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Interim Completion Report for Characterization Well R-9

Environmental Restoration Project
A Department of Energy Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545

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Produced by the Canyons Focus Area

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ABSTRACT

Characterization well R-9, located in Los Alamos Canyon near the eastern boundary of Los Alamos National Laboratory ("the Laboratory"), is the first of approximately 32 wells being installed in the regional aquifer as part of the Laboratory's *Hydrogeologic Workplan* (LANL 1996, 55430). R-9 was installed by the Laboratory's Environmental Restoration (ER) Project and is primarily designed to provide water quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of multiple mesa-top and canyon floor contaminant source areas in upper Los Alamos Canyon and Pueblo Canyon. R-9 is also designed to collect hydrologic, geochemical, and geologic data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory.

R-9 was drilled to a total depth of 710 ft using air-rotary techniques. Drilling methods included downhole percussion hammers and dual-wall casing to drill open hole, a continuous coring system to core open hole, and Holte/Stratex casing advance systems that operated on dual-wall casing and downhole percussion hammers. In descending order, geologic units penetrated in R-9 included alluvium, basaltic rocks of the Cerros del Rio volcanic field, old alluvium, the Puye Formation, and basaltic rocks of the Santa Fe Group.

Six zones of saturation were encountered during the drilling of R-9. Two perched groundwater zones were encountered in Cerros del Rio basalt at depths of 180 and 275 ft. The upper zone was confined, and water rose in the hole to 137 ft after the top of the zone was penetrated. The saturated thickness of the upper zone is approximately 45 ft. The second perched zone occurs at the base of the Cerros del Rio basalt and is approximately 7 ft thick. Thin zones of saturation were also encountered in the Puye Formation at depths of 579, 615, and 624 ft. These zones, which are of uncertain origin, occur in transmissive zones intercalated in clay-rich tuffaceous sedimentary deposits. These three zones are confined and appear to be hydraulically connected because water levels rose to a depth of 524 ft after the tops of each of the zones were penetrated. The deepest groundwater zone was encountered at a depth of 688 ft near the top of basalt in the Santa Fe Group. This deep groundwater is unconfined, and it is almost certainly associated with the regional aquifer.

Groundwater in the six saturated zones was chemically characterized for major ions, trace elements, dissolved organic carbon, stable isotopes, tritium, and other radionuclides. Analytical methods recommended by both the Environmental Protection Agency (EPA) and the Laboratory were followed for groundwater (filtered and nonfiltered) and core samples. Groundwater from the uppermost perched zone (180-ft depth) is characterized by a sodium-calcium-chloride-bicarbonate ionic composition with a pH value of 8.30. This zone contains 347 pCi/L tritium (analysis by low-level electrolytic enrichment), which is similar to tritium activities detected in alluvial groundwater within upper Los Alamos Canyon. The perched zone at the base of the Cerros del Rio basalt at a depth of 275 ft is characterized by a sodium-sulfate-bicarbonate ionic composition with a pH value of 8.79. This zone contains 106 pCi/L tritium (low-level electrolytic enrichment) and 48.4 parts per billion (ppb) dissolved uranium. The lower zone in the Cerros del Rio basalt has a higher total dissolved solids (TDS) content (389 parts per million [ppm]) than the upper zone (252 ppm), possibly reflecting a longer groundwater residence time. Composition of groundwater within the Puye Formation varies from a calcium-sodium-bicarbonate to sodium-chloride-bicarbonate type. Tritium activities in groundwater of the Puye Formation range from 2.71 to 30.3 pCi/L. The saturated zone in Santa Fe Group basalt at a depth of 688 ft is characterized by a calcium-sodium-bicarbonate ionic composition with a TDS content of 387 ppm. This groundwater is chemically similar to that in the regional aquifer in wells PM-1 and PM-3. It has a tritium activity of 14.43 pCi/L.

1.0 INTRODUCTION

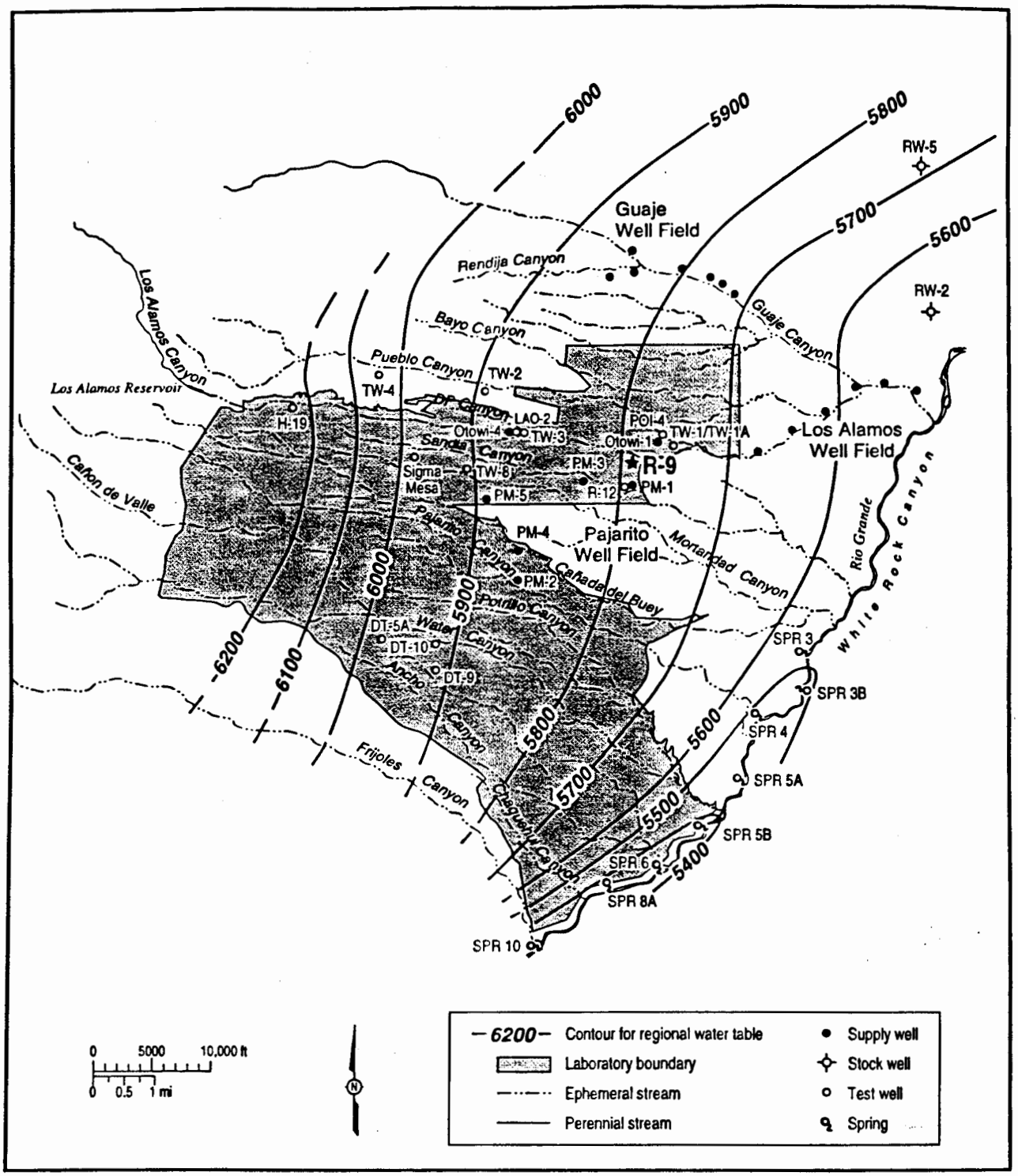
This interim report describes the drilling, construction, temporary completion, and testing activities for characterization well R-9. R-9 is located in Los Alamos Canyon at the eastern Laboratory boundary (Figure 1-1) west of state road NM 4. This well was installed by personnel from the Canyons Focus Area of the ER Project. It is the first characterization well drilled to the regional aquifer as part of the *Hydrogeologic Workplan* (LANL 1996, 55430) in support of the Laboratory's *Groundwater Protection Management Program Plan* (LANL 1995, 50124).

Preliminary interpretations are presented for some of the data collected, but discussion of other data is deferred until they can be evaluated in the context of site-wide information collected from other ER Project and *Hydrogeologic Workplan* boreholes. A future report will provide an integrated human health and ecological risk assessment for Los Alamos Canyon and will include groundwater data from R-9 and other ER Project wells in Los Alamos Canyon. The risk assessment in the future report will consider exposure to potential contaminants both in canyon floor sediments (as defined by reach investigations) and in groundwater.

R-9 was identified as well LAOI-7 in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* ("the work plan"; LANL 1995, 50290). The original intent was to complete this well in the first intermediate-depth perched groundwater zone encountered at this location. Work on LAOI-7 began in May 1997, but drilling was suspended at a depth of 32.5 ft and surface casing was set to a depth of 10 ft after caving problems were encountered in the borehole. The purpose of LAOI-7 was reevaluated during development of the *Hydrogeologic Workplan* (LANL 1996, 55430) in the summer of 1997, and it was redesignated as a characterization well to the regional aquifer. The well was renamed R-9 to be consistent with the nomenclature used to designate regional aquifer wells in the *Hydrogeologic Workplan* and the *Core Document for Canyons Investigations* ("the core document"; LANL 1997, 55622). Work on R-9 resumed on September 24, 1997, using LAOI-7 as a starter hole; the well was temporarily completed on February 3, 1998.

R-9 was designed to address and satisfy a portion of the requirements in Module VIII, Sections I.5 and Q, Tasks I through V, of the Laboratory's Hazardous Waste Facility Permit. Based on the current understanding of groundwater flow directions, R-9 was sited to characterize water quality within the regional aquifer downgradient of potential contaminant source areas, including Technical Area (TA) -1, -2, -21, -45, and -53, located in the upper part of the Los Alamos Canyon and Pueblo Canyon drainage basins. The general direction of groundwater flow in the regional aquifer is eastward near R-9 (Figure 1-1). R-9 was also designed to characterize the occurrence, movement, and quality of intermediate-depth perched groundwater at this location. This well also provided an opportunity to collect hydrologic and geologic data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory. Data collected include key parameters that will be used for numerical flow and transport models and for geochemical models. The hydrologic and geologic data collected in R-9 are being used in conjunction with data from other planned characterization boreholes as well as from other data sources to evaluate and update the site-wide conceptual hydrogeologic model.

