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REVISION 1
WELL R-2 COMPLETION REPORT
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
PROJECT NO. 37151/TASK 6.12
DOCUMENT NO. ALB04RP001

Prepared for:

The United States Department of Energy and the
National Nuclear Security Administration through the
United States Army Corps of Engineers
Sacramento District

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LIST OF ACRONYMS AND ABBREVIATIONS

AITH	array induction tool, version H
ASTM	American Society for Testing and Materials
bgs	below ground surface
°C	degrees Celsius
CD	compact disc
CMR™	Combinable Magnetic Resonance
CNTG	compensated neutron tool, model G
CQMP	Contractor Quality Management Plan
DH	down hole
DOE	United States Department of Energy
DP	Drilling Plan
DTH	down-the-hole
DTW	depth to water
DVD	digital video disc
EES	Earth and Environmental Sciences
EnviroWorks	EnviroWorks, Inc
FMI	formation microimager
FMU	Facility Management Unit
ft	feet
FTA	Facility Tenant Agreement
gal	gallon
GPS	global positioning system
g	grams
hp	horsepower
hr	hour
HSA	hollow-stem auger
ID	inner diameter
in	inches
ISE	Ion Selective electrode
KA	Kleinfelder, Inc.
KBr	potassium bromide
Kg	Kilograms
LANL	Los Alamos National Laboratory
LC/MS	Liquid Chromatography/Mass Spectrometry
MDL	Method Detection Limit
mil	1/1000 of an inch
mL	milliliters
NAD	North American Datum
NGS	natural gamma spectroscopy
NGVD	National Geodetic Vertical Datum
NMED	New Mexico Environment Department
NOI	Notice of Intent
NTU	nephelometric turbidity unit
OD	outer diameter
PI	Principal Investigator

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

PMP	Project Management Plan
psi	pounds per square inch
PVC	polyvinyl chloride
SAP	sampling and analysis plan
SSHASP	Site-Specific Health and Safety Plan
TA	technical area
TD	total depth
TDS	Total Dissolved Solids
TLD	triple detector lithodensity
USACE	United States Army Corps of Engineers
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
WDC	WDC Exploration & Wells

ABSTRACT

Well R-2 was installed at Los Alamos National Laboratory (LANL) for LANL's Groundwater Protection Program as part of the "Hydrogeologic Workplan" (LANL 1998, 59599). The Department of Energy (DOE) contracted and directed the installation of Well R-2. The well is intended to provide hydrogeologic and water quality data for regional groundwater in the vicinity of potential contaminant sources in Pueblo Canyon. The data will be used with similar data from other wells in the area to improve the conceptual model for geology, hydrogeology, and hydrochemistry in these canyons and provide constraints on numerical models that address contaminant migration in the vadose (unsaturated) zone and the regional aquifer.

Pueblo Canyon contains active and inactive potential contaminant sources derived from LANL. Well R-2 is located downgradient of Acid Canyon, which received radioactive liquid releases from TA-45. At Well R-2, the fieldwork was conducted from September 4, 2003 through March 5, 2004.

Phase I of the fieldwork was conducted from September 16 to September 30, 2003, and consisted of drilling a corehole to collect continuous core for geochemical analysis, contaminant profiling and identification of perched water zones. Phase I included collecting continuous core from the surface to a depth of 241.0 feet (ft) below ground surface (bgs). No perched water zones were identified during drilling.

Phase II of the fieldwork was performed from October 10 to October 16, 2003. In Phase II drilling, a borehole was drilled to a depth of 944 ft bgs using fluid-assisted air-rotary and mud-rotary methods. Well R-2 was installed in the regional aquifer and sampled for water quality. Samples of drill cuttings were collected at regular intervals for stratigraphic, petrographic, and geochemical analysis. The stratigraphy encountered during borehole drilling included, in descending order, alluvium, ash-flow tuffs of the Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed of the Otowi Member, Puye Formation sediments, unassigned pumiceous sediments, and unassigned fanglomerates. The R-2 well screen was installed in the regional aquifer from 906.4 ft to 929.6 ft bgs. Two groundwater samples were collected and submitted to LANL for analysis of organic, inorganic and radiochemical compounds. A constant rate pumping test was conducted at Well R-2.

1.0 INTRODUCTION

This completion report summarizes the drilling, well construction, well development, and related activities conducted from September 4, 2003 to March 5, 2004 for Well R-2 (R-2). R-2 was drilled and installed for LANL's Groundwater Protection Program as part of the "Hydrogeologic Workplan" (LANL 1998, 59599). The R-2 investigation was funded and directed by the Department of Energy (DOE). Kleinfelder, Inc. (KA), under contract to the US Army Corps of Engineers (USACE), was responsible for executing the drilling, installation, testing, and sampling activities.

The information presented in this report was compiled from field reports and activity summaries generated by KA, LANL and subcontractor personnel. Results of these activities are discussed briefly and shown in tables and figures contained in this report. Detailed analysis and interpretation of geologic, geochemical, and hydrologic data will be included in separate technical documents prepared by LANL.

R-2 is designed to provide water quality and water level monitoring data from the regional aquifer downgradient of potential contaminant sources in Pueblo Canyon as shown in Figure 1.0-1. Data from R-2 will be evaluated in conjunction with data from other hydrogeologic work plan wells. The evaluation will form the technical basis for the design of a groundwater monitoring system, if needed. Water quality, geochemical, hydrologic, and geologic information obtained from R-2 will augment knowledge of regional subsurface characteristics and distribution of contaminants downgradient of potential release sites.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities at R-2 included administrative and site preparation.

