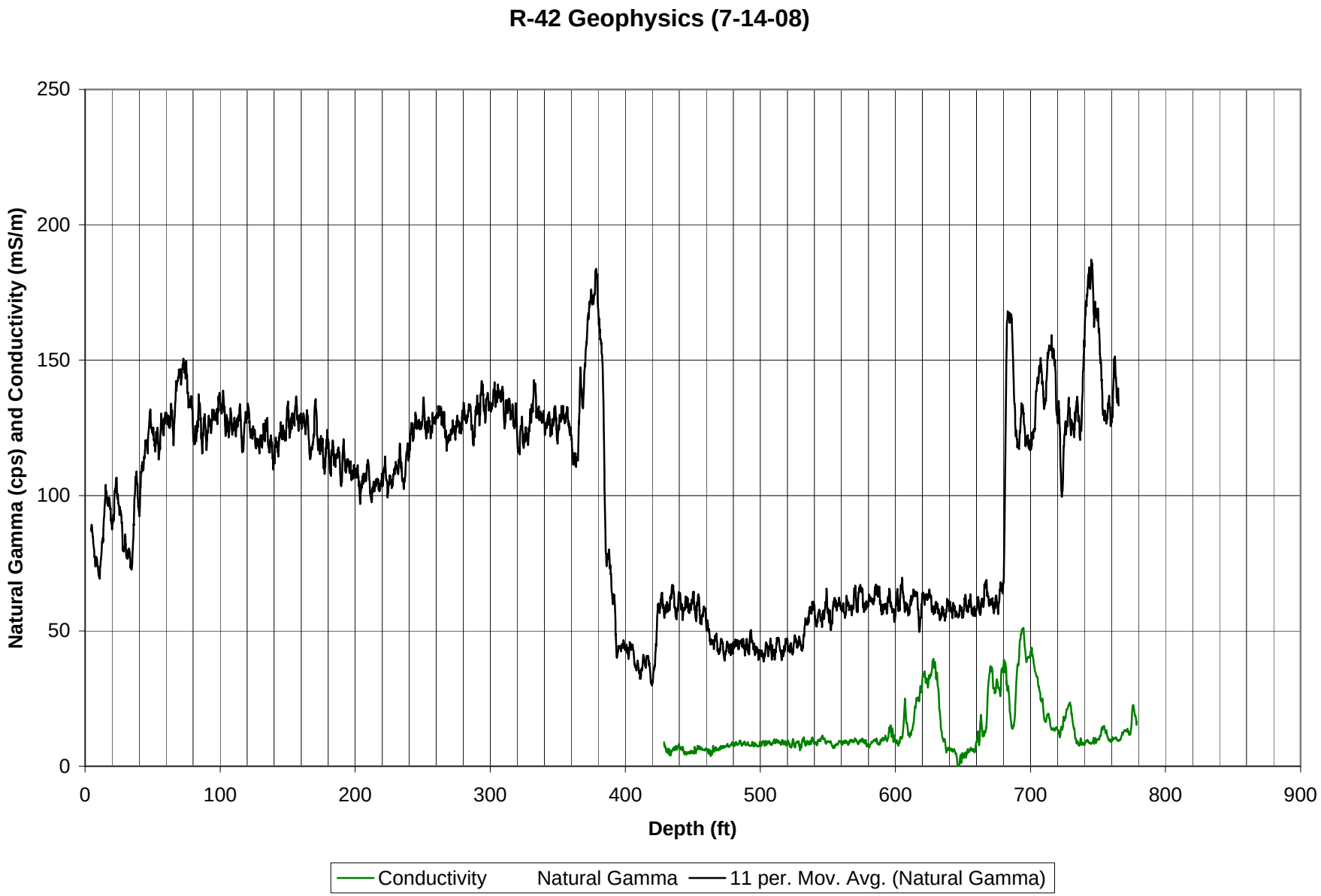
Appendix D

July 14, 2008, Borehole Video
(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

Los Alamos National Laboratory Geophysical Logs and Schlumberger Geophysical Logging Report (on CD included with this document)


R-42 Geophysics (7-14-08)
Natural Gamma (cps) and Conductivity (mS/m)
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Depth (ft)
Conductivity
Natural Gamma
11 per. Mov. Avg. (Natural Gamma)

```
~VERSION INFORMATION
VERS    .2.0                :CWLS LOG ASCII STANDARD-VERSION 2.0
WRAP    .NO                 :ONE LINE PER DEPTH STEP
~WELL INFORMATION
STRT    .FT         778.806:START DEPTH
STOP    .FT         423.491:STOP DEPTH
STEP    .FT        -0.16404:STEP
NULL    .           -999.25:NULL VALUE
COMP    .         N/A       :COMPANY
WELL    .         N/A       :WELL
FLD     .         N/A       :FIELD
LOC     .         N/A       :LOCATION
PROV    .         N/A       :PROVINCE
SRVC    .         N/A       :SERVICE COMPANY
DATE    .         N/A       :LOG DATE
UWI     .         N/A       :UNIQUE WELL ID
~CURVE INFORMATION
DEPT    .FT                 :DEPTH
COND    .MS                 :Cond.
I__R    .OHM-M              :I. Res.
~PARAMETER INFORMATION
Dept    .                   :Depth Logger
BH F    .         air       :BH Fluid
File    .         R4207140:File Name
COMP    .         TPMC w/E:COMPANY:
Dept    .         775'      :Depth Driller
OTHE    .                   :OTHER SERVICES
Witn    .                   :Witness:
Loca    .         Mortandac:Location:
Casi    .         16" 0-419 :Casing
Date    .          7/14/2008:Date
Well    .         R-42      :Well
Logg    .         Mark Ever:Logged by:
~OTHER
~A
   778.806   16.5421   60.4516
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   778.478   15.3731   65.0486
   778.314   16.2791   61.4284
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   777.986   17.7209   56.4305
   777.822   18.3931   54.3682
   777.657   18.7243   53.4064
   777.493     18.51   54.0248
   777.329   18.6756   53.5457
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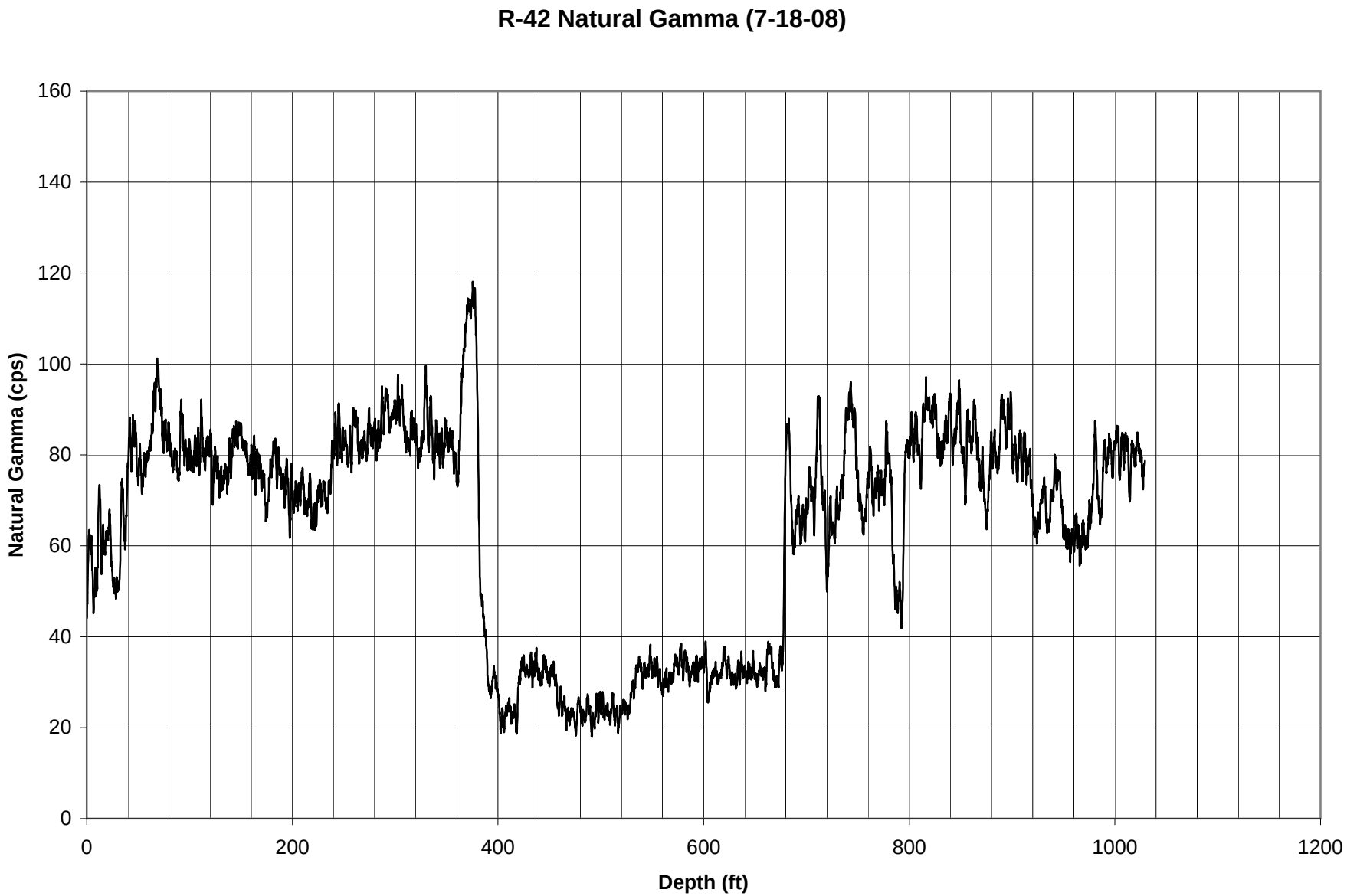
699.738	40.595	24.6336
699.574	40.3612	24.7763
699.409	40.3125	24.8062
699.245	40.1469	24.9085
699.081	40.3125	24.8062
698.917	40.3028	24.8122
698.753	40.3125	24.8062
698.589	40.4392	24.7285
698.425	40.4781	24.7047
698.261	40.4586	24.7166
698.097	40.069	24.957
697.933	39.9715	25.0178
697.769	39.7864	25.1342
697.605	39.6598	25.2145
697.441	39.2409	25.4836
697.277	38.8902	25.7134
697.113	38.6466	25.8755
696.949	38.4713	25.9934
696.785	39.0071	25.6364
696.621	39.8936	25.0667
696.457	40.5073	24.6869
696.293	41.7933	23.9273
696.129	42.8357	23.345
695.965	43.352	23.067
695.801	43.8878	22.7854
695.636	45.1543	22.1463
695.472	46.6155	21.4521
695.308	47.882	20.8847
695.144	49.1095	20.3627
694.98	50.6974	19.7249
694.816	50.9799	19.6156
694.652	51.1066	19.5669
694.488	50.9312	19.6343
694.324	50.6097	19.759
694.16	50.3759	19.8507
693.996	50.4734	19.8124
693.832	50.7851	19.6908
693.668	50.3175	19.8738
693.504	49.7914	20.0838
693.34	49.1485	20.3465
693.176	48.6808	20.542
693.012	48.8172	20.4846
692.848	48.1645	20.7622
692.684	47.2001	21.1864
692.52	46.8396	21.3495
692.356	47.0052	21.2742
692.192	46.6058	21.4566
692.028	45.8752	21.7983
691.864	44.1801	22.6346
691.699	41.4621	24.1184
691.535	39.689	25.1959
691.371	38.5784	25.9212
691.207	37.5555	26.6272
691.043	37.0684	26.9771
690.879	37.2633	26.8361
690.715	37.6822	26.5377
690.551	37.7796	26.4693
690.387	37.4289	26.7173
690.223	36.8639	27.1268
690.059	35.6851	28.0229
689.895	34.2822	29.1696
689.731	32.7235	30.5591
689.567	31.4571	31.7894
689.403	29.4892	33.9107
689.239	27.1706	36.8045
689.075	25.2222	39.6476
688.911	23.644	42.294
688.747	21.832	45.8043
688.583	20.2343	49.4209
688.419	18.8997	52.9109
688.255	17.7404	56.3685
688.091	16.698	59.8873
687.927	16.133	61.9848
687.762	15.6946	63.7162
687.598	14.8665	67.2652
687.434	15.2172	65.7149
687.27	14.8958	67.1332
687.106	14.1164	70.8396
686.942	13.8241	72.3372
686.778	13.8631	72.1339
686.614	13.9508	71.6805
686.45	13.9898	71.4809
686.286	13.9313	71.7808
686.122	14.2236	70.3059
685.958	14.6132	68.4311
685.794	15.4511	64.7205
685.63	16.5421	60.4516
685.466	17.0292	58.7225
685.302	17.8183	56.1219
685.138	19.0361	52.5318
684.974	19.8739	50.3173
684.81	19.8252	50.4409
684.646	20.7604	48.1686
684.482	22.0171	45.4192
684.318	23.4784	42.5923
684.154	25.6801	38.9407
683.99	26.703	37.449
683.825	27.5213	36.3355
683.661	28.8755	34.6315
683.497	29.7133	33.655
683.333	28.7878	34.737
683.169	27.9695	35.7533
683.005	28.5247	35.0573
682.841	28.0084	35.7035
682.677	29.7133	33.655
682.513	31.2428	32.0074
682.349	31.3791	31.8683
682.185	30.2004	33.1122
682.021	35.4708	28.1922
681.857	36.5424	27.3655
681.693	35.8312	27.9086
681.529	37.1756	26.8994
681.365	38.2764	26.1257
681.201	34.5842	28.9149
681.037	35.7143	28
680.873	38.7538	25.8039
680.709	39.1045	25.5725
680.545	39.0753	25.5916
680.381	39.2701	25.4647
680.217	39.0071	25.6364
680.053	37.3899	26.7452
679.888	36.367	27.4974
679.724	36.5813	27.3363
679.56	36.065	27.7277
679.396	34.6719	28.8418
679.232	35.3539	28.2855
679.068	36.1917	27.6307
678.904	36.065	27.7277
678.74	35.841	27.901
678.576	35.5877	28.0996
678.412	34.2822	29.1696
678.248	31.6227	31.6229
678.084	29.0021	34.4803
677.92	27.8818	35.8657
677.756	26.8296	37.2722
677.592	25.797	38.7642
677.428	26.6348	37.5449
677.264	27.5603	36.2841
677.1	27.911	35.8282
676.936	28.6806	34.8668
676.772	28.9047	34.5965
676.608	29.1385	34.3189
676.444	28.6611	34.8905
676.28	29.0411	34.434
676.116	29.2067	34.2387
675.951	29.08	34.3878
675.787	29.4892	33.9107
675.623	30.9115	32.3504
675.459	31.2428	32.0074
675.295	31.5058	31.7402
675.131	32.0806	31.1715
674.967	32.139	31.1148
674.803	31.272	31.9775
674.639	29.9178	33.4249
674.475	28.4663	35.1293
674.311	27.6869	36.1181
674.147	27.2193	36.7386
673.983	27.7844	35.9915
673.819	27.8136	35.9537
673.655	27.5408	36.3098
673.491	26.9271	37.1374
673.327	28.4273	35.1774
673.163	28.8073	34.7135
672.999	28.7488	34.784
672.835	28.8462	34.6666
672.671	29.0995	34.3648
672.507	28.7196	34.8194
672.343	30.1517	33.1657
672.178	32.139	31.1148
672.014	34.1459	29.2861
671.85	35.3149	28.3167
671.686	35.2662	28.3558
671.522	35.8312	27.9086
671.358	36.6106	27.3145
671.194	35.9091	27.8481
671.03	34.9934	28.5768
670.866	36.1527	27.6605
670.702	36.6398	27.2927
670.538	36.747	27.2131
670.374	37.0002	27.0268
670.21	36.5521	27.3582
670.046	35.9773	27.7953
669.882	35.1882	28.4186
669.718	34.4089	29.0623
669.554	34.0484	29.3699
669.39	33.5808	29.7789
669.226	32.3046	30.9553
669.062	31.6617	31.5839
668.898	31.1064	32.1478
668.734	29.5282	33.866
668.57	28.3884	35.2257
668.406	26.5374	37.6827
668.241	24.7741	40.3647
668.077	21.6274	46.2375
667.913	19.6109	50.9921
667.749	19.0458	52.5049
667.585	17.9158	55.8166
667.421	15.6361	63.9544
667.257	14.1164	70.8396
667.093	14.3502	69.6854
666.929	13.415	74.5435
666.765	12.8597	77.7624
666.601	12.509	79.9426
666.437	12.2459	81.6597
666.273	12.3434	81.0152
666.109	12.9961	76.9463
665.945	13.0838	76.4306
665.781	12.0511	82.9799
665.617	11.3107	88.4117
665.453	11.5543	86.5481
665.289	11.0672	90.3573
665.125	11.2425	88.948
664.961	11.2328	89.0251
664.797	11.262	88.7941
664.633	10.9698	91.1597
664.469	12.5577	79.6325
664.304	13.3078	75.1438
664.14	14.1261	70.7907
663.976	15.1003	66.2237
663.812	16.4447	60.8098
663.648	16.5421	60.4516
663.484	17.8671	55.9689
663.32	19.0166	52.5856
663.156	18.3834	54.397
662.992	16.5811	60.3096
662.828	16.1817	61.7982
662.664	13.7949	72.4905
662.5	10.7554	92.9763
662.336	9.07982	110.134
662.172	8.70962	114.816
662.008	7.76465	128.789
661.844	8.51478	117.443
661.68	10.7847	92.7243
661.516	12.3336	81.0792
661.352	12.8012	78.1174
661.188	12.9571	77.1777