Although R-9 is primarily a characterization well, its design also meets the requirements of a monitoring well as defined in the Hazardous and Solid Waste Amendments (HSWA) permit. Incorporation of this well into a Laboratory-wide groundwater monitoring program will be evaluated at a later date when the results of this characterization activity are integrated with other groundwater investigations in the *Hydrogeologic Workplan* (LANL 1996, 55430).



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F1-1 / R-9 WELL COMPLETION RPT / 090698

Figure 1-1. Location of R-9, existing water supply wells and test wells, and generalized water-level contours for the regional water table.

2.0 SUMMARY OF DRILLING ACTIVITIES

R-9 drilling was halted at a depth of 710 ft, and a temporary characterization well was installed. Completion of a permanent well will take place when additional hydrological, geological, and geochemical data are collected from nearby well R-12 and the combined data for R-9 and R-12 are evaluated by the Groundwater Integration Team. The final design for the permanent well will be submitted to the regulators for approval before completion. Therefore, this section summarizes drilling and temporary completion activities to date and will be revised in a final report when a permanent well is installed.

2.1 Equipment

R-9 was drilled by Tonto Environmental Drilling Company (Tonto) using an Ingersoll-Rand T-4 drill rig with a T-5 rotating head. Tonto provided three-man drilling crews, crew vehicles, drilling hammers and bits, the Longyear 101-mm Geobarrel core system, dual-wall rod systems, a 1-ton flatbed truck, and a 5-ton boom truck for handling casing, drill pipe, and heavy support apparatus such as casing jacks.

The ER Project's Field Support Facility (FSF) provided drill casings, drilling bits, a small front-end loader, the dust suppression system, field support trailers including logging and sampling, water containment tanks, drums for cuttings management, and a diesel-powered electric generator. The Laboratory's Environmental Science and Waste Technology group (CST-7) provided on-site water sample testing and filtering apparatus. The Water Quality and Hydrology group (ESH-18) provided a Hermit data logger, depth-to-water meter, bailers, and pressure transducers. The Geology and Geochemistry group (EES-1) and the FSF provided core logging microscopes.

The subcontractors Colog and Science and Engineering Associates (SEA) provided geophysical logging equipment and air permeability measuring equipment, respectively.

2.2 Schedule

The T-4 drill rig was mobilized to R-9 on September 22, 1997, and it was demobilized on February 3, 1998. Drilling operations required 116 drilling shifts. The following table compares the actual number of shifts with the number of shifts projected for R-9 in planning documents.

	Conceptual Design Report	Field Implementation Plan	Actual
Number of shifts	32	51	116

The following reasons account for the difference between planned and actual duration at R-9.

- The multiple perched water zones encountered in R-9 required more time for characterization than originally planned.
- A high hydraulic head (approximately 100 ft) at the base of the first perched water zone (180 ft below the ground surface) presented problems achieving a casing seal; extra under-reaming operations using a Servco three-wing under-reamer were unexpected.
- The thick sequence of clay-rich sedimentary rocks in the lower part of the Puye Formation was unexpected, and the clay repeatedly plugged drilling systems.

- The 14-in.-diameter drill casing and Holte 14-in.-diameter under-reamer were not delivered in time to start drilling R-9 as planned; therefore, the alternative was to start drilling R-9 using available systems inside the poorly installed LAOI-7 surface casing. This process caused numerous operational problems and reduced production efficiency.

Drilling shifts were either 10 or 12 hours each, depending on production needs. From October 22, 1997, to October 30, 1997, and from November 10, 1997, to December 18, 1997, Tonto provided two drill crews who worked two 12-hour shifts per day. To minimize rig standby costs, support contractors performed activities such as air permeability measurements and geophysical logging during nondrilling periods, such as weekends. Chronological operations for R-9 are summarized in Appendix A.

2.3 Production

Drilling techniques used in R-9 consisted of open borehole drilling, air-rotary coring, air-rotary placement of a surface casing, and air-rotary under-reamer advance of five different casing strings. In addition, other drilling operations involved borehole/corehole/casing drill out, reaming, augering, milling, and cleaning. Changing drilling systems typically involved tripping-out one system, modifying the drilling head and/or circulation plumbing, and tripping-in another drilling system from the ground surface to the depth of operations. Production statistics are summarized in Table 2.3-1.

From the ground surface to 710 ft, the total footage drilled by the different drilling techniques and casing sizes was 2570.8 ft. The total footage drilled does not include the footage of one drill system or casing size tripped in or out of another drill system or casing size. The total trip-in footage was 26,857 ft, and the total trip-out footage was 23,640 ft.

2.3.1 Open Borehole Drilling

Open borehole drilling provided a suitable environment for geophysical logging and air permeability profiles of bedrock strata without the interference of drill systems or casing strings. Open borehole drilling was also used to explore deeper sections of bedrock before coring or casing advancement. Tonto drilled 175 ft of open borehole in basaltic rocks at an average rate of 22.6 ft per hour using an RC 44 4-7/8-in.-diameter percussion hammer or a 4-1/2-in.-diameter tricone roller bit. Open borehole drilling in sedimentary strata was not attempted because of concerns about borehole stability in loose, unconsolidated materials.

2.3.2 Core Drilling

Core was collected in R-9 to provide undisturbed samples for geological, contaminant, and hydrological characterization. In addition, core was used to identify confining layers beneath perched groundwater zones and provide information for placing casing seals. Tonto cored a total of 244.5 ft, or 34.4% of the 710 ft depth, using a Longyear 101-mm Geobarrel air-rotary coring system. The following table compares the actual core production with the projected core production from R-9 in planning documents.

	Conceptual Design Report	Hydrogeologic Workplan	Field Implementation Plan	Actual
% Core	10%	10%	38%	34.4%

TABLE 2.3-1

DRILLING PERFORMANCE STATISTICS[a]

Drilling Types	Open Hole	Core	Other[b]	6-5/8-in. Casing[c]	8-5/8-in. Casing[c]	10-3/4-in. Casing[d]	12-3/4-in. Casing[d]	14-in. Casing[e]	16-in. Casing	Casing Advance System (4-1/2-in. rods)[c]	Casing Advance System (7-in. rods)[d,e]	Total (ft)[f]
Total footage drilled (ft)	175	244.5[e]	648.8	728	311	162.5	54.5	239	7.5	0	0	2570.8
Total footage rate (ft/hr)[g]	22.6	3.3	9.8	9.1	5.3	4.5	1.8	3.4	2			
Total recovery		81%										
Basalt[h] footage (ft)	175	120	489.8	275	44	0	42.5	239	7.5	0	0	1387.8
Basalt[h] rate (ft/hr)[g]	22.6	2.8	9.9	5.5	3.2	0	1.5	3.4	2			0
Puye[i] clastics footage (ft)	0	124.5	159	445	268	162.5	12	0	0	0	0	1171
Puye[i] clastics rate (ft/hr)[g]	0	4.2	9.6	15.1	6.0	4.5	4.8	0	0			0
Trip-in footage (ft)	0	3782.5	11430	4323	2395.9	677.5	959.5	6.5	0	1890	1392	26856.9
Trip-in rate (ft/hr)[g]	0	322.8	236.2	225.2	187.9	46.7	37.3	26	0	153.0	151.3	0
Trip-out footage (ft)	0	3336	11776.8	0	0	0	0	0	0	6842.5	1684.5	23639.8
Trip-out rate (ft/hr)[g]	0	307.5	338.7	0	0	0	0	0		370.9	137.5	0
Pull back footage (ft)	0	0	0	1341	319	0	258.5	34.5	0	0	0	1953
Pull back rate (ft/hr)[g]				79.8	93.8		48.3	5.9	0	0	0	0
											Total	55103.5
Mill shoe[j] (number)							1	3				
Mill shoe (hr)								19.9				
Seal extrusion (number)					1		2	4				
Under-ream (ft)							4	7.5				
Under-ream footage (ft)							285–289	236–243.5				
Under-ream (hr)[k]							43	132				
Life-of-hole casing TD (ft)				645.5	679	420	292.5	243.8	7.5			
Water zone					3rd		2nd	1st				

a. These performance statistics represent performance to date and will be updated when the permanent well is installed.
b. Other drilling includes borehole/corehole/casing drill out, reaming, augering, and cleaning with percussion hammer, tricone bit, or bentonite auger.
c. Stratex 6-5/8-in. and 8-5/8-in. casing advance systems use 4-1/2-in. reverse circulation (RC) rods.
d. Stratex 10-3/4-in. and 12-3/4-in. casing advance systems use 7-in. RC rods.
e. Holte 14-in. casing advance system uses 7-in. RC rods.
f. Total depth (TD) of borehole is 710 ft. Total cored footage (325.5 ft) is 45.8% of total borehole footage (710 ft).
g. Rates are weighted averages over footages drilled or tripped, including breaks but excluding repairs and change out of tools.
h. Basalt footage and rates include Puye Formation basalt from 10 to 282 ft and Santa Fe Group basalt from 686 to 710 ft.
i. Puye footage and rates include the old alluvium stratigraphic interval from 282 to 329 ft.
j. Milling bits for 14-in., 12-3/4-in., and 10-3/4-in. casing shoes are tripped in on 7-in. RC rods.
k. Duration encompasses activity specific operations (i.e., operations that would not have been done if under-reaming had not been implemented).

Average core recovery was 81% from all cored intervals. Of the 244.4 ft cored, 120 ft were produced from basaltic rocks at an average rate of 2.8 ft per hour and average recovery of 84%; 124.5 ft were produced from sedimentary rocks at an average rate of 4.2 ft per hour and average recovery of 78%.

2.3.3 Casing Advancement

After the 16-in.-diameter surface casing was installed, multiple casing strings were installed in a telescoped fashion to prevent perched water from communicating downhole as the borehole advanced (see Figure 2.3-1). As a casing string was used to seal off a perched water zone (e.g., 14-in.-diameter and 12-3/4-in.-diameter casings) the casing shoe was milled downhole allowing the next smaller casing size to advance past the shoe and continue borehole production. Table 2.3-1 lists the casings and casing advance systems used in R-9.