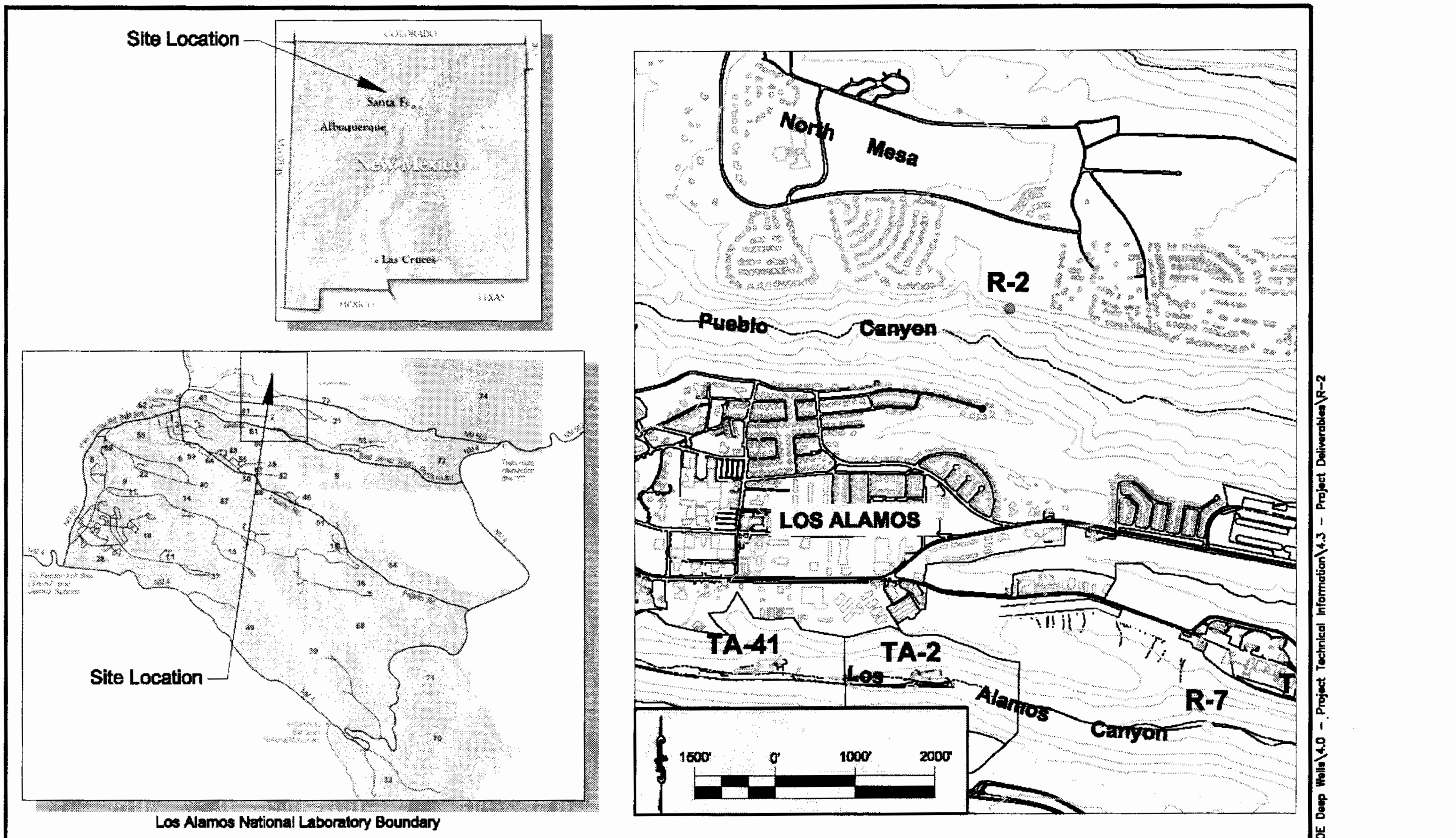
2.1 Administrative Preparation

KA received contractual authorization to start administrative preparation tasks in the form of a notice to proceed on July 11, 2003. As part of this preparation, KA developed a Project Management Plan (PMP), a Contractor's Quality Management Plan (CQMP), a Site-Specific Health and Safety Plan (SSHASP), a traffic control plan, and a Drilling Plan (DP) for the work at R-2. The host facility signed a Facility-Tenant Agreement (FTA) to provide access and security controls for site preparation, drilling and well installation activities. Necessary permits and access agreements were obtained prior to beginning fieldwork.

2.2 Site Preparation

EnviroWorks, Inc. (EnviroWorks) was subcontracted by KA to conduct site preparation. Activities included site clearing, access road improvement, construction of the drill pad, and construction of a lined borehole-cuttings containment area. Site preparation was begun on September 4, 2003 and completed on September 23, 2003.

The R-2 site was initially cleared of vegetation. The drilling pad was developed by grading an area with a front-end loader. A primary layer of base-course gravel was distributed over the drill pad, equipment storage area and on the access road, as necessary. Drill pad construction was completed with an additional graded layer of base-course gravel. To store R-2 drilling fluids and borehole cuttings, two (2) 20 cubic yard roll-off containers and four (4) 3,000 gallons (gal)



Los Alamos National Laboratory Boundary

● R-2 Characterization Well   Existing R Characterization Wells

Note: R-2 Well Identification Modified from Proposed R Characterization Well Location Map Provided by Los Alamos National Laboratory

KLEINFELDER		SITE LOCATION MAP Well R-2 Location LANL Well Program Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 1.0-1
Drawn By: C. Landon	Date: March 2004		
Project No.: 37151	Filename: FIGURE 1.0-1		
Scale: 1" = 2000'	Revision: 0		

L:\2003\Projects\37151 DOE Deep Wells\4.0 – Project Technical Information\4.3 – Project Deliverables\R-2 polyethylene tanks were located on the southwest portion of the site. Safety barriers and signs were installed around the borehole-cuttings containment area. Office and supply trailers, generators, and safety lighting equipment were moved to the site during subsequent mobilization of drilling equipment.

Sediment from site preparation work was controlled on-site through the use of silt fences and bales of hay. In accordance with the 401/404 permit that was issued for the project, no sediments were added to the nearby stream channel.

Potable water was trucked to the R-2 site from the municipal (Pajarito Mesa Well Field) supply water and stored in a water tank near the drilling site. A sample of the potable water was collected and submitted for background analysis.

No disturbance occurred to the Hoodoos located upgradient of the site. Additionally, operations were coordinated with the county to provide continuous access to the area surrounding the drill site.

3.0 SUMMARY OF DRILLING ACTIVITIES

Drilling activities at the R-2 site were completed in two phases during September and October 2003.

Phase I core drilling at R-2 was performed from September 16 to September 26, 2003. The objective of Phase I was to collect continuous rock core samples for geologic characterization and determination of moisture, anion, stable isotope, radionuclide, metals, and tritium distributions in the upper part of the geologic section. The core was to be visually examined for lithologic descriptions and to determine geologic unit contacts. Additionally, groundwater samples were to be collected from significant perched water zones, if encountered. Planned corehole total depth (TD) ranged from 200 ft to 300 ft bgs, or up to 155 ft below the top of the Puye Formation.

Phase II borehole drilling was performed from October 11 to October 16, 2003. Phase II objectives were to collect cuttings of geologic formations, collect groundwater samples from significant perched water and the regional aquifer, and provide a borehole for geophysical logging and installation of a single-screen monitoring well in the regional aquifer. The planned TD of the R-2 borehole was approximately 910 ft bgs or to approximately 100 ft below the top of the regional water table.

Phase I and II drilling activities were performed generally in one 12-hour shift per day, 7-days per week by the drill crew and two site geologists.

Figure 3.0-1 summarizes well data and graphically depicts groundwater and geologic conditions encountered during core and borehole drilling at R-2. Table 3.0-1 is a chronology of drilling and other on-site activities. Sections 3.1 and 3.2 discuss specific Phase I and Phase II drilling activities, respectively.

Location: Upper Pueblo Canyon,
Los Alamos County Property

Description: Brass Marker
Northing: Survey to be performed Spring 2004
Easting: Survey to be performed Spring 2004
Elevation: Survey to be performed Spring 2004

Description: Well Casing
Northing: Survey to be performed Spring 2004
Easting: Survey to be performed Spring 2004
Elevation: Survey to be performed Spring 2004

Description: Core Hole
Northing: Survey to be performed Spring 2004
Easting: Survey to be performed Spring 2004
Elevation: Survey to be performed Spring 2004

Coring:
(0' - 39') Auger with Continuous Sampler
(39' - 241') Auger with Split Spoon

Drilling:
(0' - 40') 13-3/8" Air Rotary Casing Hammer
(40' - 944') 12-1/4" Milltooth Tri-Cone
(40'-143') Air
(143'-403') Fluid Assisted Air Rotary
(403'-944') Mud Rotary

Data Collection:
- Hydrologic Properties:
  Constant Discharge Pumping Test: 01/07/04 - 01/13/04
- Cores/Cuttings submitted for geochemical and contaminant characterization: 12
- Groundwater Samples Submitted
  Perched Groundwater - none encountered
  Regional Groundwater -
  - Screening Samples: none; mud filled borehole
  - Well Samples: 12/11/03
    01/13/04
- Geologic Properties:
  Cuttings collected for mineralogy, petrography, and chemistry: 7

Borehole Logs:
- Lithologic: 0' - 944'
- Video (LANL tool): none
- Schlumberger logs: mud filled borehole
  Compensated Neutron Log:
  Cased: 20'-40', Open Hole: 40'-941'
  Triple Litho-Density:
  Cased: 20'-40'; Open Hole: 40'-941'
  Array Induction Imager:
  Cased: 20'-40'; Open Hole: 40'-936'
  Elemental Capture Sonde:
  Cased: none, Open Hole: 50'-937'
  Natural GR Spectroscopy:
  Cased: 20'-40'; Open Hole: 40'-919'
  Combinable Magnetic Resonance:
  Cased: none; Open Hole: 50'-919'
  Fullbore Formation Micro Imager:
  Cased: none; Open Hole: 50'-937'