661.024	12.5285	79.8182
660.86	11.4861	87.0619
660.696	10.4632	95.5733
660.532	9.81046	101.932
660.367	9.38182	106.589
660.203	8.9824	111.329
660.039	9.01162	110.968
659.875	8.64143	115.722
659.711	8.45633	118.255
659.547	7.84259	127.509
659.383	7.73543	129.275
659.219	6.57613	152.065
659.055	5.72858	174.563
658.891	5.51426	181.348
658.727	5.57271	179.446
658.563	5.01742	199.306
658.399	5.41684	184.609
658.235	6.03059	165.821
658.071	6.03059	165.821
657.907	5.92342	168.821
657.743	6.50794	153.658
657.579	6.34223	157.671
657.415	5.93317	168.544
657.251	5.7091	175.159
657.087	5.60194	178.51
656.923	5.60194	178.51
656.759	6.15723	162.411
656.595	6.3813	156.708
656.43	6.22542	160.632
656.266	6.05007	165.287
656.102	6.51768	153.429
655.938	6.8002	147.055
655.774	6.78072	147.477
655.61	6.70278	149.192
655.446	6.56639	152.291
655.282	6.25465	159.881
655.118	5.76755	173.384
654.954	5.72858	174.563
654.79	5.53375	180.709
654.626	5.33891	187.304
654.462	5.222	191.497
654.298	5.12458	195.138
654.134	5.43633	183.948
653.97	6.03059	165.821
653.806	6.29362	158.891
653.642	6.28388	159.137
653.478	6.29362	158.891
653.314	5.54349	180.392
653.15	4.8031	208.199
652.986	4.53033	220.735
652.822	4.47187	223.62
652.657	4.99794	200.082
652.493	4.48162	223.134
652.329	3.21516	311.026
652.165	3.88736	257.244
652.001	5.12458	195.138
651.837	5.08562	196.633
651.673	4.85181	206.109
651.509	4.62774	216.088
651.345	4.82258	207.358
651.181	3.94581	253.434
651.017	3.28336	304.566
650.853	3.8289	261.171
650.689	4.30626	232.22
650.525	3.91658	255.325
650.361	3.03981	328.968
650.197	3.75097	266.598
650.033	4.014	249.128
649.869	4.66671	214.284
649.705	4.92	203.252
649.541	4.90052	204.06
649.377	3.8289	261.171
649.213	2.40658	415.527
649.049	1.49084	670.764
648.885	1.40316	712.678
648.72	1.23755	808.051
648.556	2.21174	452.133
648.392	3.50742	285.11
648.228	4.24781	235.416
648.064	3.85813	259.193
647.9	3.31258	301.879
647.736	2.53323	394.754
647.572	1.16935	855.174
647.408	0.497158	2011.43
647.244	-0.47704	-2096.27
647.08	-1.95781	-510.776
646.916	-2.23059	-448.312
646.752	-2.87356	-348.001
646.588	-3.10736	-321.816
646.424	-2.36698	-422.48
646.26	-0.37962	-2634.22
646.096	0.097728	10232.5
645.932	0.818642	1221.53
645.768	1.81232	551.779
645.604	2.9229	342.126
645.44	3.41	293.255
645.276	3.8971	256.601
645.112	4.21858	237.046
644.948	4.76413	209.902
644.783	4.66671	214.284
644.619	4.53033	220.735
644.455	4.54007	220.261
644.291	4.76413	209.902
644.127	5.38762	185.611
643.963	5.44607	183.619
643.799	5.69926	175.458
643.635	5.90394	169.378
643.471	6.35207	157.429
643.307	6.24491	160.13
643.143	5.67013	176.363
642.979	5.66039	176.666
642.815	5.61168	178.2
642.651	5.67013	176.363
642.487	5.8942	169.658
642.323	5.36813	186.285
642.159	5.46555	182.964
641.995	5.85523	170.787
641.831	6.3813	156.708
641.667	6.46897	154.584
641.503	6.46897	154.584
641.339	6.39104	156.469
641.175	6.11826	163.445
641.011	5.826	171.644
640.846	5.72858	174.563
640.682	5.92342	168.821
640.518	6.18646	161.643
640.354	6.29362	158.891
640.19	6.35207	157.429
640.026	6.92684	144.366
639.862	6.78072	147.477
639.698	6.71252	148.975
639.534	6.67355	149.845
639.37	6.80994	146.844
639.206	5.92342	168.821
639.042	6.1962	161.389
638.878	6.74175	148.329
638.714	6.64433	150.504
638.55	6.51768	153.429
638.386	6.51768	153.429
638.222	6.27413	159.385
638.058	5.90394	169.378
637.894	5.31942	187.99
637.73	5.05639	197.77
637.566	5.54349	180.392
637.402	6.18646	161.643
637.238	7.18014	139.273
637.074	7.94001	125.944
636.909	8.94343	111.814
636.745	9.5182	105.062
636.581	9.87866	101.228
636.417	10.0345	99.6559
636.253	10.1612	98.4138
636.089	9.8884	101.129
635.925	9.32336	107.257
635.761	9.30388	107.482
635.597	9.16749	109.081
635.433	9.2844	107.708
635.269	9.71304	102.954
635.105	10.3658	96.4715
634.941	10.4534	95.6624
634.777	10.7554	92.9763
634.613	11.3107	88.4117
634.449	12.4018	80.6333
634.285	12.8889	77.586
634.121	12.9181	77.4105
633.957	13.0838	76.4306
633.793	13.5416	73.8464
633.629	14.2138	70.354
633.465	16.5714	60.345
633.301	17.6527	56.6485
633.136	18.7243	53.4064
632.972	19.7862	50.5402
632.808	20.6825	48.3501
632.644	20.7117	48.2819
632.48	21.267	47.0212
632.316	22.8929	43.6798
632.152	24.9592	40.0654
631.988	27.1706	36.8045
631.824	28.2227	35.4324
631.66	28.7098	34.8313
631.496	29.3236	34.1022
631.332	29.684	33.6881
631.168	30.5998	32.68
631.004	33.0548	30.2528
630.84	34.633	28.8742
630.676	33.9608	29.4458
630.512	33.2106	30.1108
630.348	32.9671	30.3333
630.184	32.0903	31.1621
630.02	32.6553	30.6229
629.856	33.7562	29.6242
629.692	36.026	27.7577
629.528	37.2341	26.8571
629.364	38.2667	26.1324
629.199	38.6564	25.869
629.035	38.4031	26.0396
628.871	36.328	27.5269
628.707	36.9126	27.091
628.543	37.4484	26.7034
628.379	38.2667	26.1324
628.215	38.9194	25.6941
628.051	39.7182	25.1773
627.887	38.8707	25.7263
627.723	38.8122	25.7651
627.559	39.0363	25.6172
627.395	38.1108	26.2393
627.231	36.5521	27.3582
627.067	35.6461	28.0535
626.903	35.1298	28.4659
626.739	34.6135	28.8905
626.575	34.0582	29.3615
626.411	33.347	29.9877
626.247	33.7562	29.6242
626.083	33.99	29.4204
625.919	33.7757	29.6071
625.755	33.2886	30.0403
625.591	33.1229	30.1905
625.427	32.441	30.8252
625.262	32.5579	30.7145
625.098	32.8891	30.4052
624.934	33.6685	29.7014
624.77	32.8307	30.4593
624.606	31.7201	31.5257
624.442	30.5608	32.7216
624.278	29.4989	33.8995
624.114	29.0411	34.434
623.95	29.3041	34.1249

623.786	30.0153	33.3164
623.622	30.6485	32.628
623.458	31.6519	31.5937
623.294	32.402	30.8623
623.13	31.7201	31.5257
622.966	30.8628	32.4015
622.802	31.4571	31.7894
622.638	30.9408	32.3198
622.474	30.7459	32.5246
622.31	32.1585	31.096
622.146	33.0645	30.2439
621.982	33.3178	30.014
621.818	33.8049	29.5815
621.654	35.0713	28.5133
621.49	34.9642	28.6007
621.325	34.9544	28.6087
621.161	33.9997	29.412
620.997	33.9608	29.4458
620.833	33.3178	30.014
620.669	33.5613	29.7962
620.505	33.2399	30.0844
620.341	34.1264	29.3029
620.177	32.9184	30.3782
620.013	31.8468	31.4004
619.849	30.5218	32.7634
619.685	29.1775	34.273
619.521	28.6806	34.8668
619.357	28.4468	35.1533
619.193	27.8428	35.9159
619.029	27.3265	36.5945
618.865	28.2909	35.347
618.701	29.0411	34.434
618.537	29.6646	33.7103
618.373	28.7391	34.7958
618.209	27.6382	36.1818
618.045	26.3913	37.8913
617.881	25.5827	39.0889
617.717	24.55	40.7331
617.553	23.9558	41.7436
617.388	24.1506	41.4068
617.224	24.6377	40.5882
617.06	25.0566	39.9096
616.896	25.0176	39.9718
616.732	25.3586	39.4343
616.568	25.4073	39.3587
616.404	24.93	40.1124
616.24	24.2578	41.2239
616.076	24.5695	40.7008
615.912	24.93	40.1124
615.748	25.2904	39.5407
615.584	25.193	39.6936
615.42	24.7254	40.4443
615.256	23.6635	42.2591
615.092	22.6991	44.0547
614.928	21.5398	46.4258
614.764	21.8125	45.8452
614.6	22.1827	45.0801
614.436	21.8515	45.7634
614.272	20.5851	48.5789
614.108	19.7083	50.7401
613.944	18.6756	53.5457
613.78	17.1559	58.289
613.615	16.3181	61.2817
613.451	16.1232	62.0223
613.287	15.8407	63.1284
613.123	15.4998	64.5171
612.959	14.8568	67.3093
612.795	14.2723	70.0659
612.631	13.6001	73.529
612.467	13.3663	74.8152
612.303	13.3468	74.9244
612.139	13.2286	75.5308
611.975	13.1909	75.8097
611.811	12.5577	79.6325
611.647	11.7978	84.7614
611.483	11.525	86.7676
611.319	11.7491	85.1128
611.155	12.2167	81.855
610.991	12.3044	81.2717
610.827	11.5543	86.5481
610.663	11.0379	90.5966
610.499	10.7847	92.7243
610.335	11.4958	86.9881
610.171	12.2947	81.3361
610.007	12.2459	81.6597
609.843	11.827	84.552
609.678	11.4374	87.4327
609.514	11.827	84.552
609.35	12.3434	81.0152
609.186	13.0448	76.659
609.022	14.0287	71.2823
608.858	14.6717	68.1585
608.694	15.6167	64.0342
608.53	15.9576	62.6659
608.366	15.7043	63.6767
608.202	15.8602	63.0509
608.038	16.2012	61.7239
607.874	17.7209	56.4305
607.71	19.7083	50.7401