2.3.4 Other Drilling Activities

Other drilling activities included milling the casing shoes and reaming the borehole. These activities are summarized as "other drilling" in the operations chronology (Appendix A) and are tabulated in the performance statistics (Table 2.3-1). These activities also included operations to clean bentonite out of the borehole or casing(s) after the casing seals were emplaced and to remove clay cake from drill bits, casing, and air-circulation equipment during drilling of clay-rich Puye Formation sedimentary rocks.

3.0 STRATIGRAPHY/LITHOLOGY

Geologic units encountered in R-9 consisted of, in descending order, alluvium, basaltic rocks of the Cerros del Rio volcanic field, old alluvium, Puye Formation, and Santa Fe Group basalt. A brief summary of unit characteristics is given in the following sections, and a lithologic log is provided in Appendix B. An interpretive east-west cross section based on wells TW-3 and R-9 is given in Figure 3-1. Descriptions of geologic units are based on examination of core and cuttings, geophysical logs, drilling information, and laboratory tests of borehole materials.

3.1 Alluvium

Quaternary alluvium was penetrated from the surface to 10 ft at R-9. No samples were collected in the alluvium; therefore, it is not described in detail in this section.

3.2 Basaltic Rocks of the Cerros del Rio Volcanic Field

Late Pliocene basaltic rocks of the Cerros del Rio volcanic field occur from a depth of 10 to 289.8 ft. These rocks consist of a thick sequence of vesicular to massive basalt flows, thin zones of basaltic breccia, and a thin basal layer of basaltic tephra. The overall appearance of the basaltic flows is uniform except for variations in vesicularity and fracture density. Lithologic descriptions of these basalts are provided in the lithologic log (Appendix B).

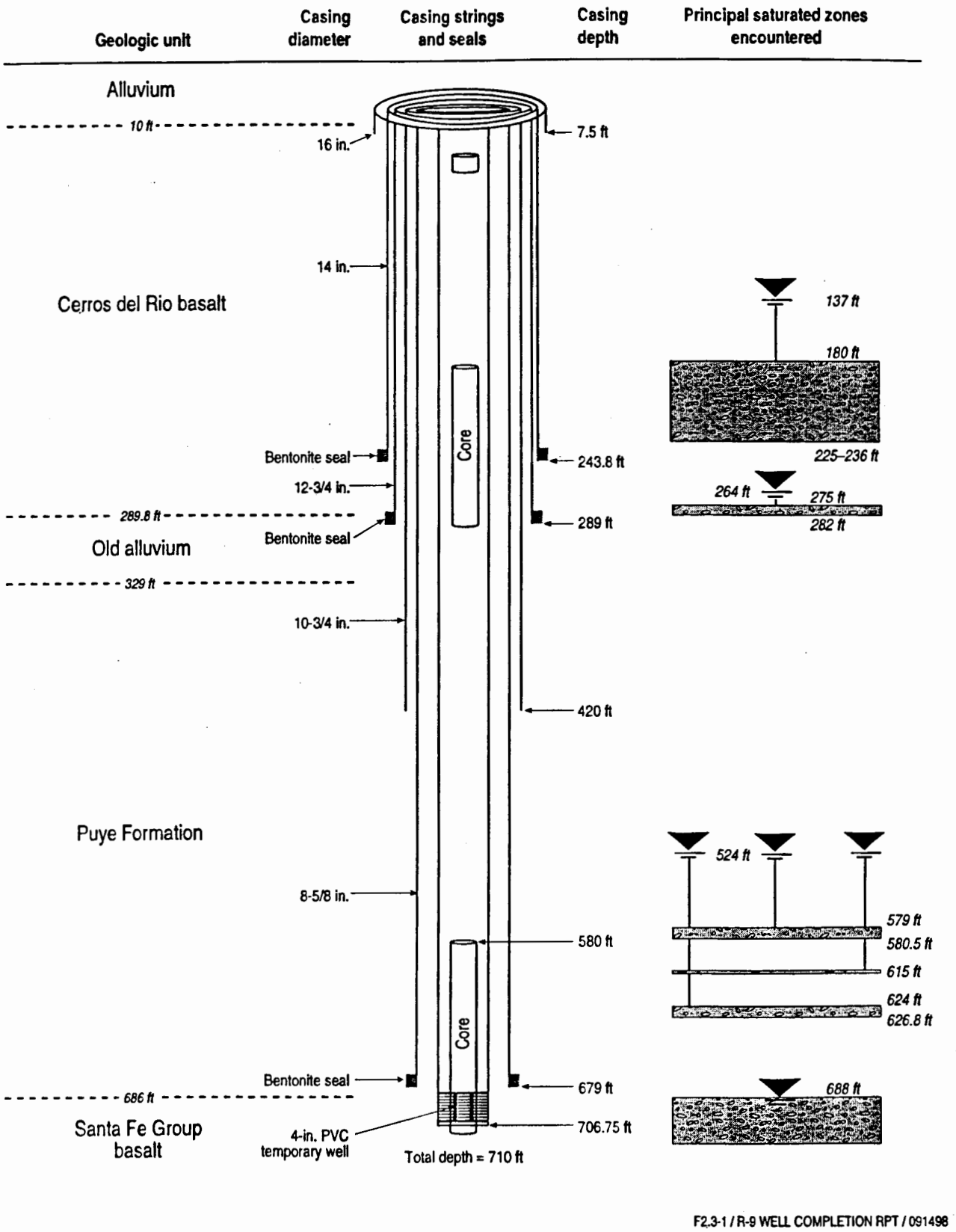


Figure 2.3-1. Configuration of R-9 as of January 30, 1998.

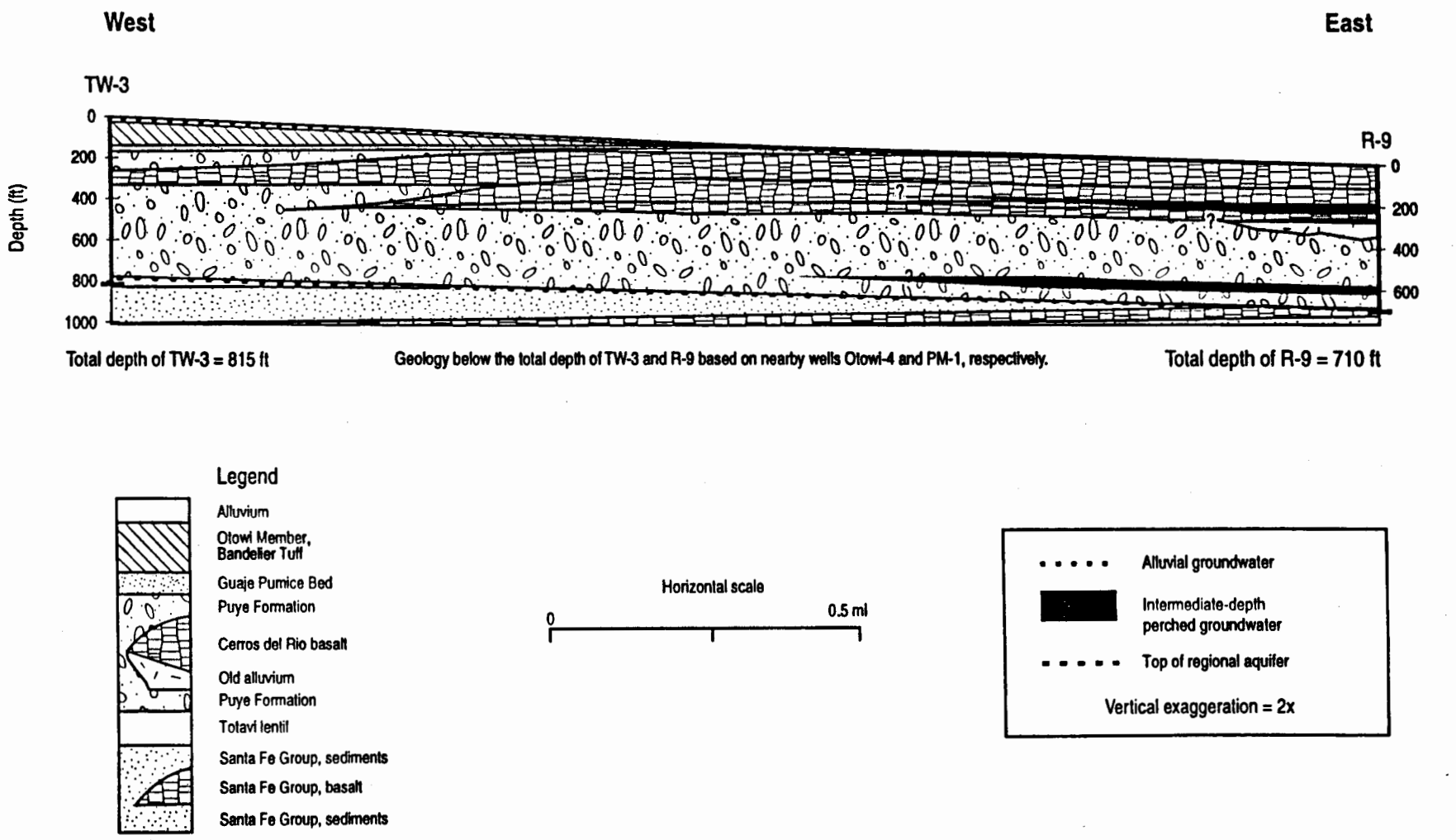


Figure 3-1. East-west cross section showing geologic relations and groundwater near the eastern Laboratory boundary in upper Los Alamos Canyon.

Preliminary c1hemical and petrographic analyses, lithologic logs, and geophysical logs define four distinct groups of basalt flows. In descending stratigraphic position, these groups consist of an upper tholeiitic flow, a lower tholeiitic flow, an upper alkalic flow, and a lower alkalic flow (Figure 3.2-1). Each group is assumed to represent separate eruptive events. The upper and lower tholeiitic flows are each characterized by means of a single petrographic analysis and by two chemical analyses (x-ray fluorescence [XRF]). The upper alkalic flow is characterized by means of a single petrographic analysis and two XRF analyses, and the lower alkalic flow is characterized by means of three samples. The lower alkalic flow also includes a thin basal basaltic tephra, which is characterized by three samples. The upper tholeiitic flow has an age of 2.15 Ma, and the lower alkalic flow has an age of 2.45 Ma (Table 3.2-1).