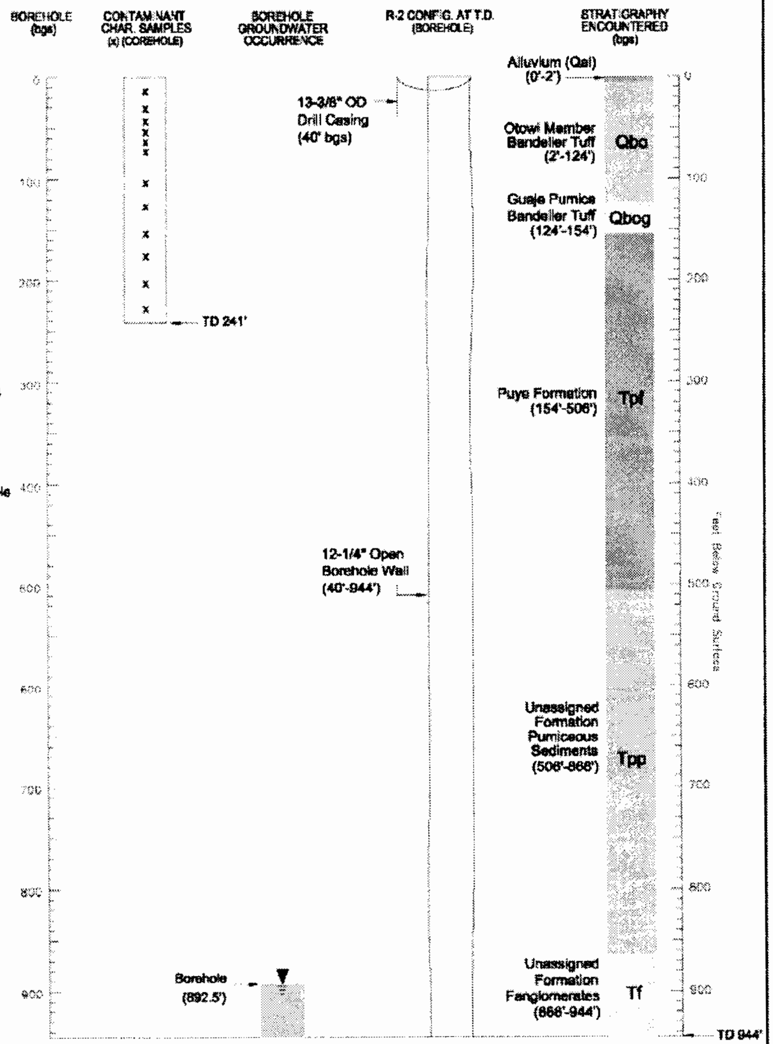
Corehole Logs:
- Lithologic: 0' - 241'
- Video (LANL Tool): none

Core Drilling Completed: 9/16/03 - 9/26/03
Rotary Drilling Completed: 10/10/03 - 10/16/03
Contract Geophysics: 10/17/03 & 10/18/03
Well Installation: 10/19/03 - 10/22/03
Well Development Completed: 10/23/03 - 10/28/03
11/17/03 - 11/24/03
12/01/03 - 12/11/03

- Casing:
  4.5" I.D. / 5.0" O.D. A304 Stainless Steel casing with external couplings
- Screen Type:
  One (1) 4.46" I.D./5.27" O.D. wire wrapped stainless steel rod-based 0.020 slot screen with external couplings.
- Screen Interval: 906.4' - 929.6'

Well Development performed by airlifting, bailing/swabbing, and pumping.
Total Volume Purged: 17,303 gallons

Geologic contacts for R-2 were determined from core samples, cuttings, and geophysical logs.



Keyed Notes:

1. Coordinates - NM State Plane Grid Central Zone (North America) Datum - 1983 (NAD83); expressed in feet.
2. Elevations - National Geodetic Vertical Datum (NGVD 29), expressed in feet above mean sea level.
3. Surface completion and surveying pending.
4. All depths are below ground surface (bgs).
5. Groundwater level measured after well development - 10-28-03
6. Drill casing removed prior to well installation
7. Three well development intervals were due to scheduling requirements and aquifer characteristics.

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Drawn By: C. London	Date: March 2004
Project No.: 37151	Filename: Figure 3.0-1
Scale: Not-To-Scale	Revision: 0
Reviewed By: F. Schelby	Approved By: M. Everett

Well Summary Data Sheet
For Well R-2
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
3.0-1

Table 3.0-1
Operations Chronology Graph for R-2

TASK DESCRIPTIONS	DATE						
	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04
SITE PREPARATION ACTIVITIES	9/4 9/23						
COREHOLE DRILLING AND SAMPLING	9/16 9/30						
Mobilization	9/16						
Continuous Coring	9/16 9/26						
Plug & Abandon Corehole	9/29-30						
BOREHOLE DRILLING AND SAMPLING		10/10-16					
Mobilization		10/10					
Air-Rotary		10/11					
Fluid Assisted Air-Rotary		10/12					
Mud-Rotary		10/13-16					
BOREHOLE GEOPHYSICS		10/17-18					
Schlumberger Logging		10/17-18					
WELL DESIGN AND CONSTRUCTION		10/19-22					
WELL DEVELOPMENT		10/23-28	11/17-24	12/1-11			
GROUNDWATER WELL SAMPLING				12/11	1/13		
HYDROLOGIC TESTING					1/7-13		
SITE RESTORATION						2/04 - 3/04	

3.1 Phase I Drilling Activities

On September 16, 2003, KA mobilized the StrataStar SS15 hollow-stem auger (HSA) drill rig and support equipment to the R-2 site. Core drilling was performed with 8-in. OD HSA. Sampling was conducted using a conventional 5-ft.-long core barrel in drilling through alluvium and the upper section of the Otowi Member of the Bandelier Tuff to 39 ft bgs.

From 39 ft to 195 ft bgs samples were collected from the Otowi Member of the Bandelier tuff, Guaje Pumice Bed and Puye Formation using a 1.5-ft-long, hammer-driven split-spoon sampler. Core samples from the Guaje Pumice Bed, (129 ft to 142.5 ft bgs), appeared to be wet. Drilling was stopped to allow groundwater to collect in the corehole. Attempts to measure a water level at depths of 129.8 ft and 136.5 ft bgs, respectively, produced no response from the electric water-level sounder. No water accumulated in the corehole. Drilling continued to 195.5 ft bgs (Puye sediments). Drilling then stopped to allow groundwater to collect in the corehole. According to procedure, after waiting 12 hours for groundwater to accumulate in the borehole, depth-to-water (DTW) measurements were taken on September 19, 2003; no water was present.

Difficult drilling and sampling conditions were encountered below 195 ft. On September 19, 2003, the split-spoon sampler twisted off in the hole at both 203 ft and 229 ft bgs. Additionally, a conventional core barrel twisted off in the hole at about 190 ft. Downhole equipment was recovered with the exception of the sampler shoe. Between September 19 and 26, 2003, the drilling program experienced delays due to fishing and equipment retrieval, corehole instability and collapse, augers binding in the hole, low penetration rates, and drill rig repairs. On September 26, 2003, due to refusal of formation, DOE decided to terminate coring activities at a depth of 241 ft bgs.

The R-2 corehole was plugged and abandoned on September 29 to September 30, 2003. Bentonite chips were tremied through the augers and hydrated with potable water from 241 ft to 70 ft bgs. A total of 58 bags of $^{3}/_{8}$-in Hole-Plug® bentonite pellets were used in the backfilling process. Cement grout, consisting of 20 bags of Portland cement and 4 bags of powdered bentonite mixed with municipal water, was pumped into the upper part of the corehole from 70 ft bgs to ground surface.