607.546	21.0819	47.4341
607.382	22.7965	43.8664
607.218	24.5695	40.7008
607.054	25.0274	39.9562
606.89	23.8291	41.9654
606.726	22.0269	45.3991
606.562	20.5656	48.6249
606.398	18.8705	52.9928
606.234	17.1559	58.289
606.07	15.6946	63.7162
605.906	14.4963	68.9829
605.741	13.4929	74.1129
605.577	12.4992	80.0049
605.413	11.4666	87.2099
605.249	10.8236	92.3905
605.085	10.6288	94.0841
604.921	10.4924	95.3071
604.757	10.7554	92.9763
604.593	10.4924	95.3071
604.429	10.0638	99.3665
604.265	10.5216	95.0424
604.101	10.8139	92.4737
603.937	10.5898	94.4303
603.773	10.7944	92.6406
603.609	10.697	93.4843
603.445	10.015	99.8498
603.281	8.84601	113.045
603.117	8.70962	114.816
602.953	8.62194	115.983
602.789	8.87523	112.673
602.625	8.84601	113.045
602.461	8.45633	118.255
602.297	7.67697	130.26
602.133	7.57956	131.934
601.969	7.96923	125.483
601.804	8.28098	120.759
601.64	8.87523	112.673
601.476	9.30388	107.482
601.312	9.5864	104.314
601.148	9.15775	109.197
600.984	9.01162	110.968
600.82	9.07007	110.253
600.656	9.0993	109.899
600.492	8.34917	119.772
600.328	8.54401	117.041
600.164	8.59272	116.378
600	9.16749	109.081
599.836	10.0443	99.5593
599.672	9.8884	101.129
599.508	10.2683	97.3868
599.344	10.9698	91.1597
599.18	11.4861	87.0619
599.016	11.1841	89.4128
598.852	10.7554	92.9763
598.688	9.86891	101.328
598.524	8.97265	111.45
598.36	9.48898	105.385
598.196	11.2912	88.5642
598.032	12.733	78.5358
597.867	13.3176	75.0888
597.703	13.9898	71.4809
597.539	13.4442	74.3815
597.375	13.1227	76.2037
597.211	10.8236	92.3905
597.047	11.5932	86.2572
596.883	12.5674	79.5707
596.719	12.8597	77.7624
596.555	13.3663	74.8152
596.391	15.1978	65.7992
596.227	14.321	69.8276
596.063	12.8207	77.9987
595.899	12.8987	77.5274
595.735	13.5416	73.8464
595.571	14.4087	69.4027
595.407	13.5416	73.8464
595.243	13.1812	75.8658
595.079	11.8465	84.4129
594.915	11.4276	87.5072
594.751	10.7262	93.2296
594.587	10.3852	96.2905
594.423	10.2878	97.2023
594.259	10.4924	95.3071
594.095	10.0832	99.1745
593.93	9.22594	108.39
593.766	9.22569	108.276
593.602	9.5182	105.062
593.438	10.0053	99.947
593.274	9.87866	101.228
593.11	10.2683	97.3868
592.946	10.4047	96.1102
592.782	10.8821	91.8942
592.618	10.9113	91.6481
592.454	11.3399	88.1838
592.29	10.9113	91.6481
592.126	10.5606	94.6917
591.962	10.3852	96.2905
591.798	10.1417	98.6029
591.634	9.87866	101.228
591.47	9.5182	105.062
591.306	9.5182	105.062
591.142	9.74227	102.645
590.978	10.0735	99.2704
590.814	10.1027	98.9832
590.65	10.2586	97.4793
590.486	10.5216	95.0424
590.322	10.4927	95.3057
590.157	10.2878	97.2023
589.993	9.75201	102.543
589.829	9.38182	106.589
589.665	9.33311	107.145
589.501	9.22569	108.276
589.337	9.15775	109.197
589.173	9.82969	101.629
589.009	9.67407	103.369
588.845	9.19672	108.734
588.681	8.45633	118.255
588.517	8.6122	116.114
588.353	8.17381	122.342
588.189	7.90104	126.566
588.025	8.51478	117.443
587.861	8.44659	118.391
587.697	8.35891	119.633
587.533	8.55375	116.908
587.369	8.25175	121.186
587.205	8.23227	121.473
587.041	8.06665	123.967
586.877	8.54401	117.041
586.713	8.45633	118.255
586.549	9.01162	110.968
586.385	9.55717	104.633
586.22	9.84943	101.529
586.056	10.0832	99.1745
585.892	10.2586	97.4793
585.728	10.1807	98.2255
585.564	9.86891	101.328
585.4	9.12853	109.547
585.236	9.38182	106.589
585.072	9.45975	105.711
584.908	9.49872	105.277
584.744	9.78124	102.237
584.58	9.8202	101.831
584.416	9.48898	105.385
584.252	9.49872	105.277
584.088	9.64485	103.682
583.924	9.54743	104.74
583.76	9.4013	106.368
583.596	9.25517	108.048
583.432	9.20646	108.619
583.268	9.0993	109.899
583.104	8.83627	113.17
582.94	8.74859	114.304
582.776	8.97265	111.45
582.612	8.94343	111.814
582.448	8.93369	111.936
582.283	9.07982	110.134
582.119	8.70962	114.816
581.955	8.55375	116.908
581.791	8.23227	121.473
581.627	8.15433	122.634
581.463	8.09588	123.52
581.299	7.93027	126.099
581.135	7.66723	130.425
580.971	7.18988	139.084
580.807	7.15091	139.842
580.643	7.12168	140.416
580.479	7.25807	137.778
580.315	6.95607	143.759
580.151	7.39446	135.236
579.987	7.60878	131.427
579.823	8.26149	121.044
579.659	8.03743	124.418
579.495	8.16407	122.488
579.331	7.81336	127.986
579.167	7.97898	125.329
579.003	7.61852	131.259
578.839	7.27755	137.409
578.675	7.38472	135.415
578.511	8.29072	120.617
578.346	8.6804	115.202
578.182	9.5864	104.314
578.018	9.64485	103.682
577.854	9.5864	104.314
577.69	8.62194	115.983
577.526	8.44659	118.391
577.362	8.38814	119.216
577.198	8.72885	114.432
577.034	8.72885	114.432
576.87	9.68382	103.265
576.706	9.15775	109.197
576.542	9.29414	107.595
576.378	9.03111	110.728
576.214	9.4013	106.368
576.05	8.88498	112.55
575.886	9.45975	105.711
575.722	10.0345	99.6559
575.558	10.1417	98.6029
575.394	10.2878	97.2023
575.23	9.81046	101.932
575.066	9.82969	101.629
574.902	9.78124	102.237
574.738	9.22569	108.276
574.574	9.19672	108.734
574.409	9.12853	109.547
574.245	9.01162	110.968
574.081	9.26491	107.934
573.917	9.77149	102.338
573.753	9.68382	103.265
573.589	9.39156	106.479
573.425	9.5182	105.062
573.261	9.39156	106.479
573.097	8.72885	114.432
572.933	8.59272	116.378
572.769	8.39788	119.078
572.605	8.28098	120.759
572.441	8.10562	123.371
572.277	8.4953	117.712
572.113	8.55375	116.908
571.949	8.6122	116.114
571.785	8.83627	113.17
571.621	8.93369	111.936
571.457	9.04085	110.609
571.293	9.61562	103.997
571.129	9.54743	104.74
570.965	9.38182	106.589
570.801	9.43053	106.039
570.636	9.74227	102.645
570.472	10.1417	98.6029
570.308	10.3365	96.7443
570.144	10.3268	96.8356
569.98	10.1709	98.3196
569.816	9.71304	102.954
569.652	9.36233	106.811
569.488	9.30388	107.482
569.324	9.00188	111.088
569.16	8.90446	112.303
568.996	8.97265	111.45
568.832	8.88498	112.55
568.668	9.07007	110.253
568.504	9.45001	105.82
568.34	8.9824	111.329
568.176	9.2844	107.708
568.012	9.43053	106.039
567.848	9.84943	101.529
567.684	9.5182	105.062
567.52	9.29414	107.595
567.356	9.10904	109.781
567.192	9.22594	108.39
567.028	9.68382	103.265
566.864	9.78124	102.237
566.699	9.33311	107.145
566.535	9.55717	104.633
566.371	9.68382	103.265
566.207	9.39156	106.479
566.043	8.64143	115.722
565.879	8.81678	113.42
565.715	9.03111	110.728
565.551	9.00188	111.088
565.387	8.47581	117.983
565.223	8.39788	119.078
565.059	7.83285	127.668
564.895	8.03743	124.418
564.731	8.39788	119.078
564.567	8.64143	115.722
564.403	8.51478	117.443
564.239	8.83627	113.17
564.075	9.10904	109.781
563.911	8.84601	113.045
563.747	9.2844	107.708
563.583	9.12853	109.547
563.419	8.64143	115.722
563.255	8.51478	117.443
563.091	9.16749	109.081
562.927	9.57666	104.421
562.762	9.03111	110.728
562.598	8.71936	114.687
562.434	8.84601	113.045
562.27	8.64143	115.722
562.106	8.9824	111.329
561.942	9.2844	107.708
561.778	8.47581	117.983
561.614	8.69014	115.073
561.45	8.69014	115.073
561.286	8.70962	114.816
561.122	9.30388	107.482
560.958	9.2844	107.708
560.794	8.34917	119.772
560.63	7.87181	127.036
560.466	7.90104	126.566
560.302	8.22252	121.617
560.138	8.0082	124.872
559.974	8.4953	117.712
559.81	8.97265	111.45
559.646	9.25517	108.048
559.482	8.96291	111.571
559.318	9.04085	110.609
559.154	8.9824	111.329
558.99	8.97265	111.45
558.825	9.29414	107.595
558.661	9.45001	105.82
558.497	9.15775	109.197
558.333	8.96291	111.571
558.169	9.20646	108.619
558.005	8.90446	112.303
557.841	8.58298	116.51
557.677	8.3784	119.355
557.513	8.23227	121.473
557.349	8.3784	119.355
557.185	8.03743	124.418
557.021	7.93027	126.099
556.857	7.84259	127.509
556.693	8.23227	121.473
556.529	8.30046	120.475
556.365	7.90104	126.566
556.201	8.03743	124.418
556.037	7.78414	128.466
555.873	7.91078	126.41
555.709	7.66723	130.425
555.545	7.94001	125.944
555.381	7.5893	131.765
555.217	7.83285	127.668
555.053	6.90736	144.773
554.888	6.82943	146.425
554.724	6.95607	143.759
554.56	6.87814	145.388
554.396	6.93659	144.163
554.232	7.34575	136.133