TABLE 3.2-1

GEOCHRONOLOGY OF BASALTS IN R-9

Sample No.[a]	Basalt Flow Unit	Age (Ma)[b]	Two-Sigma Age Uncertainty
R9-50.5D	Cerros del Rio basalt, upper tholeiitic flow	2.15	0.02
R9-273.7	Cerros del Rio basalt, lower alkalic flow	2.45	0.10
R9-690.4	Santa Fe Group basalt	8.63	0.24
R9-699.1	Santa Fe Group basalt	8.45	0.21

a. Numerical value in sample number indicates depth in feet at bottom of sampled interval.

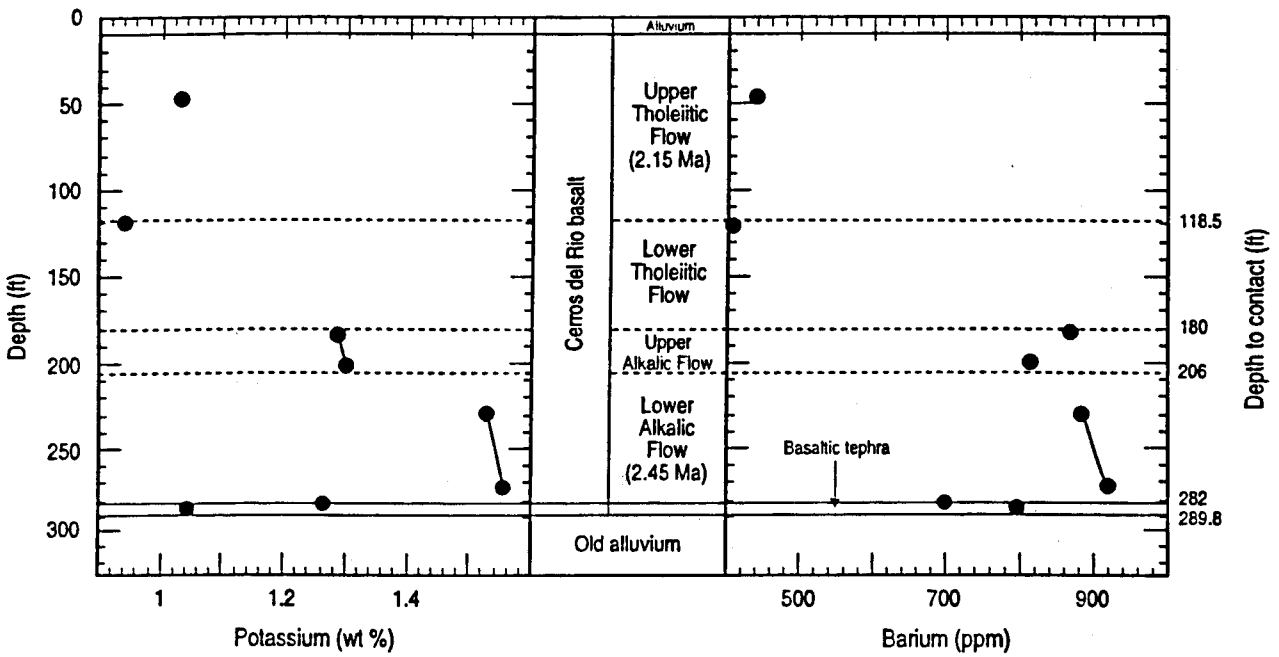
b. Ages provided by Giday WoldeGabriel (WoldeGabriel 1998, 58705). Ages determined using the argon-40/argon-39 method by W. McIntosh at the New Mexico Institute of Mining and Technology.

The upper tholeiitic flow, which extends from a depth of 10 to 118.5 ft, is a tholeiitic basalt with common plagioclase and scarce to common olivine phenocrysts. Compared with the underlying alkalic flows, this flow has low concentrations of barium and potassium (Figure 3.2-1). It is also characterized by the highest plagioclase and lowest olivine content among all flows (Table 3.2-2). The depth of the contact with the lower tholeiite flow is poorly constrained.

The lower tholeiitic flow, which extends from a depth of 118.5 to 180 ft, is a tholeiitic basalt with common olivine phenocrysts. Compared with the underlying alkalic flows, this flow has low concentrations of barium and potassium (Figure 3.2-1). The distinguishing characteristics of this flow are its tholeiitic chemistry, ophitic texture, and absence of plagioclase. The depth of the lower contact with the upper alkalic flow is defined by a thin basaltic breccia (?) that contains abundant clay.

The upper alkalic flow, which extends from a depth of 180 to 206 ft, is an alkali basalt with scarce to common plagioclase and common olivine phenocrysts. Compared with overlying and underlying basalts, this flow has intermediate concentrations of barium and potassium (Table 3.2-3 and Figure 3.2-1).

The lower alkalic flow, which extends from a depth of 206 to 282 ft, is an alkali basalt with rare plagioclase and common to abundant olivine. Compared with the overlying flows, this flow has high contents of barium and potassium (Figure 3.2-1). Phenocryst contents (Table 3.2-2) distinguish this flow as having a very low plagioclase content and the highest olivine content among the four flows. In open borehole geophysical logs, a decrease in gamma count rate at a depth of 225.5 ft is attributed to the transition from clay-rich, vesicular basalt above to massive, clay-free basalt below. The massive basalt is the lower perching layer for the upper perched zone in the Cerros del Rio basalt. A sample collected from a depth of 219 ft, near the top of the lower alkalic flow, had an original porosity of at least 22% and contains abundant palagonitic clay. Samples from depths of 228 and 273.7 ft, from the interior of the lower alkalic flow, contain no clay and are characterized by low porosities as observed in thin section.



F3.2-1 / R-9 WELL COMPLETION RPT / 090898

Figure 3.2-1. Concentrations of potassium and barium in basaltic rocks of the Cerros del Rio volcanic field encountered in R-9.

TABLE 3.2-2

NORMALIZED MINERAL CONTENTS FROM DETAILED PETROGRAPHIC ANALYSES OF SAMPLES FROM R-9[a,b,c]

Depth (ft)at Bottom of Sampled Interval	Flow Unit	Plagioclase Phenocrysts	Olivine Phenocrysts	Groundmass Feldspar	Groundmass Mafics	Groundmass Iron-Titanium Oxides	Apatite	Total Crystalline Material Reported	Mesostasis	Exogenetic Clay	Voids	Normalization Factor	Spinel[d]
50.5	UT[e]	12.9	2.4	46.3	21.6	3.1	0	86.3	6.6		6.6	1.071	0.22
122[f]	LT[g]	0	5										
201.5	UA[h]	7.1	3.7	50.6	16.5	3.4	0	81.4	4.1		9.5	1.104	0.25
219	LA[i]	0.10	7.2	29.2	5.0	0.038	0	41.6		8.2	13.9	1.284	0.41
228	LA	0.08	8.8	56.4	19.8	5.9	0.37	91.4			4.2	1.044	0.40
273.7	LA	0.05	8.1	59.5	17.4	5.0	1.93	91.9			3.4	1.035	0.40
282.6	T[j]	0.62	7.6	21.8	0.12	0.012	0	30.2	3.7	39.0	20.7	2.479	0.53

a. All values are in volume percent, except for normalization factor.

b. Except for voids (VO), exogenetic clay (CY), and cryptocrystalline residue, or mesostasis, all mineral contents are normalized free of VO and CY.

c. Palagonitic clay matrix and unrecognizable secondary minerals cannot be confidently distinguished from microscopic voids and so are undetermined. Samples with the lowest totals have the highest contents of palagonitic clay matrix.

d. Values for spinel represent their concentration within olivine.

e. UT = upper tholeiite

f. Values are visual estimates.

g. LT = lower tholeiite

h. UA = upper alkalic basalt

i. LA = lower alkalic basalt

j. T = basaltic tephra

TABLE 3.2-3

X-RAY FLUORESCENCE ANALYSES OF ROCK UNITS IN R-9

Sample No.	R9-50.5D	R9-122D	R9-181.3	R9-201.5	R9-228	R9-273.7
Geologic Unit	CR basalt[a]	CR basalt	CR basalt	CR basalt	CR basalt	CR basalt
Sample Type	cuttings	cuttings	core	core	core	core
Lithology	basalt	basalt	basalt	basalt	basalt	basalt
Alteration (major)	glassy					
Alteration (minor)				argillic		
Laboratory Number	5899	5929	5892	5893	5894	5895
Major Elements (wt %)						
SiO_2	52.4 ± 0.7	51.2 ± 0.7	50.0 ± 0.7	49.9 ± 0.7	48.6 ± 0.7	48.6 ± 0.7
TiO_2	1.49 ± 0.05	1.45 ± 0.04	1.61 ± 0.06	1.62 ± 0.06	1.77 ± 0.06	1.79 ± 0.06
Al_2O_3	16.1 ± 0.2	15.9 ± 0.2	16.2 ± 0.2	16.0 ± 0.2	15.3 ± 0.2	15.5 ± 0.2
Fe_2O_3	11.3 ± 0.1	11.9 ± 0.1	11.2 ± 0.1	11.2 ± 0.1	11.4 ± 0.1	11.3 ± 0.1
MnO	0.16 ± 0.01	0.17 ± 0.12	0.17 ± 0.01	0.17 ± 0.01	0.17 ± 0.01	0.17 ± 0.01
MgO	5.83 ± 0.16	7.23 ± 0.19	6.58 ± 0.19	7.00 ± 0.20	8.37 ± 0.26	8.53 ± 0.26
CaO	9.01 ± 0.08	8.94 ± 0.07	9.08 ± 0.08	9.09 ± 0.08	9.07 ± 0.08	8.96 ± 0.08
Na_2O	3.33 ± 0.10	3.18 ± 0.09	3.38 ± 0.10	3.23 ± 0.10	3.41 ± 0.10	3.44 ± 0.10
K_2O	1.03 ± 0.03	0.94 ± 0.03	1.29 ± 0.03	1.30 ± 0.03	1.52 ± 0.03	1.56 ± 0.03
P_2O_5	0.29 ± 0.01	0.30 ± 0.01	0.54 ± 0.01	0.56 ± 0.01	0.64 ± 0.02	0.67 ± 0.02
LOI[b]	-0.04	-0.43	0.18	0.27	0.32	0.36
Total	100.9	100.8	100.2	100.4	100.5	101.0
Trace Elements						
V	176 ± 20	173 ± 19	192 ± 22	181 ± 21	186 ± 23	183 ± 23
Cr	148 ± 11	252 ± 12	205 ± 12	215 ± 12	243 ± 13	241 ± 13
Ni	64 ± 9	106 ± 10	119 ± 12	125 ± 12	184 ± 18	198 ± 19
Zn	108 ± 12	106 ± 10	110 ± 10	103 ± 10	107 ± 10	111 ± 10
Rb	14 ± 9	19 ± 7	19 ± 8	18 ± 9	26 ± 8	28 ± 8
Sr	427 ± 20	440 ± 20	669 ± 34	676 ± 35	794 ± 41	827 ± 43
Y	21 ± 6	25 ± 9	25 ± 6	32 ± 9	26 ± 9	38 ± 9
Zr	149 ± 13	138 ± 13	191 ± 17	187 ± 17	200 ± 19	207 ± 19
Nb	16 ± 7	15 ± 8	26 ± 8	29 ± 8	27 ± 8	33 ± 8
Ba	391 ± 48	389 ± 47	776 ± 53	732 ± 51	794 ± 53	822 ± 54

a. CR basalt = Cerros del Rio basalt

b. LOI = loss on ignition; generally equates to water content. A negative value indicates a slight gain in weight after the sample was heated because of the oxidation of iron.