3.2 Phase II Drilling Activities

Phase II drilling was performed by WDC Exploration & Wells (WDC) using a Star 50-CH Failing/Speedstar air/mud rotary drill rig equipped with conventional circulation drilling rods, tricone bits, down-the-hole (DTH) hammer bits, and support equipment. Drilling fluid mixing and circulation equipment for Phase II included a mixing tank and pump assembly, and a generator to power the mixing unit. Drilling fluids were used as needed to improve borehole stability, minimize fluid loss, and facilitate cuttings removal from the borehole.

On October 10, 2003, WDC mobilized to the R-2 site in preparation for Phase II borehole drilling. The R-2 borehole is located approximately 100 feet west of the corehole. The following day, drillers installed 13 $^{3}/_{8}$-in. OD drill casing to a depth of 40 ft bgs using a 12¼-in. milltooth tricone bit. The borehole was drilled using a 12¼-in. milltooth tricone bit and air-rotary methods to 143 ft bgs. A zone of high moisture was noted while drilling from 123 ft to 143 ft bgs in the Guaje Pumice Bed. This same moist to wet zone was identified during Phase I activities. Drilling was then stopped to allow water to accumulate in the borehole. On the morning of October 12, 2003, after 12 hours, water level measurements were taken; no water had accumulated in the borehole.

On October 12, 2003, WDC began using fluid-assisted air-rotary drilling methods at R-2 to stabilize the borehole from 143 ft bgs to 403 ft bgs. Drilling fluids consisted of a mixture of municipal water with QUIK-FOAM® (surfactant) and EZ-MUD® (polymer). Potassium bromide (KBr) was added to the fluids as a tracer to aide in determining the occurrence of groundwater saturation.

On October 13, 2003, due to the instability of the borehole, drillers changed from fluid-assisted air-rotary methods at 403 ft bgs to the use of mud-rotary techniques. The day was spent mixing and pumping drilling mud to the borehole. A batch of drilling mud consisted of 1,500-gal of water, 12 to 22 bags of Aqua-Gel, 8 quarts of Pac-L (Drispack®) and 10 pounds of soda ash. The KBr tracer was added to the mud mixture at the standard ratio of 1 kilogram (Kg) of KBr to 4000 gal. Table 3.2-1 shows the total amount of drilling fluids introduced and recovered from the borehole during Phase II drilling activities.

From October 14 to 16, 2003, the R-2 borehole was advanced without interruption in sedimentary units that included the Puye Formation, pumiceous sediments, and fanglomerate (403 ft to 944 ft bgs). Although the regional aquifer was expected to be encountered at 810 ft bgs, indications of groundwater were not observed while drilling through this interval due to the mud-filled borehole. With concurrence of DOE and NMED, the total depth for Well R-2 was established at 944 ft bgs. On October 17, 2003 drilling ceased and the borehole was prepared for geophysical logging.

Table 3.2-1
Introduced and Recovered Drilling Fluids

Material	Amount (Gallons)
QUIK-FOAM®	10
EZ-MUD®	5
Potable Water	3,500
Drilling Mud[a]	24,000
Recovered Fluids[b]	21,038

[a] Drilling Mud is a mixture of water, bentonite, soda ash and Pac-L polyanionic cellulose
[b] Recovered fluids represents approximate fluids recovered during drilling based on pit dimensions. Fluids removed during development are included in Table 8.1-1

4.0 SAMPLING AND ANALYSIS OF CORE, CUTTINGS AND GROUNDWATER

During drilling at R-2, soil and groundwater samples were collected according to the LANL-prepared Sampling and Analysis Plan (SAP) (ER20003-0470, LANL 2003). Soil and groundwater samples were submitted to LANL for analysis. Core was collected from R-2 and analyzed for geochemical analysis and contaminant profiling. Cuttings collected from R-2 may be analyzed for mineralogic, petrographic, and geochemical properties. Groundwater samples were analyzed for organic, inorganic and radiochemical compounds.

4.1 Core and Cuttings Sampling

During Phase I, twelve samples of core were collected from the unsaturated zone during drilling from 5 ft to 228 ft bgs. Approximately 500 grams (g) to 1,000 g of core samples were placed in appropriate sample jars and protective plastic bags before being delivered to EES-6, Coastal Science Laboratories, Inc., and General Engineering Laboratories (GEL) for laboratory analysis. Samples of core from R-2 were analyzed for cations, anions, metals, and radionuclides for characterization purposes. The results will be provided in the investigation report for the Pueblo Canyon watershed.

As Phase II drilling conditions permitted, a sufficient quantity of cuttings were collected from the discharge line at 5-ft intervals. A portion of the cuttings were sieved (at >#10 and >#35 mesh or >#35 and >#60 for finer grain samples) and placed in chip-tray bins along with an unsieved portion. These chip trays were studied to determine lithologic characteristics and used to prepare the lithologic log. The remaining cuttings were sealed in Ziploc® bags, labeled and archived in core boxes for curation. Up to seven samples may be removed by LANL for mineralogic, petrographic, and geochemical analyses. No cuttings samples were submitted for contaminant characterization analysis.

4.2 Groundwater Sampling

During Phase I and Phase II drilling, no groundwater was identified in either the corehole or the borehole. R-2 was completed in a water bearing zone identified by geophysical logs. Groundwater samples were collected after well development on December 11, 2003 and after aquifer testing on January 13, 2003. These samples were collected from the screened interval and submitted to LANL for analysis.

4.3 Geochemistry of Sampled Water

No maximum contaminant levels for drinking water were exceeded. Uranium was detected at less than 0.2 parts per billion and tritium was 0.23 pCi/L. These results suggest that groundwater has not been impacted by LANL operations in the area of R-2. Analytical results are included in Appendix A.

5.0 BOREHOLE GEOPHYSICS

Using subcontractor-owned tools, Schlumberger performed borehole geophysics logging operations at R-2.

5.1 Schlumberger Geophysical Logging

Schlumberger personnel conducted geophysical logging in the mud-filled R-2 borehole on October 17 and October 18, 2003. The primary purpose of the Schlumberger logging was to characterize the conditions in the hydrogeologic units penetrated by the R-2 borehole, with emphasis on gathering moisture distribution data, identifying water zones, measuring capacity for flow (porosity and moisture), and obtaining lithologic/stratigraphic data. Secondary objectives included evaluating borehole geometry and determining the degree of drilling fluid invasion along the borehole wall.

Schlumberger personnel performed a suite of geophysical logging tools in the cased and uncased portions of the borehole; the suite included the following tools:

- Combinable Magnetic Resonance (CMR™) measures the nuclear magnetic resonance response of the formation, which is used to evaluate total and effective water-filled porosity of the formation and to estimate pore size distribution and in situ hydraulic conductivity.
- Array Induction Tool, version H (AITH™) measures formation electrical resistivity and borehole fluid resistivity, thus evaluating the drilling fluid invasion into the formation, the presence of moist zones away from the borehole wall, and the presence of clay-rich zones.
- Triple Detector Litho-Density (TLD™) measures formation bulk density related to porosity, photoelectric effect related to lithology, and borehole diameter using a single-arm caliper.
- Natural Gamma Spectroscopy (NGS™) measures spectral and overall natural gamma ray activity, including potassium, thorium, and uranium concentrations, thus evaluating geology and lithology.
- Elemental Capture Spectroscopy (ECS™) measures concentrations of hydrogen, silicon, calcium, sulfur, iron, aluminum, potassium, titanium, chlorinity, and gadolinium to characterize mineralogy, lithology, and water content of the formations.
- Epithermal Compensated Neutron Tool, model G (CNTG™) measures volumetric water content beyond the casing to evaluate formation moisture content and porosity.
- Full-Bore Formation Micro-Imager (FMI™) measures electrical conductivity images of the borehole wall and the borehole diameter with a two-axis caliper to evaluate geologic bedding and fracturing, including strike and dip of these features, fracture apertures, and rock textures.