554.068	7.32626	136.495
553.904	6.64433	150.504
553.74	6.90736	144.773
553.576	7.13143	140.224
553.412	7.49188	133.478
553.248	7.41394	134.881
553.084	7.77439	128.627
552.92	7.72543	129.275
552.756	8.05691	124.117
552.592	8.29072	120.617
552.428	8.54401	117.041
552.264	8.71936	114.687
552.1	9.16749	109.081
551.936	9.36233	106.811
551.772	9.15775	109.197
551.608	8.83627	113.17
551.444	8.77782	113.924
551.28	8.97265	111.45
551.115	8.9142	112.181
550.951	8.96291	111.571
550.787	9.01162	110.968
550.623	9.10904	109.781
550.459	9.07982	110.134
550.295	9.07982	110.134
550.131	8.9824	111.329
549.967	9.16749	109.081
549.803	9.22569	108.276
549.639	8.97265	111.45
549.475	9.0993	109.899
549.311	9.32336	107.257
549.147	8.86549	112.797
548.983	8.87523	112.673
548.819	8.34917	119.772
548.655	8.30046	120.475
548.491	8.38814	119.216
548.327	8.45633	118.255
548.163	8.62194	115.983
547.999	9.25517	108.048
547.835	9.57666	104.421
547.671	9.8884	101.129
547.507	10.2976	97.1104
547.343	10.2294	97.7578
547.178	10.2878	97.2023
547.014	10.0053	99.947
546.85	9.86891	101.328
546.686	9.98582	100.142
546.522	10.0053	99.947
546.358	10.0832	99.1745
546.194	11.0769	90.2778
546.03	11.3887	87.8067
545.866	10.9698	91.1597
545.702	10.9795	91.0789
545.538	11.0477	90.5167
545.374	10.7554	92.9763
545.21	10.6483	93.912
545.046	10.4339	95.841
544.882	10.1027	98.9832
544.718	9.33311	107.145
544.554	9.33311	107.145
544.39	9.47924	105.494
544.226	9.54743	104.74
544.062	9.30388	107.482
543.898	9.86891	101.328
543.734	9.96633	100.338
543.57	9.69356	103.161

463.025	5.09536	196.257
462.861	5.56297	179.76
462.697	5.87471	170.221
462.533	6.11826	163.445
462.369	5.43633	183.948
462.205	5.05639	197.77
462.041	4.59852	217.461
461.877	5.02716	198.919
461.713	4.59852	217.461
461.549	5.33891	187.304
461.385	5.90394	169.378
461.22	6.27413	159.385
461.056	6.03059	165.821
460.892	6.00136	166.629
460.728	6.00136	166.629
460.564	5.51426	181.348
460.4	6.34233	157.671
460.236	6.29362	158.891
460.072	6.21568	160.883
459.908	6.05007	165.287
459.744	6.6151	151.169
459.58	6.05007	165.287
459.416	6.08904	164.23
459.252	6.3131	158.401
459.088	6.27413	159.385
458.924	5.87471	170.221
458.76	5.79678	172.51
458.596	5.96239	167.718
458.432	6.17671	161.898
458.268	6.06955	164.757
458.104	6.03059	165.821
457.94	6.14749	162.668
457.776	6.05981	165.022
457.612	6.05981	165.022
457.448	6.09878	163.967
457.283	6.14749	162.668
457.119	6.06955	164.757
456.955	6.1962	161.389
456.791	6.28388	159.137
456.627	6.67355	149.845
456.463	6.3813	156.708
456.299	6.63459	150.725
456.135	6.35207	157.429
455.971	6.97555	143.358
455.807	7.05349	141.774
455.643	6.3813	156.708
455.479	6.09878	163.967
455.315	6.32284	158.157
455.151	6.42026	155.757
454.987	6.43975	155.286
454.823	6.85865	145.801
454.659	7.45291	134.176
454.495	6.80994	146.844
454.331	6.56639	152.291
454.167	6.53717	152.971
454.003	6.32284	158.157
453.839	6.73201	148.544
453.675	7.49188	133.478
453.511	7.5211	132.959
453.346	6.74175	148.329
453.182	6.22542	160.632
453.018	6.21568	160.883
452.854	6.1962	161.389
452.69	5.95265	167.992
452.526	5.75781	173.677
452.362	5.2902	189.029
452.198	4.72516	211.633
452.034	5.01742	199.306
451.87	5.50452	181.669
451.706	5.96239	167.718
451.542	6.6833	149.627
451.378	7.2191	138.521
451.214	5.826	171.644
451.05	5.15381	194.031
450.886	5.21226	191.855
450.722	4.95897	201.655
450.558	4.63749	215.634
450.394	4.8031	208.199
450.23	4.96871	201.259
450.066	5.2902	189.029
449.902	4.9882	200.473
449.738	5.58246	179.133
449.574	5.36813	186.285
449.409	5.4071	184.942
449.245	5.58246	179.133
449.081	4.85181	206.109
448.917	4.85181	206.109
448.753	5.01742	199.306
448.589	5.48504	182.314
448.425	5.73833	174.267
448.261	5.53375	180.709
448.097	5.18304	192.937
447.933	5.33891	187.304
447.769	4.66671	214.284
447.605	4.62774	216.088
447.441	4.67645	213.837
447.277	4.72516	211.633
447.113	4.8031	208.199
446.949	4.94923	202.052
446.785	5.01742	199.306
446.621	5.11484	195.509
446.457	5.33891	187.304
446.293	5.12458	195.138
446.129	5.06613	197.389
445.965	4.85181	206.109
445.801	4.54007	220.261
445.636	4.90052	204.06
445.472	5.08562	196.633
445.308	4.26729	234.341
445.144	4.59852	217.461
444.98	4.57903	218.387
444.816	5.17329	193.3
444.652	5.38762	185.611
444.488	5.01742	199.306
444.324	4.51084	221.688
444.16	4.83233	206.94
443.996	4.54007	220.261
443.832	4.36471	229.11
443.668	4.53033	220.735
443.504	5.222	191.497
443.34	4.94923	202.052
443.176	5.34865	186.963
443.012	6.05007	165.287
442.848	6.74175	148.329
442.684	6.66381	150.064
442.52	6.86839	145.594
442.356	7.16065	139.652
442.192	7.19962	138.896
442.028	6.51768	153.429
441.864	5.99162	166.9
441.699	6.47872	154.352
441.535	6.73201	148.544
441.371	6.63459	150.725
441.207	6.78072	147.477
441.043	6.99504	142.958
440.879	6.77097	147.689
440.715	6.22542	160.632
440.551	6.32284	158.157
440.387	6.29362	158.891
440.223	7.1022	140.801
440.059	7.34575	136.133
439.895	7.5211	132.959
439.731	7.87181	127.036
439.567	8.22252	121.617
439.403	7.7062	129.766
439.239	7.56981	132.104
439.075	7.37497	135.594
438.911	7.24833	137.963
438.747	6.86839	145.594
438.583	6.78072	147.477
438.419	6.28388	159.137
438.255	6.27413	159.385
438.091	6.14749	162.668
437.927	6.34233	157.671
437.762	6.80994	146.844
437.598	7.05349	141.774
437.434	7.5893	131.765
437.27	7.2873	137.225
437.106	7.03401	142.166
436.942	6.05981	165.022
436.778	6.34233	157.671
436.614	5.826	171.644
436.45	6.35207	157.429
436.286	7.07297	141.383
436.122	6.96581	143.558
435.958	6.15723	162.411
435.794	6.37155	156.948
435.63	6.74175	148.329
435.466	6.78072	147.477
435.302	6.66381	150.064
435.138	6.00136	166.629
434.974	5.826	171.644
434.81	5.79678	172.51
434.646	5.60194	178.51
434.482	5.37787	185.947
434.318	5.64091	177.276
434.154	5.72858	174.563
433.99	5.48504	182.314
433.825	4.82258	207.358
433.661	4.17961	239.256
433.497	3.95555	252.809
433.333	3.94581	253.434
433.169	4.18936	238.7
433.005	4.92975	202.85
432.841	5.24149	190.786
432.677	6.27413	159.385
432.513	4.72516	211.633
432.349	4.316	231.696
432.185	5.37787	185.947
432.021	5.38762	185.611
431.857	5.19278	192.575
431.693	6.46897	154.584
431.529	6.05007	165.287
431.365	4.96871	201.259
431.201	5.17329	193.3
431.037	6.43975	155.286
430.873	5.99162	166.9
430.709	5.09536	196.257
430.545	5.2902	189.029
430.381	5.53375	180.709
430.217	5.63117	177.583
430.053	6.48846	154.12
429.888	6.58588	151.84
429.724	6.99504	142.958
429.56	6.83917	146.217
429.396	7.56981	132.104
429.232	7.74517	129.113
429.068	7.15091	139.842
428.904	7.38472	135.415
428.74	8.87523	112.673
428.576	10.1125	98.8879
428.412	10.5996	94.3435
428.248	11.2718	88.7173
428.084	11.7881	84.8315
427.92	13.152	76.0343
427.756	14.545	68.7519
427.592	16.7662	59.6438
427.428	20.9163	47.8096
427.264	26.6153	37.5723
427.1	34.7401	28.7852
426.936	47.5897	21.0129
426.772	67.5997	14.793
426.608	99.865	10.0135
426.444	153.115	6.53106
426.28	181.015	5.52439
426.115	-235.297	-4.24995
425.951	-235.297	-4.24995
425.787	-235.297	-4.24995
425.623	-235.297	-4.24995
425.459	-235.297	-4.24995
425.295	-235.297	-4.24995
425.131	-235.297	-4.24995
424.967	-235.297	-4.24995
424.803	-235.297	-4.24995
424.639	-235.297	-4.24995
424.475	-235.297	-4.24995
424.311	-235.297	-4.24995
424.147	-235.297	-4.24995
423.983	-235.297	-4.24995
423.819	-235.297	-4.24995
423.655	-235.297	-4.24995
423.491	-235.297	-4.24995


R-42 Natural Gamma (7-18-08)
Natural Gamma (cps)
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
Depth (ft)

GEOFRAME
PROCESSED
INTERPRETATION

Integrated Wireline Log
Well Montage

Processed Advanced Cased Hole Geophysical Logs

Using the following logs:
CNTG*, TLD*
ECS*
HNGS*, SGT*

*A Mark of Schlumberger

COMPANY:	Terranear PMC (Drilling Contractor for LANL)
WELL:	LANL R-42
FIELD:	Mortandad Canyon
STATE:	New Mexico
COUNTRY:	U.S.