TABLE 3.2-3 (continued)

X-RAY FLUORESCENCE ANALYSES OF ROCK UNITS IN R-9

Sample No.	R9-282.2	R9-285.5	R9-297B	R9-596	R9-616.5	R9-690.4
Geologic Unit	CR basalt[a]	CR basalt	Old alluvium	Puye Fm.[b]	Puye Fm.	SF basalt[c]
Sample Type	core	core	cuttings	core	core	core
Lithology	tephra	tephra	basalt	tephra	sandstone	basalt
Alteration (major)	glassy	glassy		argillic	argillic	
Alteration (minor)		calcite			glassy, calcite	
Laboratory Number	5896	5897	5898	5998	5999	5930
Major Elements (wt %)						
SiO_2	50.3 ± 0.7	49.7 ± 0.7	52.0 ± 0.7	57.3 ± 0.7	60.3 ± 0.7	48.0 ± 0.7
TiO_2	1.69 ± 0.06	1.70 ± 0.06	1.51 ± 0.05	0.82 ± 0.02	0.81 ± 0.02	1.60 ± 0.04
Al_2O_3	15.0 ± 0.2	14.5 ± 0.2	16.3 ± 0.3	20.4 ± 0.3	16.6 ± 0.2	15.5 ± 0.2
Fe_2O_3	10.5 ± 0.1	11.0 ± 0.1	9.7 ± 0.1	5.26 ± 0.07	5.64 ± 0.08	10.40 ± 0.12
MnO	0.15 ± 0.01	0.19 ± 0.01	0.15 ± 0.01	0.09 ± 0.01	0.08 ± 0.01	0.14 ± 0.01
MgO	7.60 ± 0.23	8.01 ± 0.24	5.44 ± 0.15	4.53 ± 0.11	2.51 ± 0.06	5.44 ± 0.13
CaO	8.70 ± 0.08	7.69 ± 0.07	7.88 ± 0.07	4.10 ± 0.08	5.03 ± 0.08	12.34 ± 0.09
Na_2O	2.49 ± 0.09	2.21 ± 0.09	3.70 ± 0.10	0.33 ± 0.11	3.15 ± 0.09	3.05 ± 0.09
K_2O	1.26 ± 0.03	1.04 ± 0.03	1.86 ± 0.04	0.15 ± 0.02	1.80 ± 0.03	0.85 ± 0.03
P_2O_5	0.65 ± 0.02	0.36 ± 0.01	0.80 ± 0.02	0.22 ± 0.01	0.22 ± 0.01	0.33 ± 0.01
LOI[d]	1.64	3.64	0.40	7.28	3.68	2.95
Total	100.0	100.1	99.7	100.5	99.7	100.6
Trace Elements						
V	170 ± 22	154 ± 22	165 ± 20	70 ± 14	86 ± 14	219 ± 21
Cr	235 ± 13	267 ± 13	72 ± 9	42 ± 9	69 ± 9	221 ± 12
Ni	159 ± 15	197 ± 19	50 ± 8	25 ± 10	29 ± 10	89 ± 10
Zn	99 ± 10	96 ± 10	96 ± 10	70 ± 10	61 ± 11	81 ± 11
Rb	27 ± 8	32 ± 8	38 ± 8	10 ± 8	30 ± 7	13 ± 8
Sr	628 ± 32	537 ± 28	959 ± 49	364 ± 16	794 ± 37	569 ± 28
Y	21 ± 8	31 ± 8	30 ± 9	<7	20 ± 8	26 ± 9
Zr	187 ± 16	166 ± 15	216 ± 20	217 ± 14	240 ± 18	136 ± 14
Nb	28 ± 8	17 ± 8	38 ± 8	26 ± 8	17 ± 8	12 ± 8
Ba	628 ± 50	714 ± 51	948 ± 57	274 ± 47	2536 ± 149	462 ± 48

a. CR basalt = Cerros del Rio basalt

b. Puye Fm. = fanglomerate facies of the Puye Formation

c. SF basalt = Santa Fe Group basalt

d. LOI = loss on ignition; generally equates to water content. A negative value indicates a slight gain in weight after the sample was heated because of the oxidation of iron.

In addition to palagonite formed from the *in situ* alteration of basaltic glass, the lower alkalic flow also contains locally abundant, banded, light colored, translocated clay that fills voids, particularly in the breccia zone at the base of the unit. Samples of clays at depths of 219, 228.2, and 281.8 ft were separated into size fractions and analyzed by x-ray diffraction (XRD). The mineral assemblage in the clay separates includes smectite (greater than 97% by weight) and minor amounts of quartz, kaolinite, clinoptilolite, illite/mica, and apatite. Calcite is absent in all XRD analyses and was not observed in hand specimens or thin section.

The basaltic tephra extends from a depth of 282 to 289.8 ft. This tephra, believed to be a maar deposit, is characterized by fine-grained, well stratified beds consisting of silt-sized basaltic glass and increasing proportions downsection of fine-grained material derived from the Santa Fe Group. These tephras were included in the old alluvium of Griggs (1964, 8795) but are assigned to the Cerros del Rio basalt in this report because of their petrographic and chemical similarity to the overlying lower alkalic basalt flow unit (Table 3.2-2). Mobile elements such as barium, potassium, and particularly sodium have been affected by diagenetic alteration of the basaltic glass in the tephra (Figure 3.2-1). The upper part of the tephra is made up entirely of basaltic materials as indicated by its low silica content (50% SiO_2) and by the absence of contamination detected in a petrographic analysis of sample R-9-282.6. The basaltic tephra had an original porosity of at least 60%. This original porosity is now represented by 21% open voids and 39% voids filled by clay. This matrix of the tephra contains abundant clay (Table 3.2-4) that formed from original basaltic glass. The fine-grained, clay-rich nature of the tephra probably accounts for its role as the perching layer for the lower perched zone in the Cerros del Rio basalt.

3.3 Old Alluvium

Pliocene old alluvium extends from a depth of 289.8 to 329 ft. The term "old alluvium" was used by Griggs (1964, 8795) to describe distinctive alluvium consisting of unconsolidated sands and gravels deposited on a pediment surface cut on the Puye Formation. This unit is readily distinguished from the underlying Puye Formation by its abundance of basaltic clasts. Petrographic examination of a sample from a depth of 292.7 ft indicates that about half of the clasts in the alluvium at this depth were derived from a single, distinctive basalt with conspicuous quartz xenocrysts. The other half of the clasts are primarily feldspar-poor dacitic lava derived from the Tschicoma Formation. Chemical analysis of a basalt clast from the old alluvium (sample R-9-297B) matches a sample of early Pliocene basalt collected from nearby well Otowi-1 at a depth of 460 ft. A brief examination of a sample collected from Otowi-1 revealed that this basalt also has conspicuous quartz xenocrysts. XRD data of a sample collected from a depth of 292.7 ft (Table 3.2-4) reveals a complete lack of secondary minerals, including calcite, in the old alluvium.

3.4 Puye Formation (Fanglomerate Facies)

Pliocene fanglomerate facies of the Puye Formation occurs from a depth of 329 to 686.4 ft. It consists of coarse tuffaceous volcanogenic sediments as described by Waresback (1986, 58715). Above a depth of 539 ft, clasts of lavas and pumices within the sediment are dominantly vitric, and the rock consists of poorly consolidated sand, pebbly sand, and gravel (Appendix B) derived from dacitic rocks of the Tschicoma Formation. From a depth of 539 to 686.4 ft, the unit consists of consolidated tuffaceous sandstone, pebbly sandstone, and conglomerate characterized by abundant pumice clasts. These pumice clasts, which are the largest, most conspicuous features of the rock, have a waxy appearance because they are dominantly altered to clay (Table 3.2-4), although vitric pumices are occasionally present throughout the section. Two argillic beds of primary volcanic ash, each approximately 1 ft thick, occur within this lower part of the Puye Formation.