Additionally, a calibrated natural gamma tool was used to record gross natural gamma-ray activity with each logging method (except the NGS™ run) to correlate depth runs between each of the surveys conducted.

Table 5.1-1 summarizes geophysical well logging conducted in R-2 by Schlumberger. An abstract of Schlumberger's report is presented in Appendix B along with the interpretive logging report and the geophysical logs, compiled as a montage, (on the CD on the back cover).

Table 5.1-1
Borehole Logging Survey Conducted in R-2

Operator	Date	Method	Cased Footage (ft bgs)	Open-hole Interval (ft bgs)	Remarks
Schlumberger	October 17-18, 2003	Logging suite[(a)]	20-40	40-941[(b)]	Schlumberger borehole logging conducted to TD prior to well installation

[(a)] Schlumberger suite of borehole logging surveys included triple detector litho-density, array induction tool, epithermal compensated neutron tool, elemental capture spectroscopy, full-bore formation microimager, natural gamma spectrometry, combinable magnetic resonance, platform express, and spontaneous potential.
[(b)]Variable effective depths; see Figure 3.0-1 and Appendix B

5.2 Kleinfelder-Supported Geophysical Logging

Video logging was not performed in either the R-2 corehole or borehole, due to the presence of augers or drilling mud in the borehole.

6.0 LITHOLOGY AND HYDROGEOLOGY

Core and drill cuttings samples were collected to characterize the stratigraphic units encountered during the drilling of the R-2 corehole and borehole. Presented below is a preliminary assessment of the lithology and hydrogeologic units encountered, including summary descriptions of rock units based on evidence from the examination of core and drill cuttings. Groundwater occurrences are discussed on the basis of drilling evidence and water-level measurements.

6.1 Stratigraphy and Lithologic Logging

Rock units and stratigraphic relations, interpreted from visual examination of R-2 drill cuttings and preliminary interpretation of geophysical data, are briefly discussed in order of younger to older occurrence. The interpretations presented below are preliminary and may be revised upon future analysis of petrographic, geochemical, mineralogical, and geophysical logging data. A lithologic log for R-2 containing detailed descriptions that identify texture and composition of sample intervals is presented in Appendix C.

Alluvium (0 to 2 ft bgs)

Core and cuttings samples indicated that unconsolidated alluvium (Qal) was intersected in R-2 in the interval from ground surface to approximately 2 ft bgs. This interval is made up of unconsolidated silty sand comprised of weathered tuffaceous materials derived form the Bandelier Tuff.

Bandelier Tuff (2 to 154 ft bgs)

Rhyolitic ash-flow tuff and pumice-rich tephra deposits of the Bandelier Tuff are locally represented in R-2 by the Otowi Member (Qbo) and its basal subunit, the Guaje Pumice Bed (Qbog), in the interval from 2 ft to 154 ft bgs. The compositional nature of these two units is discussed below.

Ash flows of the Otowi Member of the Bandelier Tuff (2 to 124 ft bgs)

Ash-flow tuff of the Otowi Member of the Bandelier Tuff was encountered in R-2 from 2 ft to 124 ft bgs. Core and cuttings show that the Otowi Member is pumiceous, lithic-bearing, and weakly welded. The plus-No.10-sieve fraction of drill cuttings samples throughout the Otowi section was typically composed of up to 55% by volume vitric pumice fragments, up to 45% dark-colored volcanic lithics, and minor abundances of quartz and sanidine crystals.

Guaje Pumice Bed of the Bandelier Tuff (124 to 154 ft bgs)

The Guaje Pumice Bed is made up of air-fall tephra and pumiceous surge deposits that form the basal subunit of the Otowi Member of the Bandelier Tuff. Nonwelded, pumice-rich tuff of the Guaje Pumice Bed was encountered in R-2 from 124 ft to 154 ft bgs. Core and cuttings are typically comprised of abundant (i.e., more than 50% by volume) vitric pumice fragments, quartz and sanidine crystals, and minor lithic fragments of intermediate volcanic composition. Whole rock samples of cuttings commonly contained abundant vitric ash.

Puye Formation (154 to 506 ft bgs)

Volcaniclastic sediments and dacitic gravel deposits of the Puye Formation (Tpf) were intersected in R-2 from 154 ft to 506 ft bgs. Core and cuttings samples indicated that this sedimentary section is made up of poorly cemented, fine to coarse volcanic detritus that can be informally divided into three distinct intervals on the basis of sample texture and composition. The upper interval, from 154 ft to 253 ft bgs, consists of silty sands with gravel typically comprised of pumice fragments, tuffaceous detritus, and dark colored volcanic lithic clasts. A stratified pumiceous tephra is interpreted within the sedimentary deposits of the upper interval from 185 ft to 194 ft bgs. Cuttings in the interval from 253 ft to 420 ft bgs are made up of broken chips and subangular to subrounded clasts, indicative of coarse gravel deposits. Gravel clasts in this section are composed mainly, if not exclusively, of hornblende-bearing dacite. The lower Puye interval, from 420 ft to 506 ft bgs, consists of weakly cemented volcaniclastic sandstone with grains representing a variety of constituents including dacite, rhyolite, andesite, vitrophyre, and pumice.

Unassigned Pumiceous Sediments (506 to 868 ft bgs)

Poorly consolidated, silty and clayey sandstones that contain pumice as a constituent in relatively high abundances were encountered in the R-2 borehole from 506 ft to 868 ft bgs. These pumiceous volcaniclastic sediments have not yet been identified as part of any known stratigraphic unit and are, therefore, classified as "unassigned" for purposes of this well completion report. Cuttings samples throughout the pumiceous section contain broken and subrounded clasts of diverse volcanic composition that typically include pumice, hornblende-biotite-dacite, andesite, rhyolite, vitrophyre, quartz and sanidine crystals, and local basalt. Pumice was not always observed as the dominant detrital constituent, but is consistently present in drill cuttings throughout this interval.

Unassigned Fanglomerate (868 to 944 ft bgs)

The interval from 868 ft to 944 ft bgs is made up of poorly cemented volcaniclastic sediments that represent a fanglomerate sedimentary facies currently not assigned to any known formation. Cuttings suggest that these sediments are uniformly fine grained in texture, consisting of silty and clayey fine sands. Detrital grains are composed of varied volcanic lithologies, dominantly dacite, andesite, rhyolite, vitrophyre, and subordinate abundances of pumice.

6.2 Groundwater Occurrences and Characteristics

The SAP (ER20003-0470) identified three stratigraphic intervals with a potential to contain perched groundwater saturation in R-2: (1) the alluvium, between the surface and 10 ft bgs; (2) the base of the Guaje Pumice Bed, between 35 ft and 45 ft bgs; and (3), the upper Puye Formation between 100 ft and 200 ft bgs.

No significant perched groundwater zones were observed in drilling the Phase I corehole from the surface to 241 ft bgs. An interval of apparent high moisture content, as indicated by wet core samples, was encountered in the Guaje Pumice Bed from 129 ft to 142.5 ft bgs. However, repeated attempts to measure DTW using an electric sounder verified the lack of any accumulated water in the borehole. Additional attempts to measure water as the corehole advanced to the Puye Formation also confirmed lack of water from potential perched water zones.

According to the processed geophysical logs, the percent water saturation (25-65%) in the interval from ground surface to 895 ft bgs is indicative of vadose zone conditions. Significant water-saturated (perched) zones in this interval are unlikely.

An exaggerated log response in the zone from 140 to153 ft bgs was noted. This response is characteristic of the Guaje Pumice Bed. The measurements for total porosity, water-filled porosity, and moveable water content are likely elevated by the influence of borehole washouts and drilling mud. Significant water-saturated (perched) zones in this interval are unlikely.