Date Logged:	19-Jul-2008 Date Processed: Oct-2008
Well Location:	NA
Elevations:	D.F. 5.17 ft above G.L. G.L. NA
API Number:	NA Job Number:

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

Ser. Oder # AS7G-00008 OP Vers.: 16C0-147 Process Date: Oct-2008 Center: SWS Sacramento Baseline: GF4.2 Log A

Mud and Borehole Measurements:

Rm @ Measured Temperature: -999.25 ohm.m	BHT: 100 degF	Bitsize: 12.75 in
Rmf @ Measured Temperature: -999.25 ohm.m	Type Fluid in Hole:	FGM:
Rmc @ Measured Temperature: -999.25 ohm.	Mud density: 8.34 lbm/gal	FGM:

Remarks:

Depth reference displayed is ground surface.
Well contained one or more string of carbon steel casing (casing advance) at time of logging.
Well water level at 826 ft bgs at time of logging.
ELAN* performed with no porosity or water saturation constraints.
Interpretation should account for well conditions.

Schlumberger

ELAN* Geophysical Log Integrated Analysis

Optimized Mineral + Pore Volume Model

COMPANY: Terranear PMC

WELL: LANL R-42

FIELD: Mortandad Canyon

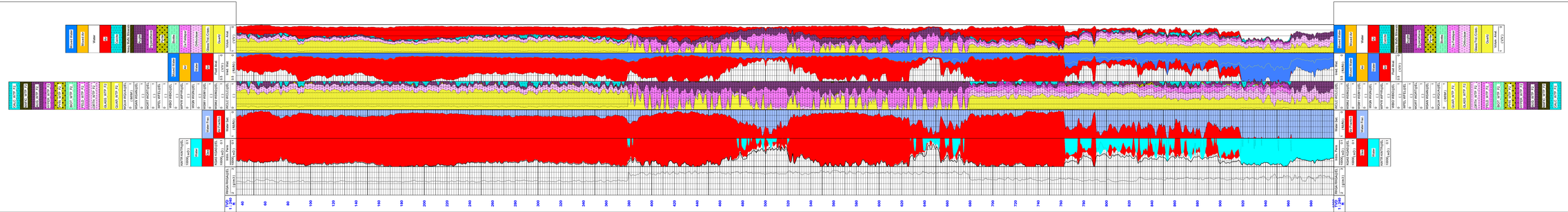
State: New Mexico

COUNTRY:

*Elemental Log Analysis, Mark of Schlumberger

Date Processed:	Oct-2008	Date Logged:	19-Jul-2008
Job Number:		Processed at:	SWS Sacramento
Well Location:	NA		
Latitude:		Longitude:	
Elevations: KB:		DF:	GL:

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



SCHLUMBERGER GEOPHYSICAL REPORT

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1.0 SUMMARY

Geophysical logging was performed by Schlumberger in characterization well R-42 in July 2008 before well completion. The logging measurements were acquired from 10 to 1,015 feet (ft) below ground surface (bgs), when the borehole contained 12 inch (in.) inner diameter (ID) freestanding steel casing from ground surface to 1,018 ft, drilled with an approximately 12.75 in. diameter bit size.

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) spectral natural gamma ray, including potassium, thorium, and uranium concentrations.

The following Schlumberger geophysical logging tools were used in the project (Table 1.1):

- Compensated Thermal/Epithermal Neutron Tool (CNT-G*)
- Triple Detector Litho-Density (TLD*) tool
- Elemental Capture Spectroscopy (ECS*) tool
- Hostile Natural Gamma Spectroscopy (HNGS*) and gamma ray (GR)

Table 1.1
Geophysical Logging Tool, Technology, Corresponding Measured Properties

Tool	Technology	Properties Measured
Compensated Neutron Tool (CNT-G*)	Epithermal and thermal neutron porosity	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

Once the Terranear PMC well drilling project team provided Schlumberger final notification that R-42 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 1.2 summarizes the geophysical logging runs performed in R-42.

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Table 1.2
Geophysical logging services, their combined tool runs and intervals logged, as performed by Schlumberger in well R-42

Date of Logging	Run #	Tool 1 (bottom)	Tool 2 (top)	Tool 3	Depth Interval (ft bgs)
19-July-2008	1	TLD	CNT-G	GR	22-1015
	2	HNGS	GR		29-1008
	3	ECS	GR		34-1012

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-42 provide, overall, good 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) 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 likely being affected by voids.

Important results from the processed geophysical logs in R-42 include the following:

1. The well standing water level in R-42 was 826 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 log borehole (1,015 ft bgs) to at least 918 ft bgs and possibly to 763 ft bgs, which lies within alluvium/fanglomerate. Below 918 ft the log estimated water content and total porosity is very high (50% of total rock/sediment volume). Above 918 ft the water content is much lower, but still high – decreasing from about 25% at 918 ft to about 18% at 826 ft, on average. Total porosity across this same interval averages from about 40% to 22%, resulting in an estimated water saturation that averages about 65% of total pore volume. Estimated water content above 826 ft stays a little above 10%, except rising to about 25% at 775 ft, then decreases to 5% at 763 ft. Estimated water saturation remains near 65% through this interval, sharply decreases to 10% or less above 763 ft. A specific depth of the Regional Aquifer water

level (depth at which there is full water saturation) cannot be conclusively determined based on these log results, although they do constrain the depth to between 763 and 918 ft.

3. Above 763 ft bgs, which the processed logs definitely show to be within the vadose zone (above the top of the Regional Aquifer), the estimated water content varies from less than 5% to 20%, mostly remaining below 10%. There are a number of zones where the water content and, correspondingly, water saturation increases, including 655–680 ft, 606–634 ft, 539–546 ft, 354–390 ft, 100–174 ft, 65–88 ft, and 30–45 ft. Estimated water saturation reaches to over 40% in the following zones:
    - 627–678 ft, located in the bottom part of a likely thick basalt lava sequence that has significantly lower estimated total porosity than the surrounding rock (presumably the basalt is more competent here
    - 475–521 ft, located in the middle of the same basalt lava sequence where the total porosity is a lot lower than the surrounding rock
    - 378–388 ft, likely located at the top of the same basalt lava that lies immediately below the Guaje Pumice bed, perhaps where the basalt is eroded and/or re-worked
4. The predicted relative flow capacity profile generated from the integrated log analysis results suggest that the most productive interval is at the bottom of the logged section, across the interval 918–960 ft bgs, coinciding with a very high porosity zone (possibly elevated due washouts behind the casing). Within this zone the most productive intervals are 924–936 ft, 944–949 ft, and 955–960 ft
5. The geophysical log results clearly delineate that the saturated/water-filled section of the borehole consists of alluvium/fanglomerate that extends well into the unsaturated section up to 680 ft bgs. Above 680 ft bgs the processed logs strongly indicate a change in the matrix geochemical makeup and lithology to a thick basaltic lava sequence, which extends up to 380 ft (it's possible the top is reworked/altered basalt). The geophysical log response in the zone 359 to 380 ft is characteristic of the Guaje Pumice Bed, with very high total porosity that decreases in the upward direction, and a large increase in thorium and uranium concentrations. The log results corroborate volcanic tuff overlying the pumice bed and extending to the top of the log interval (34 ft bgs), although it is possible the top section is alluvium composed of reworked tuff-like material.

2.0 INTRODUCTION

Geophysical logging services were performed in characterization well R-42 by Schlumberger in July 2008 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-42 were the

- Compensated Thermal/Epithermal Neutron Porosity (CNT-G*), which measures, through casing and in water or air-filled hole, volumetric water content of the formation to evaluate moist/porous zones using both epithermal and thermal neutron measurements;
- Triple Detector Litho-Density (TLD*) tool, which measures formation bulk density through casing to estimate total porosity;
- 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; and
- 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).

In addition, calibrated gross gamma ray (GR) was recorded with every service for the purpose of correlating depths between the different logging runs. Table 2.1 summarizes the geophysical logging runs performed in R-42.