TABLE 3.2-4

X-RAY DIFFRACTION RESULTS FOR R-9 SAMPLES[a,b,c,d]

Depth (ft) at Base of Sampled Interval	Smectite	Illite/ Mica	Clinoptilolite	Kaolinite[e]/ Chlorite	Quartz	Cristobalite	Tridymite	Feldspar	Hornblende	Hematite	Pyroxene	Olivine	Apatite	Calcite	Glass	Total
181.3		ND[f]	ND	ND	ND	ND	ND	major	ND	minor	major	minor	minor	ND	ND	
282.6	major	ND	Trc.[g]	ND	Trc.	ND	ND	major	ND	minor	major	minor	ND	ND	minor	
285.2	minor	ND	ND	ND	minor	ND	ND	major	ND	ND	major	minor	ND	ND	major	
285.5	minor	ND	ND	ND	Trc.	ND	ND	minor	ND	ND	Trc. ?	minor	ND	ND	major	
292.7	20 ± 6	1 ± 1	2 ± 1	1 ± 1	25 ± 2	2 ± 1	2 ± 1	45 ± 6	1 ± 1	1 ± 1	ND	ND	ND	ND	ND	100 ± 9
587.4	52 ± 16	Trc.	Trc.[h]	1 ± 1	4 ± 1	2 ± 1	ND	41 ± 6	1 ± 1	1 ± 1	ND	ND	ND	ND	ND	102 ± 17
596	88 ± 26	ND	Trc.[h]	2 ± 1	ND	ND	ND	4 ± 1	ND	4 ± 1	ND	ND	ND	ND	ND	98 ± 26
606.4	94 ± 28	ND	ND	ND	Trc.	ND	ND	2 ± 1	ND	ND	ND	ND	ND	3 ± 1	ND	99 ± 28
616.5[i]	24 ± 7	Trc.	1 ± 1[h]	1 ± 1	4 ± 1	10 ± 1	1 ± 1	47 ± 7	Trc.	1 ± 1	ND	ND	ND	1 ± 1	ND	90 ± 10
621.3	28 ± 8	1 ± 1	4 ± 1	ND	3 ± 1	9 ± 3	1 ± 1	48 ± 7	1 ± 1	1 ± 1	ND	ND	ND	ND	ND	96 ± 11
639.8	37 ± 11	1 ± 1	Trc.[h]	Trc.	6 ± 1	2 ± 1	ND	50 ± 7	1 ± 1	ND	ND	ND	ND	ND	ND	97 ± 13
645.3	61 ± 18	Trc.	1 ± 1[h]	Trc.	14 ± 1	ND	ND	32 ± 5	1 ± 1	1 ± 1	ND	ND	ND	1 ± 1	ND	111 ± 19
661	74 ± 22	1 ± 1	Trc.[h]	Trc.	2 ± 1	1 ± 1	ND	26 ± 4	3 ± 1	ND	ND	ND	ND	ND	ND	107 ± 22
679	16 ± 5	Trc.	ND	ND	9 ± 1	3 ± 1	Trc.	58 ± 8	Trc.	ND	ND	ND	ND	ND	14 ± 10	100 ± 10
688.6	35 ± 11	Trc.	9 ± 1	1 ± 1	4 ± 1	ND	ND	33 ± 5	ND	1 ± 1	ND	ND	ND	21 ± 2	ND	104 ± 12

a. wt %

b. Quantitative x-ray diffraction for old alluvium sample at a depth of 292.7 ft, Puye Formation samples at a depth of 587 to 679 ft, and Santa Fe basalt sample at a depth of 688.6 ft. X-ray diffraction results are not standardized for minerals commonly found in basalts, and only qualitative results are presented.

c. All samples are bulk rocks except for the sample collected at a depth of 688.6 ft, which is fracture fill in a basalt.

d. See Figure 2.3-1 for geologic units.

e. The kaolinite reported in these samples could be halloysite.

f. ND = not detected

g. Trc. = trace

h. Zeolite, believed to be clinoptilolite

i. This sample contains an additional phase that was not identified. It also has a low total, possibly due to presence of glass (?).

The fanglomerate facies of the Puye Formation is normally dominated by gravels, cobbles, and boulders of devitrified dacitic lava in coarse sandy matrix. However, in R-9 no dacitic lava clasts larger than gravel size were observed in core between 580 ft and the base of the unit at 686.4 ft, and cuttings for the upper part of the Puye Formation indicate a complete lack of clasts larger than pebble size. Thus, the fanglomerate facies of the Puye Formation is much finer grained than reported at other drill holes west of R-9, such as Otowi-4 (Stoker et al. 1992, 58718), or in outcrops throughout the region (Griggs 1964, 8795; Waresback 1986, 58715; Dethier 1997, 49843). Evidently, most of the Puye Formation at R-9 consists of subaerial mudflows dominated by tuffaceous materials (Waresback 1986, 58715, pp. 120–122).

The consistent presence of volcanic glass in the rock matrix suggests that the Puye Formation has undergone minimal diagenetic alteration to a depth of 539 ft in R-9, although some minor clay is probably concentrated within finer size fractions (Table 3.2-4). The unit has undergone pervasive argillic alteration below 539 ft, and the original volcanic glass is generally altered to clay in the rock matrix (Table 3.2-4). Petrographic and XRD analyses demonstrate the general presence of calcite within the lower argillic portion of the Puye Formation but not in the upper vitric portion of the unit. Secondary opal was observed in samples collected below a depth of 436.5 ft.

The tuffaceous deposits in the lower Puye Formation probably correlate with waxy tuffs that occur between the depths of 795 and 836 ft in water supply well PM-1. Cooper et al. (1965, 8582) assigned these tuffs to the Tesuque Formation, but their dacitic lithology suggests these tuffs were derived from Tschicoma volcanic sources to the west. Therefore, these tuffaceous deposits are considered to be part of the Puye Formation.

3.5 Puye Formation (Axial Facies)

Axial deposits of the ancestral Rio Grande (Totavi Lentil of Griggs 1964, 8795) were predicted to occur at the base of the Puye Formation based on lithologic logs from nearby water supply wells, but these deposits were not present.

3.6 Santa Fe Group Basalt

The deepest unit encountered in R-9 is a massive to vesicular basalt that correlates with a late Miocene Santa Fe Group basalt at the same stratigraphic position in well PM-1 (Cooper et al. 1965, 8582). In R-9, this basalt occurs from a depth of 686.4 ft to greater than 710 ft (total depth). Preliminary argon-40/argon-39 age dates for two samples of this basalt yielded ages of 8.45 ± 0.21 Ma to 8.63 ± 0.24 Ma (Table 3.2-1). These dates are considered minimum eruptive ages. XRF analysis of a sample collected at a depth of 690.4 ft indicates this basalt is a tholeiite (Table 3.2-3). Vesicles and fractures within the uppermost foot of this basalt have been filled by accumulations of translocated clay, calcite, clinoptilolite, and drusy quartz (Table 3.2-4). Calcite veins extend downward in hairline fractures an additional 0.8 ft; secondary mineralization appears to be absent below this level. The upper zone of alteration may reflect weathering of the basalt before its burial by the Puye Formation.

4.0 OCCURRENCES OF GROUNDWATER

Six saturated groundwater zones were encountered during drilling operations. The tops of the saturated zones occurred at depths of 180, 275, 579, 615, 624, and 688 ft. Five of these zones are believed to be perched groundwater zones, and the sixth is believed to be associated with the regional aquifer. Figure 2.3-1 summarizes the occurrences of these saturated zones.

4.1 Perched Zones

The first perched zone encountered in R-9 occurs in the middle of basaltic rocks of the Cerros del Rio volcanic field (Figure 4.1-1). This perched system is one of the thickest occurrences of intermediate-depth groundwater identified at the Laboratory. Water was first encountered at a depth of 180 ft and quickly rose to a depth of 137 ft after the top of the water-bearing zone was penetrated. These conditions indicate that the perched zone is relatively permeable and confined. The top of the perched zone occurs in a thin clay-rich basaltic breccia (?) separating two basalt flows. It is uncertain whether the upper confining bed is the clay-rich basaltic breccia or overlying massive basalt because coring operations did not begin until the zone was first detected. The basalt flow beneath the breccia is highly fractured, and these fractures probably provide the saturated porosity in this perched zone. The base of the perched zone is believed to occur between a depth of 225 and 236 ft, which marks the transition between highly fractured basalt above to massive unfractured basalt below. Rare fractures in the perching layer are notably clay-poor compared with clay-rich fractures in the overlying saturated zone.

A second perched zone was encountered in a breccia zone at the base of the basaltic rocks of the Cerros del Rio volcanic field (Figure 4.1-1). Water was first encountered at a depth of 275 ft and slowly rose to a static water level (SWL) of 264 ft after the top of the zone was penetrated. The upper confining layer of the second perched zone appears to be massive unfractured basalt that overlies a saturated clay-rich basaltic breccia. The basaltic breccia appears to provide the saturated porosity within the second perched zone. The perching layer occurs at a depth of 282 ft within fine-grained, highly stratified basaltic tephra. These tephras occur immediately above the old alluvium of Griggs (1964, 8795). Groundwater flow rates in the second zone appear to be significantly lower than in the first perched zone as evidenced by the slow recovery of water levels in the borehole after the samples were collected.

Three hydraulically-connected saturated zones were encountered in the lower part of the Puye Formation at depths of 579, 615, and 624 ft. These zones occur within thin, transmissive sand and gravel beds intercalated within a thick sequence of clay-rich, tuffaceous sedimentary deposits. The clay-rich deposits are lower in permeability and act as confining beds. When the top of the saturated zone at a depth of 579 ft was penetrated, the water level rapidly rose 55 ft to a depth of 524 ft, indicating confined conditions. The base of the 579-ft zone occurred at a depth of 580.5 ft. The vertical extent of saturation at a depth of 615 ft is not well characterized because water rose slowly while the borehole rested over the weekend. By the following Monday, the SWL was 524.7 ft. The slow infiltration of water into the 615-ft zone indicates that it is not as transmissive as the other two zones. The saturated zone at a depth of 624 ft is associated with transmissive sand and gravel. The base of this zone occurs at a depth of 626.8 ft. When the top of this zone was penetrated, the water level rapidly rose 100 ft in the borehole to a depth of 524 ft, also indicating confined conditions. The similar SWLs encountered in all three zones indicate that the zones probably occur in stratigraphic zones that are hydraulically connected. Presently, these three zones are believed to be perched.

4.2 Regional Aquifer

The sixth saturated zone occurs within the top of a basalt that is identified as the top of the Santa Fe Group. This zone occurs at a depth of 688 ft and is unconfined. Saturation occurs in highly fractured basalt and extends beyond the total depth of the borehole. This basalt correlates with similar basalts identified near the top of the Santa Fe Group in PM-1, 1 km to the south (Cooper et al. 1965, 8582). This saturated zone is believed to be associated with the regional aquifer based on its similar chemistry to water from nearby supply wells PM-1 and PM-3 as well as test well TW-3. In addition, the elevation at the top of this zone (5696 ft) is lower than SWLs for the regional aquifer in wells PM-1 (5758 ft) and Otowi-1 (5724 ft), and it is lower than the elevation predicted based on regional water table maps (5780 ft) (Figure 1-1).