The regional water table at R-2 was predicted to occur in the Puye Formation at an estimated depth of 810 ft bgs. However, drillers were unable to detect groundwater saturation while drilling in the regional aquifer using mud-rotary drilling methods. KBr was added to the fluids as a tracer to aide in determining the occurrence of groundwater saturation. No saturated zones were identified using the KBr tracer monitoring technique while drilling with fluid-assisted air-rotary and foam methods from 0 ft to 403 ft bgs. Sampling and analysis for KBr in drilling mud proved unreliable as a technique for recognizing when the water table had been intersected. The presence of drilling mud masked abrupt declines in drilling fluid KBr concentration.

The geophysical logs identified a zone of saturation from 897 ft to 950 ft bgs. The most porous zone was identified from 908 ft to 912 ft bgs. R-2 was constructed with a screen interval at 906.4 ft to 929 ft bgs. After well development, on October 28, 3003, the water level was measured at 892.5 ft bgs. The processed log results strongly suggest that R-2 penetrates a fully saturated zone around 900 ft bgs. Water content increased from 17% at 895 ft bgs to 25% at 900 ft bgs, indicating a transition from vadose to saturated conditions. Unsaturated conditions above 895 ft bgs are corroborated by a sharp decrease in the water saturation estimate from the ELAN analysis.

The estimated pore volume water saturation computed from the ELAN integrated log analysis is over 90% from 897 to 948 ft bgs. The estimate is higher (100%) when computed directly from the processed bulk density and compensated neutron porosity for a grain density range of 2.45 g/cc to 2.65 g/cc. Water-filled and total porosity mostly range from 20 to 30% across the interval interpreted as saturated below 900 ft. Moveable water content is high and ranges from 10 to 20% of total rock volume. The highest total and effective porosity occurs in the zone 908 to 912 ft, reaching 35% and 20%, respectively.

Detailed results of geophysical surveys and the ELAN Analysis relating to water occurrence and logs for the Schlumberger surveys are presented in Appendix B.

7.0 WELL DESIGN AND CONSTRUCTION

R-2 was installed as a hydrogeologic characterization and groundwater monitoring well. Following approval of the well design by DOE, LANL and NMED, KA received the final construction specifications for R-2 on October 17, 2003. Well installation activities were performed from October 19 to October 22, 2003.

7.1 Well Design

Data from geophysical logs and borehole geologic samples were analyzed to determine the screen placement interval for R-2. The well was designed with a single screen interval to monitor potential contaminants in the uppermost productive zone of the regional aquifer in the unassigned fanglomerates. Design specifications were in accordance with the CQMP.

7.2 Well Construction

R-2 was constructed of 4.5-in ID/5.0-in-OD, type A304 stainless-steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The casing and screens were factory cleaned before shipment and delivery to the site. Additional decontamination of the stainless-steel components was performed on site prior to well construction using a high-pressure steam cleaner and scrub brushes. Two 10 ft lengths of 5-in OD compatible, 0.020-in continuous slot rod-based well screens were used. The screened interval in R-2 is 906.4 ft to 929.6 ft bgs. Stainless-steel casing was placed below the screen to construct a 13.7 ft sump. Figure 7.2-1 is a schematic as-built diagram of the completed R-2 well.

External couplings, also of type A304 stainless steel fabricated to American Society for Testing and Materials (ASTM) A312 standards, were used to connect individual casing and screen joints. Centralizers were installed above, at and below the well screen. In addition, another centralizer was placed approximately 82 ft above the screen interval. Centralizers for R-2 are located at 824 ft, 905 ft, 916 ft, and 930 ft bgs (Figure 7.2-1).

7.2.1 Annular Fill Placement

Well casing and screens were lowered in the hole and the bottom of the sump positioned at 943.3 ft bgs. Prior to placement, filter pack materials were generally mixed with municipal water to form a slurry. Placement of annular fill consisted of using a 2.5-in OD steel tremie pipe to deliver various materials to specified backfill intervals. Approximately 4 ft of formation material sloughed into the borehole from 944 ft to 940 ft bgs. A primary filter pack consisting of 10/20 silica sand was placed across the screen interval from 940 ft to 899 ft bgs. A secondary filter pack of 20/40 silica sand was placed above the primary filter pack from 899 ft to 897 ft bgs. Next, a transition seal consisting of a 50:50 mixture of 10/20 sand and bentonite chips was placed above the secondary filter pack in the annular space between 897 ft and 888 ft bgs. The annulus was then filled from 888 ft to 85 ft with a bentonite seal consisting of $^{3}/_{8}$-in bentonite chips. The bentonite seal was hydrated in approximately 60 ft lifts. After removing the 13$^3/_8$-in drill casing, approximately 4 ft of formation material sloughed into the borehole from 85 ft to 81 ft bgs. Concrete backfill, consisting of 2,500 pounds per square inch (psi) concrete with 4 percent bentonite, was placed from 81 ft bgs to the ground surface. The quantities of annular fill materials used in the completion of R-2 are presented in Table 7.2-1.

Table 7.2-1
Annular Fill Materials Used in Well R-2

Material	Amount	Unit[a]	Mix
Primary Filter Pack: 10/20 sand	24	Bag	-
Secondary Filter Seal: 20/40 sand	2	Bag	-
Transition Seal: 10/20 sand and ⅜-in bentonite	4.5 sand/4 bentonite	Bag	50:50
Bentonite Seal: ⅜-in. chips	12 bentonite	Bag	-
Bentonite Seal: ⅜-in. chips	9 bentonite	SuperSack	-
Concrete Backfill	2.5	Cubic Yards	2,500 psi concrete with 4% bentonite
Water	Approx. 15,000	Gal	Transport slurry and hydration

[a] Sand bag = 45 lb each, bentonite bag/bucket = 50 lb ea, bentonite supersack = 3,000 lb ea.
Sand bag = 0.5 ft^3 each, bentonite bag/bucket = 0.67 ft^3, bentonite supersack = 41.4 ft^3
Mixing ratios are by volume