Table 2.1
Geophysical logging services, their combined tool runs and intervals logged, as performed by Schlumberger in borehole R-42

Date of Logging	Borehole Status	Run #	Tool 1 (bottom)	Tool 2 (top)	Tool 3	Depth Interval (ft bgs)
19-July-2008	Steel free-standing casing from surface to bottom. Single string of 12 in. ID casing from surface to the bottom of the borehole at 1018 ft, with bit size of 12.75 in.	1	TLD	CNT		22-1015
	Same	2	HNGS	GR		29-1008
	Same	3	ECS	GR		34-1012

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?).

3.0 METHODOLOGY

This section describes the methods Schlumberger employed for geophysical logging of Well R-42, including the following stages/tasks:

- Measurement acquisition at the well site

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- Quality assessment of logs
- Reprocessing of field data

3.1 Acquisition Procedure

Once the well drilling project team notified Schlumberger that R-42 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 is 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/mast truck)
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/CNT-G 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.

3.2 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://www.hub.slb.com/index.cfm?id=id11618).

3.3 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 modeling through integrated log analysis. Afterwards, an integrated log montage was built to combine and compile all the processed log results.

3.3.1 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-42, the log measurements requiring these corrections are the CNT porosity, TLD bulk formation density, ECS elemental concentrations, and HNGS spectral gamma ray logs.

Two neutron porosity measurements are available from the CNT tool – one that measures thermal ("slow") neutrons and one that measures epithermal ("fast") neutrons. 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. The CNT measurements were reprocessed for casing, borehole fluid type (air versus water), and other environmental conditions. For further processing and analysis (e.g., integrated log analysis), the reprocessed neutron porosity was used.

The raw ECS elemental yield measurements include the contribution of iron from steel casing and hydrogen from fluid in the borehole. 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 419 ft and two strings above. At the time of the ECS logging in R-42 the borehole contained water from bottom to 826 ft; no hydrogen correction was required in the air-filled section above 826 ft and the difference between the hydrogen yield above and below this depth was used to determine the baseline borehole hydrogen correction to apply below.

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-42 were reprocessed to account, as best as possible, for the environmental effects of the casing, borehole fluid (water below 826 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 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.

3.3.2 Depth-Matching and Reference

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, as needed, using the gross gamma ray log, acquired in all the logging runs, for depth correlation. For R-42 all the logs were already on-depth, so no depth matching was required. The depth reference for field-print outs of logs was drill table height, but the depth reference for all processed logs, including those presented in this report, is ground surface.

3.3.3 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 (Mayer 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

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constituents at each depth based on the known log measurement responses to each individual constituent by itself[1]. 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-42 are provided in Table 3.1. The final results of the analysis – an optimized mineral-fluid volume model – are shown on the integrated log montage (see Attachment 1), 3rd 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 (35 to 1,000 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 3.1 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.

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 35 to 379 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, potassium feldspar, and augite, with accessory minerals calcite and pyrite). 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 379 to 680 ft bgs was assumed to be basaltic lava flows/material with a possible mineral suite of plagioclase and potassium feldspar, quartz, augite, hypersthene, heavy mafic minerals (such as magnetite), montmorillonite, and pyrite. The log interval 680 to 1,000 ft bgs was assumed to possibly be the Puye Formation, or fanglomerate/alluvium with 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, hypersthene, heavy mafic minerals, 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). Thus, the presence and amount of air in the pore space is unconstrained. Total porosity and water-filled porosity are also left unconstrained throughout the analysis interval, despite the obvious influence on the log response of borehole washouts and annular voids behind the casing. There is no way to objectively correct for the adverse effect on the log measurements from these borehole conditions; therefore the decision was made to perform the ELAN analysis so as to honor the log measurements. Accordingly,

[1]Mathematically this corresponds to an inverse problem – solving for constituent volume fractions from an (over)determined system of equations relating the measured log results to combinations of the tool measurement response to individual constituents.

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 3.1
Tool measurements, volumes, and respective parameters used in the R-42 ELAN analysis

Volume / Tool Measurement	Air	Water	Hypersthene	Labradorite	Silica Glass, Cristo., Tridy.	Heavy Mafic Minerals	Augite	Biotite	Pyrite	Orthoclase	Calcite	Quartz
Bulk density (g/cc)	–0.19	1.00	3.55	2.68	2.33	5.08	3.08	3.04	4.99	2.54	2.71	2.64
Epithermal neutron poro. (ft^3/ft^3)	0	1.00	0.012	-0.01	0.0	0.022	-0.01	0.14	0.165	-0.01	0.0	-0.05
Thermal neutron poro. (nonlinear) (ft^3/ft^3)	0	1.00	0.036	-0.01	-0.03	0.07	0.015	0.15	0.01	-0.01	0.0	-0.07
Dry weight silicon (lbf/lbf)	0.0	0.0	0.24	0.247	0.468	0.184	0.225	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	0.007	0.0	0.0	0.405	0.0
Dry weight iron (lbf/lbf)	0.0	0.0	0.20	0.023	0.0	0.22	0.112	0.199	0.466	0.015	0.0	0.0
Dry weight aluminum (lbf/lbf)	0.0	0.0	0.0	0.162	0.0	0.0	0.018	0.081	0.0	0.104	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	0.535	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	0.016	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	0.070	0.0	0.12	0.0	0.0
Weight hydrogen (lbf/lbf)	0.0	0.111	0.0	0.0	0.01	0.0	0.0	0.003	0.0	0.0	0.0	0.0
Wet weight thorium (ppm)	0	0	13.5	1.75	2	4	13.5	25	0	5	0	0

gAPI = gamma ray API (American Petroleum Institute) standard unit
ohm-m = ohm x meters
ft^3 = cubic feet
g/cc = grams per cubic centimeter
ppm = parts per million
lbf = pounds force

4.0 RESULTS

Preliminary results from the wireline geophysical logging measurements acquired by Schlumberger in R-42 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 4.1, 4.2, and 4.3); 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-42 are described below.

4.1 Well Fluid Level

The standing water level in R-42 (within the freestanding 12 in. ID casing) was stable during the July 19, 2008 logging, residing at 826 ft bgs. The various measurements from all three logging runs concurred on this well water level.

4.2 Regional Aquifer

The processed geophysical logs definitively indicate fully-water saturated conditions exist below 918 ft bgs, although water content and estimated water saturation are relatively high up to 763 ft (see porosity summary display in Figure 4.1 or integrated log montage in Attachment 1). The estimated pore volume water saturation (fraction of the total pore volume containing water) computed from the ELAN analysis is primarily 100% below 918 ft. Above this depth, water content and water saturation decreases. However, the ELAN water saturation remains mostly above 50%, reaching 100% in some intervals, from 763 to 918 ft. There is a definitive decrease in water content and saturation above 763 ft.

The ELAN estimated water content is notably higher below 763 ft than above. Directly above 763 ft the water content is less than 5% while directly below it reaches 27% (defined as fraction of the total rock volume containing water). From 775 to 825 ft the water content averages about 15%, increasing below 825 ft, varying between 10% and 35% down to a depth of 917 ft. Estimated water content increases dramatically below 917 ft, averaging 50% down to a depth of 961 ft, below which it decreases sharply to about 30% down to 1,000 ft (bottom of log interval).

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 definitely no deeper than 918 ft, where the results clearly indicate full saturation and high water content, but could possibly be as high as 763 ft, above which there is a distinct decrease in water content. A specific depth of the Regional Aquifer water level cannot be conclusively determined based on these log results, although they do constrain the depth to between 763 and 918 ft.

The predicted relative flow capacity profile generated from the ELAN integrated log analysis results (derived by integrating the hydraulic conductivity log and normalizing to one) potentially provides information about the depth and relative productivity of more permeable intervals within the logged

interval. The flow profile logs (computed from two hydraulic conductivity estimates) suggest that the most productive zone is near the bottom of the logged section, across the interval 918–960 ft bgs, coinciding with a very high porosity zone (possibly elevated due washouts behind the casing). Within this zone the most productive intervals are 924–936 ft, 944–949 ft, and 955–960 ft (see porosity summary display in Figure 4.1 or integrated log montage in Attachment 1).

4.3 Vadose Zone Perched Water