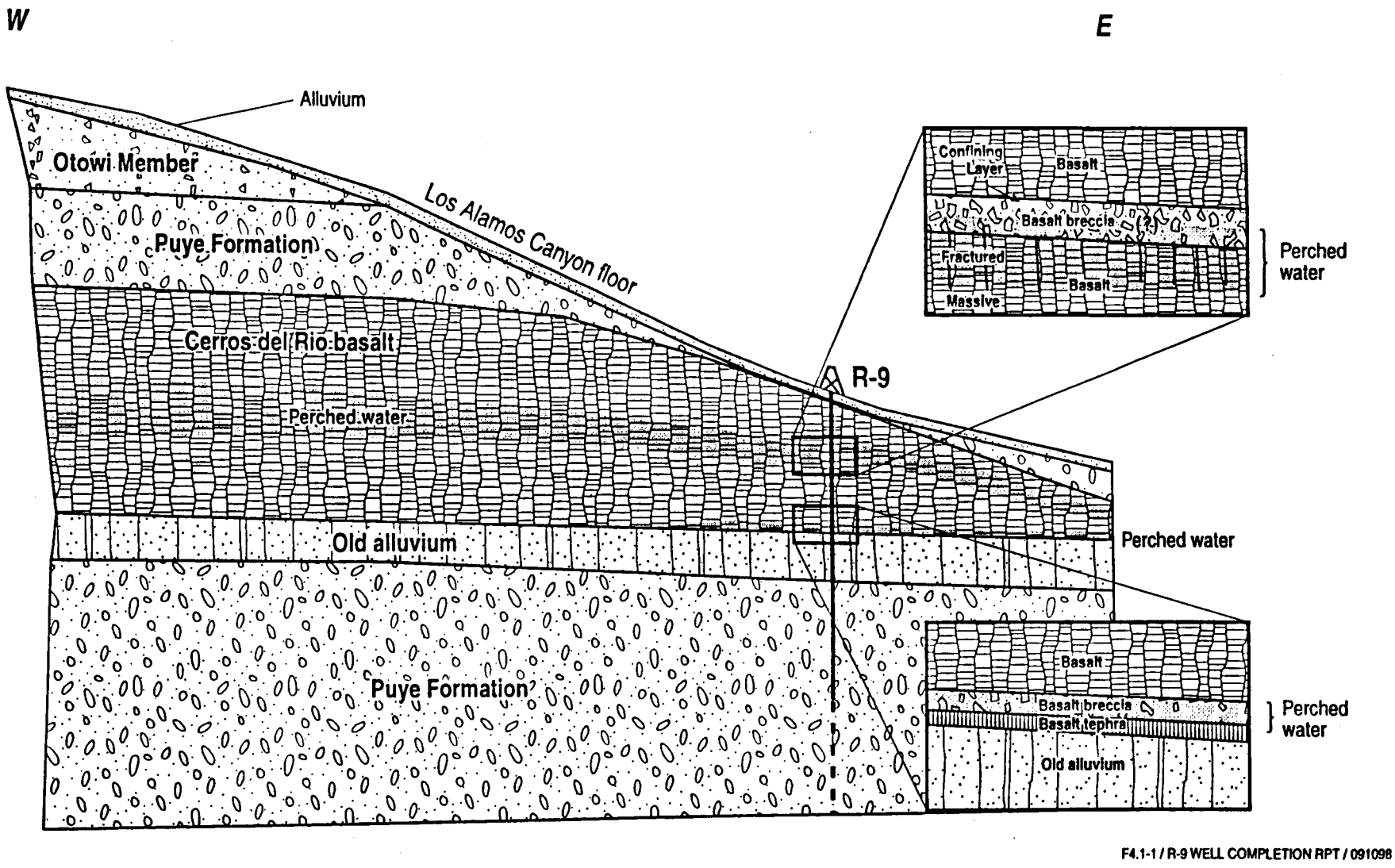


Figure 4.1-1. Setting of perched water in the basaltic rocks of the Cerros del Rio volcanic field in R-9.

5.0 SAMPLING AND ANALYSIS

5.1 Contaminant Characterization of Core and Cuttings

Samples of core and cuttings were collected and analyzed for Resource Conservation and Recovery Act (RCRA) metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and radionuclides. Results of chemical and radiochemical analyses are used to determine both naturally-occurring elements and contaminant distributions. Contaminants of concern in upper Los Alamos Canyon include americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-235; and uranium-238 (LANL 1995, 50290).

5.1.1 Methods

Fifteen samples of core and cuttings were collected for geochemical and contaminant characterization. Five samples of cuttings were collected from the following depth intervals: 41 to 50.5 ft, 50.5 to 55.5 ft, 172 to 178.5 ft, 568 to 569.7 ft, and 570 to 571.5 ft. Ten samples of core were collected from the following depth intervals: 181.1 to 182.5 ft, 185.3 to 187 ft, 205 to 206 ft, 230.4 to 231.3 ft, 236.5 to 237.3 ft, 237.3 to 238.1 ft, 268.5 to 270.8 ft, 280.5 to 281 ft, 291.2 to 292.6 ft, and 582 to 583.5 ft. Approximately 500 to 1000 g of core and cuttings samples were placed in appropriate sample jars in protective plastic bags before being shipped to analytical laboratories. The locations of the samples and the stratigraphic units from which they were collected are shown in the column labeled "Field Analytical Sample Number" in Appendix B.

Samples of core and cuttings were analyzed using a variety of analytical methods specified by the EPA (1997, 57589). Field screening for VOCs was conducted using a photoionization detector instrument. No VOCs were detected with the field instrument. Solid samples were partially digested using hot HNO_3 (EPA method 3050) before metal analyses. Samples of core and cuttings were shipped to Paragon Analytics, Inc., in Fort Collins, Colorado, for metal and radionuclide analyses. Analyses for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, vanadium, and zinc were determined by inductively coupled plasma emission spectroscopy (ICPES). Concentrations of uranium, using an ICPES method, were biased high in the core and groundwater samples because of matrix interference from iron. Therefore, uranium concentrations determined from ICPES are not included in this report for either core or groundwater samples. Mercury content was analyzed for using cold vapor atomic absorption (CVAA). Core samples were washed with deionized water for 16 hours before anion analyses of the leachate. Sulfate, fluoride, bromide, sulfate, nitrate, and chloride contents were determined by ion chromatography (IC). Cyanide content was determined by colorimetry. The precision limits for analysis of major anions and trace elements were generally $\pm 10\%$. The occurrence of VOCs and SVOCs was analyzed for using gas chromatography-mass spectrometry by RECRA Weston.

Radionuclide activities in core samples were determined by alpha spectrometry (americium-241; plutonium-238; plutonium-239,240; uranium-234; uranium-235; and uranium-238), gamma spectrometry (cesium-137 and other isotopes), and gas proportional counting (strontium-90) at Paragon Analytics, Inc. Sample duplicates were collected and analyzed in accordance with EPA procedures (EPA 1997, 57589).

5.1.2 Results

Radionuclides (including americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; uranium-235; and uranium-238) were discharged into Los Alamos Canyon beginning in the early 1940s. Accordingly, distributions of these radionuclides in R-9 are addressed in this section.

Table 5.1-1 provides a summary of radionuclide distributions within the Cerros del Rio basalt and the Puye Formation. Isotopes of uranium (uranium-234, uranium-235, and uranium-238) were detected at activities less than 1 pCi/g in most core samples. These low activities are consistent with low concentrations of naturally occurring radionuclides (e.g., uranium isotopes) in basalt and suggest that little if any Laboratory contamination is present in these samples. Further comparisons with background data will be made when ongoing background studies for basalts are completed. Activities of americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 generally are less than minimum detectable activity in the samples of core and cuttings, indicating that no Laboratory-derived contamination is detectable in these samples.

Samples of core and cuttings were analyzed for metals including copper, iron, manganese, nickel, and zinc; however, they are not contaminants of concern in upper Los Alamos Canyon. Transition metals, including cobalt, copper, iron, manganese, and nickel, occur naturally within the basalt flows (concentrated within oxide and silicate minerals) at concentrations above those for the Bandelier Tuff. Background distributions of metals within basalt are being assessed and will be added to the Laboratory background data set.

No VOCs or SVOCs were detected in the two cuttings samples collected from depths of 41 to 50.5 ft and 50.5 to 55.5 ft, indicating that no Laboratory-derived contamination for organic compounds is detectable in these samples.

5.2 Water Quality Determinations

Groundwater samples were collected from the six saturated zones encountered in R-9. Samples were analyzed for inorganic and organic chemicals and radionuclides to determine natural solute and contaminant distributions within the different saturated zones.

Telescoping casing and bentonite seals isolated individual groundwater zones from one another so that representative water samples could be collected. In addition, these seals prevented downward migration of potential contaminants to deeper perched zones and to the regional aquifer.

5.2.1 Methods

Groundwater samples for inorganic and organic chemicals and radionuclides were collected using a stainless steel bailer. Temperature, dissolved oxygen, turbidity, pH, and specific conductance were determined on site from an aliquot collected during field sampling. Both filtered and nonfiltered samples were collected for chemical and radiochemical analyses. Groundwater samples were collected for analyses of dissolved organic carbon, stable isotopes of hydrogen and oxygen, major cations and anions, metals, and radionuclides. Aliquots of the samples were pressure-filtered through a 0.45-µm Gelman filter and acidified with ultrapure HNO_3 to a pH of 2.0 or less before metal and radionuclide analyses. All groundwater samples collected in the field were stored at 4°C until they were analyzed. Alkalinity was determined in the laboratory using standard titration techniques.