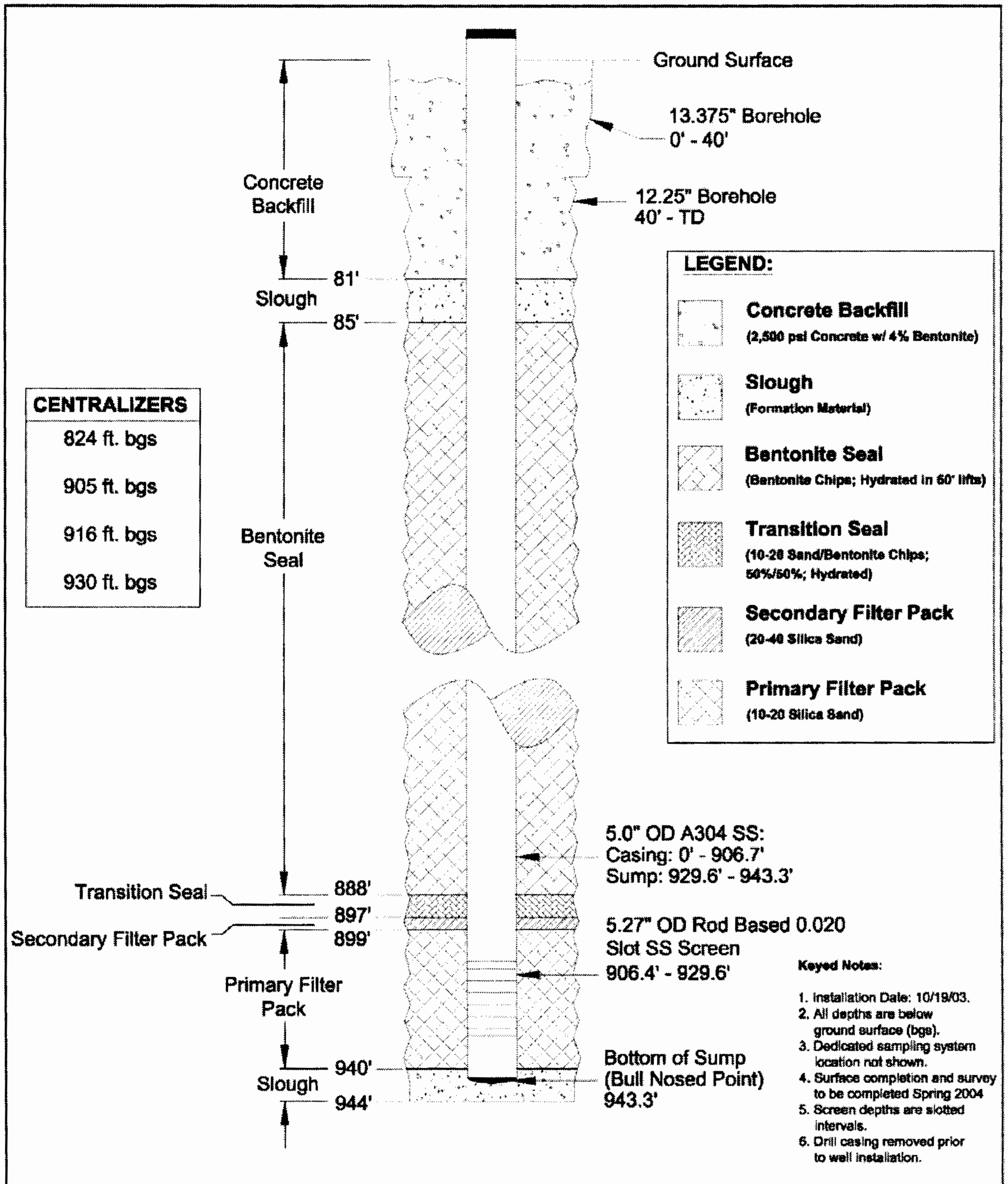
8.0 WELL DEVELOPMENT, HYDROLOGIC TESTING AND COMPLETION ACTIVITIES

Well development activities at R-2 were conducted from October 23 to October 28, 2003, November 17 through November 24, 2003, and from December 1 to December 11, 2003. Well development procedures included airlifting, well screen swabbing, surging, bailing, and pumping. A total of 17,303 gal of water were removed during well development and testing activities.

Aquifer tests at R-2, consisting of a constant rate pumping and recovery test, began on January 7, 2004 and were completed on January 13, 2004.

8.1 Well Development

Well development at R-2 was performed in three stages. The initial stage consisted of airlifting to remove excess drilling fluids and allow formation water to recharge the well. The second stage consisted for bailing and swabbing the screened interval and sump to remove bentonite materials, drilling fluids, and formation sands and fines that had been introduced into the well during drilling and installation activities. Bailing activities were conducted by WDC using a 5-gal capacity, 3-in OD by 10-ft long stainless-steel bailer. Bailing activities continued until water clarity improved. Bailing was followed by swabbing across the screened interval to enhance filter-pack development. A swabbing tool consisting of a 4.25-in OD, 1-in thick rubber disc attached to the drill rod was lowered into the well and drawn repeatedly across the screened interval for approximately one hour.



KLEINFELDER		Schematic Diagram of Well R-2 Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 7.2.1-1
Drawn By: C. Landon	Date: March 2004		
Project No.: 37151	Filename: Figure 7.2.1-1		
Scale: Not-To-Scale	Revision: 0		
Reviewed By: F. Schelby	Approved By: M. Everett		

Following swabbing, pump development procedures were applied to the screened interval (906.4 ft to 929.6 ft bgs) using a 10 horsepower (hp), 4-in Grundfos submersible pump. The pump intake was lowered to the screened interval and cycled on at a nominal rate of approximately 2.0 gal per minute (gpm). The pump intake was then drawn across the length of the screened interval. While pumping at R-2, water samples were collected for water quality parameter measurements.

The efficiency of well development was monitored by measuring field water-quality parameters (pH, temperature, specific conductance, total organic carbon, and turbidity). To monitor progress during development and hydrologic testing, samples of water were periodically collected and parameter measurements were recorded.

The primary objective of well development was to remove suspended sediment from the water until turbidity, measured in nephelometric turbidity units (NTU), was less than 5 NTUs for three consecutive samples. Turbidity did not drop below 5 NTUs, however, and after 24 days of development KA was directed by DOE to discontinue well development activities. Table 8.1-1 presents the final water quality parameters measured and the quantity of water removed during the well development process.

Table 8.1-1
Water Removed and Final Water Quality Parameters During R-2 Well Development

Method	Water Removed (gal)	pH	Temperature (°C)	Specific Conductance (μS/cm) [(a)]	Turbidity (NTU)	Total Organic Carbon (PPM)
Airlifting	600	NM[(b)]	NM	NM	NM	NM
Bailing/Swabbing Screen	415	8.53	22.6	496	NM	NM
Pumping Screen	10,880	6.47	24.2	145	11.2	2.16
Hydrologic Testing	4,976	7.77	22.0	139	23.8	NM
Total	**16,871**	–	–	–	–	–

[(a)] Specific conductance is reported in microsiemens per centimeter (μS/cm).
[(b)] NM = Not measured.

Figure 8.1-1 illustrates the effects of well development on measured field parameters.

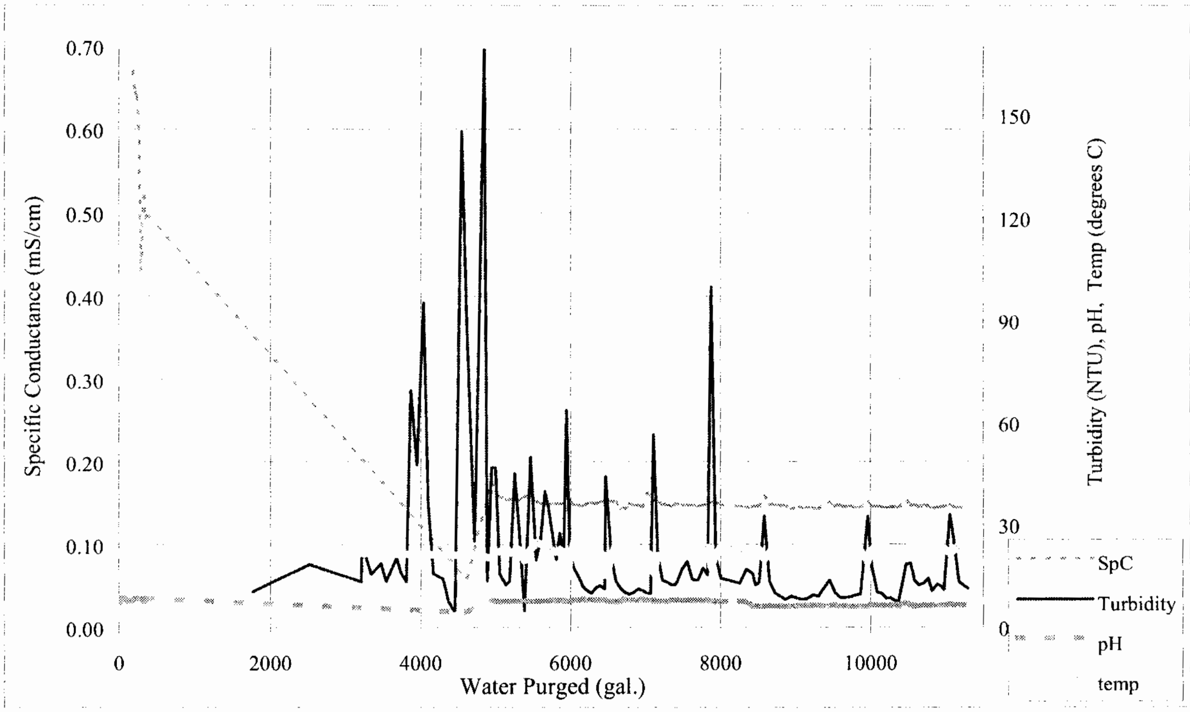


Figure 8.1-1. Effects of Well Development on Water Quality Parameters at Well R-2

8.2 Hydrologic Testing

Hydrologic testing for R-2 was set up and conducted from January 7, 2004 to January 13, 2004. KA conducted two aquifer pump tests at Well R-2. Test 1 was a modified step-drawdown test. The well was pumped at three different flow rates to evaluate drawdown and determine a sustainable flow rate for the second test. Test 2 was a conducted as a constant rate aquifer pump test using the flow rate established from the step-drawdown test. Data collected included water level measurements, discharge flow rate measurements, and barometric pressure levels. Water level data was collected during background monitoring, pumping, and recovery.