As mentioned above, the depth to the top of the Regional Aquifer and, thus, the extent of the vadose zone is not entirely certain from the geophysical logs, but definitely extends above 763 ft bgs. Above this depth to the top of the logged section (34 ft) the estimated water content varies from less than 5% to 20%, mostly remaining below 10%. It is important to note that the low water content from 727 to 763 ft correlates with unrealistically high density porosity (as high as 80%), which indicates large voids (washouts) behind casing, likely resulting in a lower water content than is representative of the formation. In a number of intervals the water content and, correspondingly, water saturation increases, including 655–680 ft, 606–634 ft, 539–546 ft, 354–390 ft, 100–174 ft, 65–88 ft, and 30–45 ft (see porosity summary display in Figure 4.1 or integrated log montage in Attachment 1). Estimated water saturation reaches to over 40% in the following zones:

- 627–678 ft, located in the bottom part of a likely thick basalt lava sequence that has significantly lower estimated total porosity than the surrounding rock (presumably the basalt is more competent here)
- 475–521 ft, located in the middle of the same basalt lava sequence where the total porosity is a lot lower than the surrounding rock
- 378–388 ft, likely located at the top of the same basalt lava that lies immediately below the Guaje Pumice bed, perhaps where the basalt is eroded and/or re-worked

4.4 Geology

The processed geophysical log results, particularly the matrix geochemistry logs, provide information on lithology and potential formation contacts intersected by R-42 across the log interval (from 35 to 1,000 ft bgs). The generalized geologic stratigraphy observed from the logs across the measured interval is as follows (depth below ground surface):

- **<u>50–78 ft bgs</u>: Relatively high porosity silicon and thorium rich volcanic tuff or alluvium** – characterized by high total porosity (28–38% of total rock volume); high silica glass/tridymite/cristobalite content; moderate potassium feldspar content; varying minor to moderate amounts of quartz and augite (or similar minerals) and calcite (or other calcium-bearing minerals); and trace amounts of pyrite (or other sulfur-bearing minerals)
- **<u>78–100 ft bgs (top of processed log interval)</u>: Very high porosity silicon and thorium rich volcanic tuff or alluvium** – characterized by very high total porosity (50% of total rock volume); high silica glass/tridymite/cristobalite content; minor to moderate amounts of potassium feldspar, quartz and augite (or similar minerals) and calcite (or other calcium-bearing minerals)
- **<u>100–155 ft bgs</u>: High porosity silicon and thorium rich volcanic tuff or alluvium** – characterized by high total porosity (35–44% of total rock volume); high silica glass/tridymite/cristobalite content; moderate potassium feldspar content; varying minor to

moderate amounts of quartz and augite (or similar minerals) and calcite (or other calcium-bearing minerals); and trace amounts of pyrite (or other sulfur-bearing minerals)

- **155–238 ft bgs: Very high porosity silicon rich volcanic tuff** – characterized by very high total porosity (40–55% of total rock volume, but possibly associated with voids behind casing); high silica glass/tridymite/cristobalite content; moderate potassium feldspar content; varying minor amounts of quartz and augite (or similar minerals) and calcite (or other calcium-bearing minerals); and trace amounts of pyrite (or other sulfur-bearing minerals)

- **238–359 ft bgs: High porosity silicon rich volcanic tuff** – characterized by high total porosity (34–46% of total rock volume); high silica glass/tridymite/cristobalite content; moderate potassium feldspar content; varying minor to moderate amounts of quartz and augite (or similar minerals) and calcite (or other calcium-bearing minerals); and trace amounts of pyrite (or other sulfur-bearing minerals)

- **359–380 ft bgs: Very high porosity silicon rich volcanic tuff/pumice** – characterized by very high total porosity (45–53% of total rock volume); high silica glass/tridymite/cristobalite content; moderate potassium feldspar content; varying minor to moderate amounts of quartz and augite (or similar minerals) and calcite (or other calcium-bearing minerals); and trace amounts of pyrite (or other sulfur-bearing minerals)

- **380–388 ft bgs: Quartz and plagioclase feldspar rich volcanics (likely basalt)** – characterized by potentially high total porosity (34–44%); high quartz and plagioclase feldspar; variably minor to moderate alkali feldspars and augite (or similar mineral) content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **388–470 ft bgs: Very high porosity plagioclase feldspar and pyroxene rich volcanics (likely basalt)** – characterized by potentially very high to unrealistically high total porosity (40 to greater than 60%, the highest likely elevated due to voids behind the casing); high plagioclase feldspar content; varying moderate to high quartz and augite (or similar mineral) content; minor alkali feldspar content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **470–520 ft bgs: Plagioclase feldspar and pyroxene rich volcanics (likely basalt)** – characterized by low to moderate total porosity (11–28%); high plagioclase feldspar content; moderate augite content (or similar mineral); variably minor to moderate alkali feldspars and quartz content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **520–628 ft bgs: Very high porosity plagioclase feldspar and pyroxene rich volcanics (likely basalt)** – characterized by potentially very high to unrealistically high total porosity (25 to greater than 60%, the highest likely elevated due to voids behind the casing); high plagioclase feldspar content; varying moderate to high quartz and augite (or similar mineral) content; minor alkali feldspar content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **628–642 ft bgs: Plagioclase feldspar and pyroxene rich volcanics (likely basalt)** – characterized by low to moderate total porosity (15–25%); high plagioclase feldspar content; moderate augite content (or similar mineral); variably minor to moderate alkali feldspars and quartz content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **642–653 ft bgs: Low porosity plagioclase feldspar and pyroxene rich volcanics (likely basalt)** – characterized by low to moderate total porosity (8–15%); high plagioclase feldspar content; moderate augite content (or similar mineral); variably minor to moderate alkali feldspars and quartz content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **653–680 ft bgs: Plagioclase feldspar and pyroxene rich volcanics (likely basalt)** – characterized by high total porosity (25–45%); high plagioclase feldspar content; moderate augite content (or similar mineral); variably minor to moderate alkali feldspars and quartz content; and variably trace to small amounts of hypersthene, pyrite and/or heavy mafic minerals

- **680–762 ft bgs: Very high porosity, silicon-rich alluvium/fanglomerate** – characterized by potentially very high total porosity (45 to greater than 60%, the highest likely elevated due to voids behind the casing); high silica glass/tridymite/cristobalite or quartz content and potassium feldspar; moderate plagioclase and potassium feldspar content; varying minor augite, hypersthene, and calcite content (or other calcium-bearing minerals); variably trace to minor amounts of biotite and/or heavy mafic minerals

- **762–779 ft bgs: Silicon-rich alluvium/fanglomerate** – characterized by high total porosity (25–40%); high silica glass/tridymite/cristobalite or quartz content and potassium feldspar; moderate plagioclase and potassium feldspar content; varying minor augite, hypersthene, and calcite content (or other calcium-bearing minerals); variably trace to minor amounts of biotite and/or pyrite

- **779–897 ft bgs: High porosity, silicon-rich alluvium/fanglomerate** – characterized by high total porosity (18–40%); high silica glass/tridymite/cristobalite or quartz content and potassium feldspar; moderate plagioclase and potassium feldspar content; varying minor augite, hypersthene, and calcite content (or other calcium-bearing minerals); variably trace to minor amounts of biotite and/or pyrite

- **897–918 ft bgs: High porosity, silicon-rich alluvium/fanglomerate** – characterized by very high total porosity (average 40%); high silica glass/tridymite/cristobalite or quartz content and potassium feldspar; moderate plagioclase and potassium feldspar content; varying minor augite, hypersthene, and calcite content (or other calcium-bearing minerals); variably trace to minor amounts of biotite and/or pyrite

- **918–952 ft bgs: Very high porosity, silicon-rich alluvium/fanglomerate** – characterized by potentially very high total porosity (42 to greater than 60%, the highest likely elevated due to voids behind the casing); high silica glass/tridymite/cristobalite or quartz content and potassium feldspar; moderate plagioclase and potassium feldspar content; varying minor augite, hypersthene, and calcite content (or other calcium-bearing minerals); variably trace to minor amounts of biotite and/or pyrite

- **952–1,000 ft bgs (bottom of log interval): Silicon-rich alluvium/fanglomerate** – characterized by moderate to high total porosity (23–40%); high silica glass/tridymite/cristobalite or quartz content and potassium feldspar

4.5 Summary Logs

Three summary log displays have been generated for R-42 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 4.1)

- 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 4.2)

- Spectral natural gamma ray 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 key lithologic/stratigraphic correlation logs from the spectral gamma ray measurement (concentrations of gamma-emitting elements); highlights the geologic lithology, stratigraphy, and correlation information obtained from the log results (Figure 4.3)

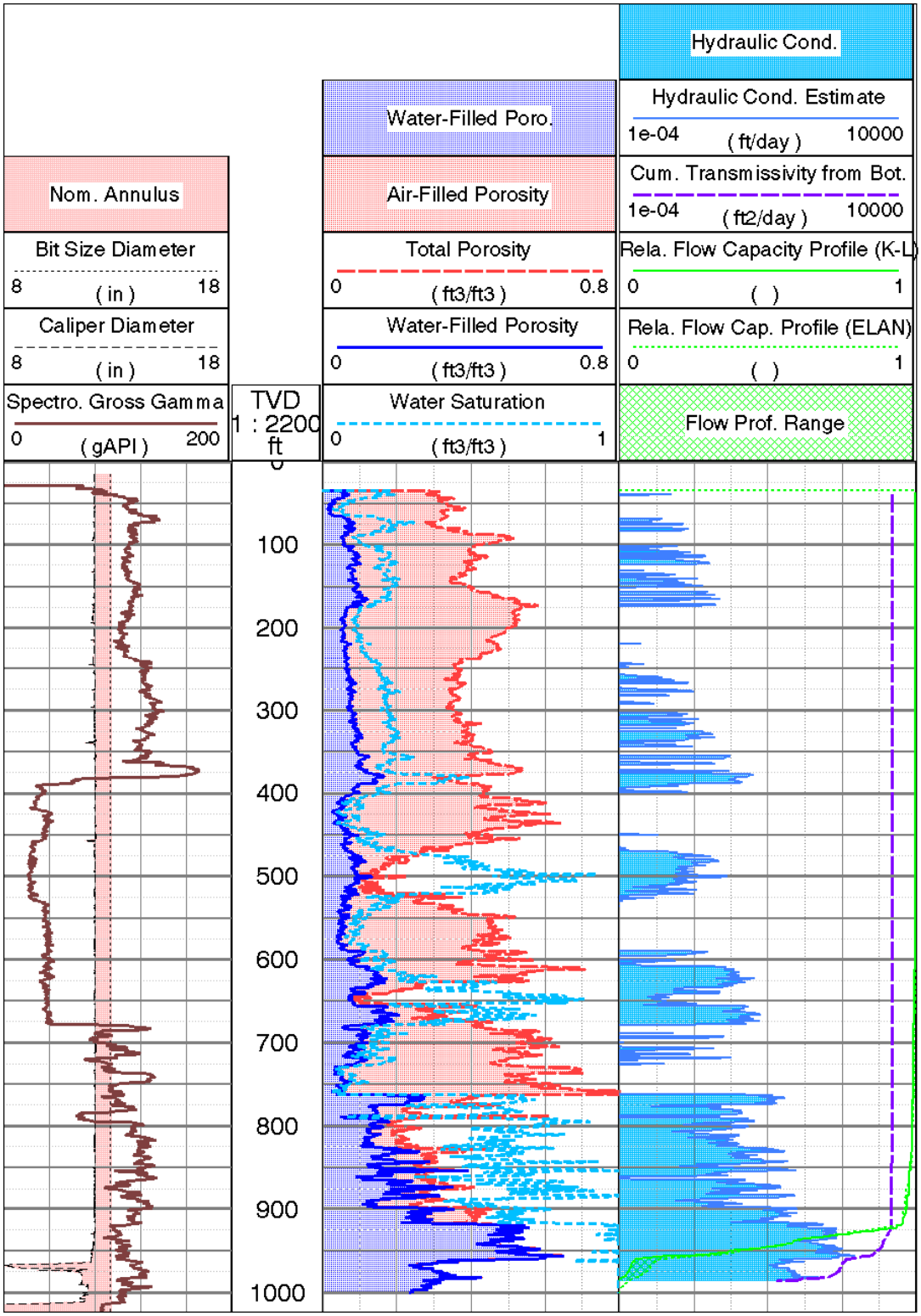

Figure 4.1. Summary of porosity logs in R-42 borehole from processed geophysical logs, interval of 34 to 1,000 ft bgs, with caliper, gross gamma, water saturation, estimated relative flow capacity profile, hydraulic conductivity, and transmissivity logs also displayed. Porosity, water saturation, and hydraulic conductivity logs are derived from the ELAN integrated log analysis.

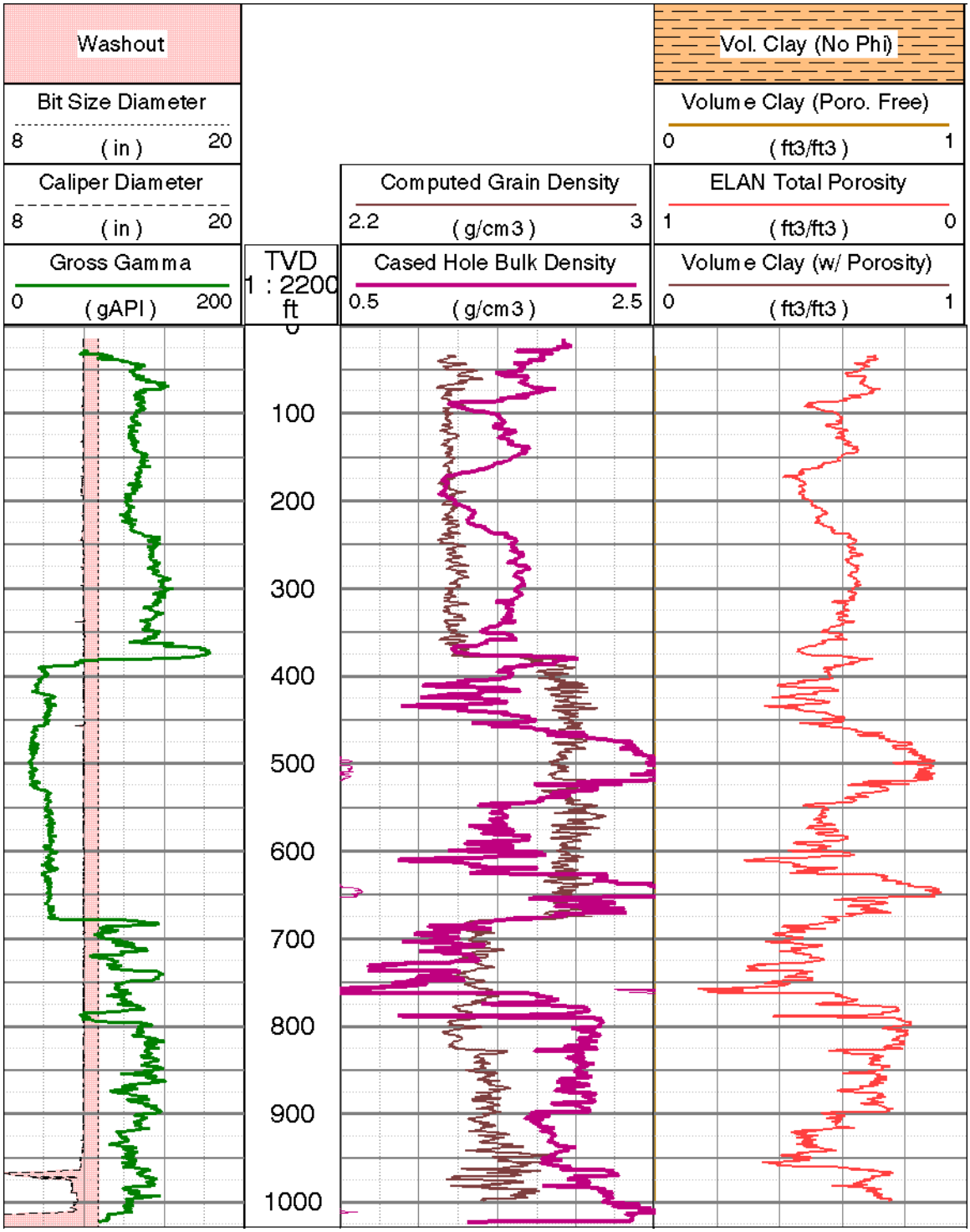

Figure 4.2. Summary of bulk density and apparent grain density logs in R-42 borehole from processed geophysical logs, interval of 22 to 1,020 ft bgs. Also shown are caliper, gross gamma, volume of clay, and total porosity logs (the latter two derived from the ELAN analysis – note that clay was not solved for and thus is zero throughout).

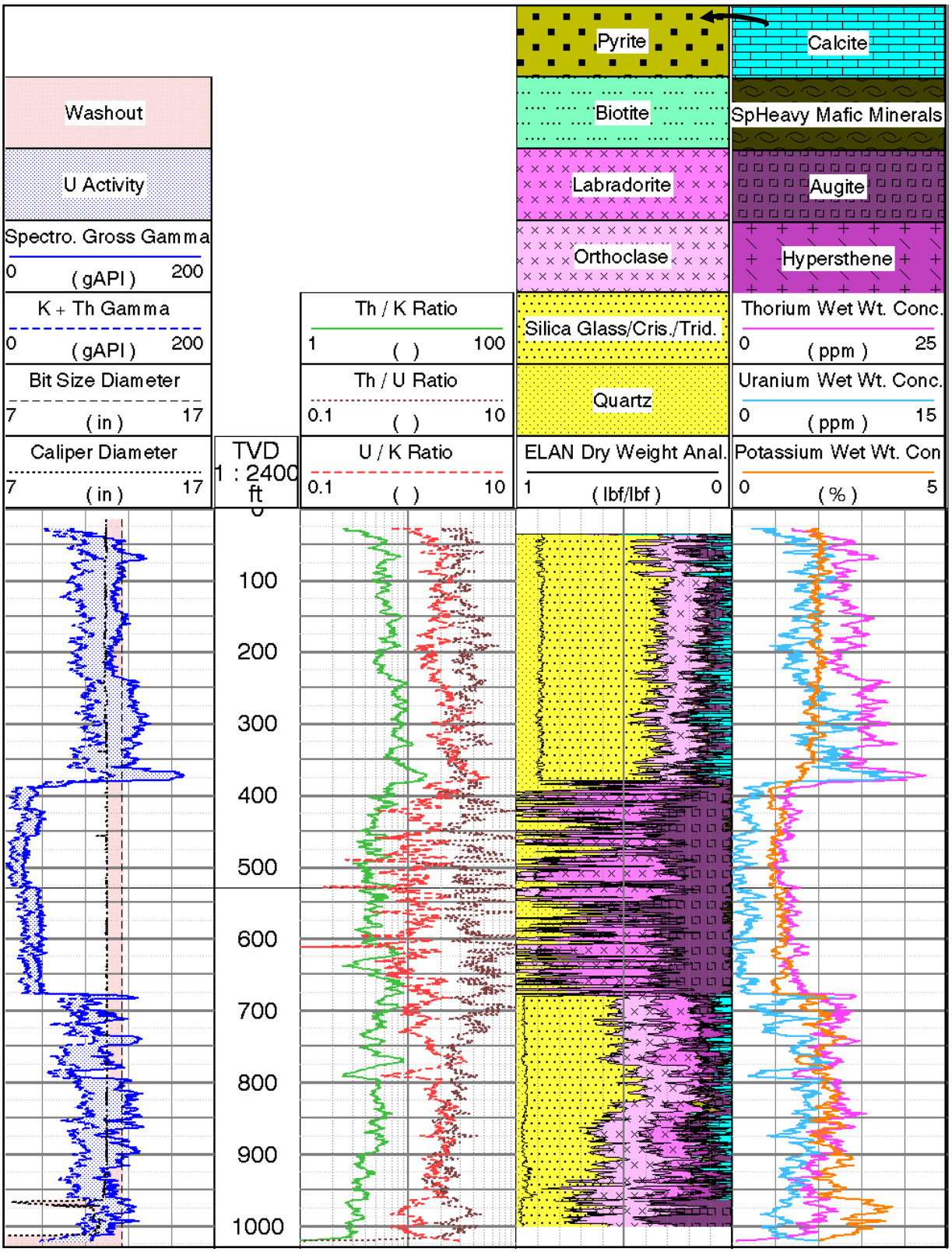

Figure 4.3. Summary of spectral natural gamma ray logs and ELAN mineralogy/lithology and pore fluid model volumes derived from the ELAN integrated log analysis for R-42 borehole, interval 30 to 1,020 ft bgs. Caliper log is also shown.

4.6 Integrated Log Montage

This section summarizes the integrated geophysical log montage for R-42. 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-42 geophysical logs are provided in the previous section

4.6.1 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 HNGS logging run. All the geophysical logs are depth-matched to the gross gamma log acquired with this logging run.

4.6.2 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 200 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 8 to 18 in.

Two gamma ray curves from the HNGS are displayed:

- total gross gamma (thick solid black curve with thinner dashed black curve as backup representing the uncorrected SGT gamma ray displayed on a scale to match the corrected HNGS gamma)
- 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.

4.6.3 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

- CNT epithermal neutron porosity (bold solid light blue curve) – processed for zoned air-filled and water-filled cased hole;
- CNT water-filled resolution enhanced thermal neutron porosity (solid dark blue curve) – thermal neutron porosity valid only in the fluid-filled borehole;
- ECS bulk volumetric water content derived from hydrogen weight concentration measurement, corrected for water in casing and converted to volume fraction (short-dashed sky blue);

- Total porosity derived from bulk density and ELAN water-filled porosity using a grain density of 2.45/2.65 g/cc (dashed red curve), 2.55/2.75 g/cc (long-dashed red curve), and 2.65/2.85 g/cc (dotted red curve)–with red shading between the 2.45/2.65 g/cc and 2.65/2.85 g/cc porosity curves to show the range (the lowest grain density range used across the tuff/pumice interval [34–374 ft] and alluvium/fanglomerate interval [674–1,000 ft], and the highest grain density range used across the basalt interval [374–674 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.

4.6.4 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 1 to 3 g/cc;
- apparent grain density (dashed brown curve), derived from the ELAN analysis, on a scale of 2.4 to 3.2 g/cc.

4.6.5 Track 5–HNGS Spectral Gamma

The fifth track from the left displays the spectral components of the HNGS measurement results as wet weight concentrations, corrected as best as possible for casing and borehole size and fluid:

- potassium (solid green curve) in units of percent weight fraction and on a scale of -5% to 5%;
- thorium (dashed brown) in units of parts per million (ppm) and on a scale of 25 to -25 ppm; and
- uranium (dotted blue) in units of parts per million (ppm) and on a scale of 20 to 0 ppm.

4.6.6 Tracks 6 to 11 – Geochemical Elemental Measurements

The narrow tracks 6 to 11 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 (H) and apparent relative bulk chlorinity (Rela. Cl), and uranium (U) and carbon yield (C Yield) — from left to right respectively, in units of dry matrix weight fraction (except K and H in wet-weight fraction, Rela. Cl in ppk, U in wet-weight ppm, and C Yield in relative yield units).

4.6.7 Track 12 – ELAN Mineralogy Model Results (Dry Weight Fraction)

Track 12 displays the results from the ELAN integrated log analysis (the matrix portion)–presented as dry-weight fraction of mineral types chosen in the model:

- 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 plagioclase feldspar (pink)

- Biotite (light green)
- Pyrite (orange-tan with black squares)
- Hypersthene (purple)
- Augite (maroon)
- Heavy mafic/ultramafic minerals, such as magnetite or olivine (dark green)
- Calcite (cyan)

4.6.8 Track 13–ELAN Mineralogy and Pore Space Model Results (Wet Volume Fraction)

Track 13 displays the results from the ELAN integrated log analysis–presented as wet mineral and pore fluid volume fractions:

- 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 plagioclase feldspar (pink)
- Biotite (light green)
- Pyrite (orange-tan with black squares)
- Hypersthene (purple)
- Augite (maroon)
- Heavy mafic/ultramafic minerals, such as magnetite or olivine (dark green)
- Calcite (cyan)
- Air (red)
- Water (white)
- Moved air (orange)
- Moved water (blue)

4.6.9 Track 14–Water Saturation

Track 14 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 [ft^3/ft^3]) and presented on a scale of 0 to 1 ft^3/ft^3 (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 2.45/2.65 g/cc (dashed cyan curve), 2.55/2.75 g/cc (solid cyan curve), and 2.65/2.85 g/cc (dotted cyan curve) – with stippled cyan shading between the 2.45/2.65 g/cc and 2.65/2.85 g/cc water saturation curves to show the range (the lowest grain density range used across the tuff/pumice interval [34–374 ft] and alluvium/fanglomerate

interval [674–1,000 ft], and the highest grain density range used across the basalt interval [374–674 ft]).

4.6.11 Track 15–Hydraulic Conductivity

Track 15 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):

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

In addition, estimates of cumulative transmissivity from the bottom of the log interval are displayed for the k-Lambda estimator (bold dashed-dotted bright green curve) and the ELAN mineral-based estimator (dashed dark green curve) – computed by integrating from bottom to top the hydraulic conductivity estimates, presented on a logarithmic scale of 10^{-5} to 10^{5} feet squared per day (ft^2/day).

4.6.12 Track 16–Predicted Flow (Production Potential) Profile

Track 16 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 (bold solid blue curve), 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 (long-dashed blue), 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;
- Predicted hypothetical well water flow versus depth profile for the entire log interval (dotted green), assuming a well radius of 4 in., entirely open to flow, and pumping is occurring under steady state conditions with a drawdown of 25 ft (incremental flow computed using the Thiem steady state flow equation) – derived from the k-Lambda water permeability log (bold solid blue), displayed on a scale of 0 to 250,000 gallons per day (gal/day).

4.6.13 Track 17–Summary Logs

Track 18, 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 intergranular water (non-clay bound 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 (solid red curve and dotted red area shading);and
- Estimate of bulk volumetric water content from the ECS tool (thin dashed dark blue curve).

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

4.6.14 Track 18–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 HNGS logging run.

5.0 REFERENCES

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