On January 10, 2004, KA conducted Test 1. The step-drawdown test was started at 8:00 am and continued to 2:24 pm. The pumping portion of Test 1 was 384 minutes. Recovery data was collected and recorded from 2:24 pm to 8:56 am on January 11, 2004. The recovery portion of Test 1 was 1,112 minutes.

On January 11, 2004, KA conducted Test 2. The 24-hour constant rate test was started at 9:00 am and continued to 9:00 am on January 12, 2004. The pumping rate was 2.9 gpm throughout the test. Recovery data was collected from 9:00 am to 10:27 am. The recovery portion of the test was 87 minutes.

KA determined the following information from the aquifer tests conducted at R-2:

1. R-2 produced flow rates of 1.1 and 2.9 gpm with 3 ft and 11.5 ft of drawdown, respectively. R-2 could not sustain a maximum flow rate of 3.85 gpm.

2. The screened sediments from 906.4 to 929.6 feet below land surface had a lower-bound hydraulic conductivity value estimate of 0.31 feet per day.
3. The unscreened sediments (within the filterpack) from 893 to 903 ft bgs had an average lower-bound hydraulic conductivity value estimate of 5.1 feet per day.

Details of the aquifer tests are included in the hydrologic testing report found in Appendix D.

8.3 Dedicated Sampling System Installation

From October 26 through October 28, 2004, Spectrum, Inc. installed a permanent submersible pump and a transducer tube in R-2. The Grundfos Model 5S20-39DS, two-horsepower pump was placed at an intake depth of 917 ft bgs. The transducer tube with a bottom end cap is at 913.8 ft bgs, and its slotted interval is 10 ft, from 903.8 to 913.8 ft bgs.

8.4 Wellhead Completion

A temporary casing was placed around the R-2 wellhead. This temporary casing will remain until a flood-proof wellhead completion design has been approved by LANL, DOE and NMED.

8.5 Geodetic Survey

Once the wellhead has been completed for R-2, the locations and elevations of relevant features will be determined by geodetic survey. Lynn Engineering and Surveying, Inc. will conduct the survey.

8.6 Site Restoration

Fluids produced during drilling and development were sampled in accordance with the Notice of Intent (NOI) to Discharge, Hydrogeologic Workplan Wells and filed with the NMED. Approval to discharge drilling and development water was received via e-mail from the NMED on March 4, 2004. A copy of the sample analysis and a copy of the discharge approval from the NMED are included in Appendix E.

Drill fluid and cuttings have been moved to the R-4 site location. Site restoration activities at the R-4 site include (1) discharge of drilling fluids from the borehole-cuttings containment area; (2) removal of the polyethylene liner and borehole cuttings from the borehole-cuttings containment; (3) backfilling and grading the containment area berms; (4) thin-spreading of the cuttings at the R-4 site; and (5) site reseeding at both R-2 and R-4 site locations in the spring of 2004. Silt fencing and straw bales have been left in place at the R-2 site to minimize possible sediment impacts from future precipitation.

9.0 DEVIATIONS FROM THE R-2 SAP

Appendix F compares the actual characterization activities performed at R-2 with the planned activities described in the "Hydrogeologic Workplan" (LANL 1998, 59599) and the R-2 SAP (LANL 2003, 03-4782). For the most part, drilling, sampling, and well construction at R-2 was performed as specified in the SAP. The main deviations from planned activities are summarized as follows:

- Planned borehole depth – the SAP anticipated a total depth of 910 ft bgs for the R-2 borehole, approximately 100 ft below the regional water table that was projected to occur at 810 ft bgs. The completed R-2 borehole was drilled to a depth of 944 ft bgs, 50 ft below the regional water table. The water table was measured at 892.5 ft bgs on October 28, 2003.
- Planned depth for coring – the SAP stated that coring would extend from ground surface to a depth between 200 and 300 ft bgs and that water samples for contaminant analysis be collected at each of the anticipated (up to three) perched groundwater zones. The Phase I borehole was terminated at 241 ft bgs due to auger refusal. No significant zones of perched water were identified and no water samples were collected in the unsaturated zone.
- Regional groundwater samples for screening analysis – the SAP specified up to two water samples for preliminary characterization of groundwater in the regional aquifer, to be collected (1) near the top of the zone of regional saturation and (2) near the bottom of the completed well. No regional groundwater samples were collected during Phase II drilling due to drilling with mud-rotary methods. One groundwater sample was collected following well development of R-2. A second groundwater sample was collected following aquifer testing.
- Number of core and cuttings samples collected for contaminant analysis—up to 15 samples from the unsaturated zone and 2 samples each from saturated zones were planned for as specified in the R-2 SAP; 12 were actually collected. Use of drilling mud precluded the collection of cuttings for contaminant characterization within the zones of saturation.

10.0 ACKNOWLEDGEMENTS

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E. Tow, P. Schuh, and R. Lawrence of Tetra Tech EM, Inc., Albuquerque, NM, contributed to the preparation of this report.

EnviroWorks, Inc provided site preparation and restoration activities.

Lynn Engineering & Surveying, Inc. provided the final geodetic survey of finished well components.

N. Clayton of Schlumberger provided processing and interpretation of borehole geophysical data.

P. Longmire of LANL contributed the geochemistry section of this report.

Tetra Tech EM, Inc. provided support for well site geology, sample collection, and hydrologic testing.

WDC Exploration & Wells provided rotary drilling services.

11.0 REFERENCES

Kleinfelder, Inc., 2003. Project Management Plan for DOE Monitoring Well Installation at Los Alamos National Laboratories, Contract Number 03-0029L-033-1009, Los Alamos, New Mexico, October 29, 2003.

Kleinfelder, Inc., 2003. Final – Contractor's Quality Management Program, Revision 1, Monitoring Well Installation, Los Alamos National Laboratory, Los Alamos, New Mexico, USACE Task Order DACW05-03-F-0090, Contract GS-10F-0029L, November 24, 2003.

Kleinfelder, Inc., 2003. Site Specific Health and Safety Plan, Characterization Well R-2, Los Alamos National Laboratory, Los Alamos, New Mexico, September 16, 2003.

Kleinfelder, Inc., 2003. Drilling Plan – Kleinfelder Drilling Plan for Characterization Wells R-2, R-4, R-11, and R-26 Final, Los Alamos National Laboratory, Los Alamos, New Mexico, Prepared for United States Department of Energy and the National Nuclear Security Administration through the United States Army Corps of Engineers, Sacramento District. Copyright 2003, Kleinfelder, Inc., June 25, 2003.

Los Alamos National Laboratory, January 1996. "Groundwater Protection Management Program Plan," Rev. 0.0, Los Alamos, New Mexico. (LANL 1996, 70215.2)

Los Alamos National Laboratory, July 2003. "SAP for Drilling and Testing Characterization Wells R-2, R-4, R-11, and R-26," Los Alamos National Laboratory Report LA-UR-03-4782, Los Alamos, New Mexico. (LANL 2003)