TABLE 5.1-1

RADIONUCLIDE ACTIVITIES IN SAMPLES OF CORE AND CUTTINGS FROM R-9[a,b]

Depth (ft)	41–50.5	50.5–55.5	172–178.5	181.1–182.5	185.3–187	205–206	230.4–231.3	236.5–237.3
Geologic Unit	CR basalt[c]	CR basalt	CR basalt	CR basalt	CR basalt	CR basalt	CR basalt	CR basalt
Strontium-90[d]	0.04 ± 0.39	0.30 ± 0.43	0.43 ± 0.50	0.03 ± 0.47	0.18 ± 0.47	0.22 ± 0.53	0.10 ± 0.49	0.06 ± 0.50
Cesium-137	0.007 ± 0.052	-0.035 ± 0.050	-0.019 ± 0.041	-0.036 ± 0.061	0.017 ± 0.065	-0.008 ± 0.033	0.019 ± 0.039	0.112 ± 0.075
Plutonium-238	0.0094 ± 0.0130	0.0088 ± 0.0170	-0.0071 ± 0.0132	0.0095 ± 0.00158	0.0036 ± 0.0118	-0.0039 ± 0.0110	-0.0071 ±0.0096	-0.0125 ± 0.0102
MDA[e]	0.025	0.036	0.044	0.033	0.011	0.033	0.030	0.039
Plutonium-239,240	-0.0006 ± 0.0090	0.0077 ± 0.0142	0.0085 ± 0.0150	0.0100 ± 0.0112	0.0167 ± 0.0162	0.0034 ± 0.0110	0.0089 ± 0.0102	0.0138 ± 0.0158
MDA	0.022	0.030	0.032	0.017	0.022	0.010	0.0089	0.028
Americium-241	0.127 ± 0.040	0.0104 ± 0.0104	0.0190 ± 0.0154	0.078 ± 0.030	0.038 ± 0.024	0.038 ± 0.024	0.077 ± 0.032	0.052 ± 0.026
MDA	0.017	0.0078	0.0095	0.027	0.026	0.036	0.031	0.028
Uranium-234	0.205 ± 0.060	0.336 ± 0.082	0.221 ± 0.066	0.236 ± 0.066	0.138 ± 0.048	0.257 ± 0.070	0.393 ± 0.094	0.415 ± 0.096
MDA	0.029	0.031	0.033	0.043	0.031	0.035	0.041	0.037
Uranium-235	0.0190 ± 0.0168	0.030 ± 0.022	0.025 ± 0.022	0.026 ± 0.020	0.0081 ± 0.0128	0.029 ± 0.022	0.026 ± 0.022	0.0198 ± 0.0184
MDA	0.011	0.019	0.022	0.019	0.026	0.026	0.023	0.021
Uranium-238	0.259 ± 0.068	0.248 ± 0.068	0.246 ± 0.070	0.279 ± 0.072	0.184 ± 0.056	0.313 ± 0.078	0.383 ± 0.092	0.402 ± 0.092
MDA	0.027	0.033	0.022	0.029	0.034	0.024	0.013	0.030
Gross Alpha	1.0 ± 1.1	1.5 ± 1.2	0.62 ± 0.81	3.4 ± 1.5	3.0 ± 1.6	3.6 ± 1.8	2.9 ± 1.8	2.7 ± 1.7
Gross Beta	-0.07 ± 1.3	0.87 ± 1.6	0.06 ± 0.96	1.8 ± 1.4	2.3 ± 1.7	1.2 ± 1.8	2.0 ± 1.7	2.3 ± 1.7
Gross Gamma	2.30 ± 0.22	2.20 ± 0.23	2.10 ± 0.25	3.35 ± 0.36	3.12 ± 0.36	3.87 ± 0.36	3.86 ± 0.33	5.68 ± 0.47
MDA	0.25	0.26	0.32	0.44	0.46	0.38	0.30	0.41

a. pCi/g

b. Error of two standard deviations is reported

c. CR basalt = Cerros del Rio basalt

d. Radionuclides and parameters analyzed by Paragon Analytics, Inc.

e. MDA = minimum detectable activity

TABLE 5.1-1 (continued)

RADIONUCLIDE ACTIVITIES IN SAMPLES OF CORE AND CUTTINGS FROM R-9[a,b]

Depth (ft)	237.3–238.1	268.5–270.8	280.5–281	291.2–292.6	568–569.7	570–571.5	582–583.5
Geologic Unit	CR basalt[c]	CR basalt	CR basalt	Old alluvium[d]	Puye Fm.[e]	Puye Fm.	Puye Fm.
Strontium-90[f]	0.04 ± 0.47	0.11 ± 0.45	0.27 ± 0.43	0.11 ± 0.65	0.84 ± 0.47	-0.04 ± 0.42	-0.22 ± 0.34
Cesium-137	-0.008 ± 0.046	-0.010 ± 0.042	-0.006 ± 0.035	0.039 ± 0.050	0.026 ± 0.049	0.002 ± 0.036	-0.080 ± 0.069
Plutonium-238	0.0044 ± 0.0156	0.0107 ± 0.0184	0.0147 ± 0.0184	0.0032 ± 0.0160	-0.006 ± 0.022	0.027 ± 0.024	0.0069 ± 0.0188
MDA[g]	0.037	0.038	0.035	0.039	0.058	0.039	0.043
Plutonium-239,240	0.0069 ± 0.0112	0.0017 ± 0.0110	0.0005 ± 0.0080	0.0102 ± 0.0130	0.0007 ± 0.0108	0.0014 ± 0.0110	0.0038 ± 0.0124
MDA	0.022	0.029	0.018	0.023	0.026	0.030	0.011
Americium-241	0.037 ± 0.024	0.032 ± 0.024	0.0164 ± 0.0156	0.0139 ± 0.0168	0.0011 ± 0.0086	0.0000 ± 0.078	-0.0069 ± 0.0086
MDA	0.033	0.036	0.023	0.031	0.024	0.023	0.031
Uranium-234	0.391 ± 0.090	0.476 ± 0.110	0.634 ± 0.136	0.993 ± 0.156	0.752 ± 0.108	0.752 ± 0.108	0.660 ± 0.116
MDA	0.038	0.037	0.037	0.027	0.023	0.021	0.029
Uranium-235	0.039 ± 0.026	0.0087 ± 0.0148	0.036 ± 0.028	0.050 ± 0.026	0.047 ± 0.020	0.046 ± 0.022	0.0204 ± 0.0172
MDA	0.020	0.024	0.027	0.022	0.0067	0.018	0.024
Uranium-238	0.521 ± 0.108	0.356 ± 0.092	0.704 ± 0.144	0.952 ± 0.152	0.822 ± 0.128	0.766 ± 0.120	0.650 ± 0.116
MDA	0.024	0.037	0.031	0.027	0.016	0.013	0.026
Gross Alpha	2.1 ± 1.4	2.8 ± 1.8	3.1 ± 1.5	6.4 ± 1.7	3.3 ± 1.3	1.5 ± 1.9	5.1 ± 1.7
Gross Beta	1.9 ± 1.5	2.1 ± 1.9	1.66 ± 0.98	4.1 ± 1.2	2.1 ± 1.1	1.7 ± 1.8	2.5 ± 1.1
Gross Gamma	4.54 ± 0.39	3.87 ± 0.32	4.36 ± 0.36	5.95 ± 0.47	6.41 ± 0.58	6.01 ± 0.51	4.98 ± 0.48
MDA	0.36	0.29	0.32	0.37	0.54	0.43	0.53

a. pCi/g
b. Error of two standard deviations is reported.
c. CR basalt = Cerros del Rio basalt
d. Old alluvium = old alluvium facies of the Puye Formation
e. Puye Fm. = fanglomerate facies of the Puye Formation
f. Radionuclides and parameters analyzed by Paragon Analytics, Inc.
g. MDA = minimum detectable activity

Filtered and nonfiltered groundwater samples were analyzed for different suites of chemicals, including major ions, trace elements, trace metals, stable isotopes, radionuclides, and organic compounds. Groundwater samples were analyzed using a variety of laboratory techniques specified in EPA SW-846 (EPA 1997, 57589) including IC for bromide, chloride, fluoride, nitrate, nitrite, phosphate, and sulfate; graphite furnace atomic absorption (GFAA); colorimetry for total organic carbon; CVAA and ICPES for aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, strontium, thallium, tin, titanium, vanadium, and zinc. Concentrations of ammonium were determined by using a specific ion electrode. Results of chemical analyses for inorganic species (major cations and anions, trace elements, and trace metals) and radionuclides are provided in Tables 5.2-1, 5.2-2, and 5.2-3.

Radionuclide activity in groundwater was determined by liquid scintillation counting (LSC) for tritium; electrolytic enrichment for low-level tritium; laser-induced kinetic phosphorimetry analysis (LIKPA) for uranium; thermal ionization mass spectrometry (TIMS) for uranium isotopes and total uranium; alpha spectrometry for americium, plutonium, and uranium isotopes; gamma spectrometry for cesium-137 and other isotopes; and gas proportional counting for strontium-90. This work was performed by contract laboratories (Paragon Analytics, Inc., Teledyne, and University of Miami) and by CST-7 for TIMS analysis of uranium.

Sample duplicates, laboratory blanks, and field blanks were collected and analyzed in accordance with EPA and Laboratory procedures. The precision limits for major ions and trace elements were generally ±10%.

Groundwater samples were analyzed for VOCs and SVOCs using gas chromatography and gas chromatography-mass spectrometry through RECRA Weston. Identifiable organic compounds were not detected in the groundwater samples. No organic compounds, except oxalate, have been identified as contaminants of concern in Los Alamos Canyon (LANL 1995, 50290).

The following sections focus primarily on inorganic and radionuclide distributions in groundwater encountered in R-9.

5.2.2 Results

5.2.2.1 Quality of Groundwater within Cerros del Rio Basalt

Field-measured parameters for the borehole groundwater samples, including pH, temperature, specific conductance, and turbidity, are provided in Table 5.2-4. These parameters were measured at the time of sample collection when groundwater was in contact with the atmosphere. Dissolved oxygen (DO) was also measured; however, DO values are not reported because of potential atmospheric contamination with the electrode and interferences from suspended particles contributing to very high turbidity values.

The water in the upper perched zone in Cerros del Rio basalt at a depth of 180 ft is characterized by a sodium-calcium-chloride-bicarbonate ionic composition with a pH value of 8.30 (Figure 5.2-1 and Table 5.2-4). The water in the lower perched zone in Cerros del Rio basalt at a depth of 275 ft is characterized by a sodium-sulfate-bicarbonate ionic composition with a pH value of 8.79 (Figure 5.2-1 and Table 5.2-2). Water in the lower zone has a higher TDS content (389 ppm) than that in the upper zone (252 ppm), possibly reflecting a longer groundwater residence time.

TABLE 5.2-1

QUALITY OF GROUNDWATER SAMPLES COLLECTED AT R-9[a,b]

Part 1						
Depth (ft)	180	180	275	275	579	579
Geologic Unit	CR basalt[c]	CR basalt	CR basalt	CR basalt	Puye Fm.[d]	Puye Fm.
Sample Treatment	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Date Sampled	10/06/97	10/06/97	10/16/97	10/16/97	12/18/97	12/18/97
Ag	<0.001	<0.001	<0.001	0.08 ± 0.01	<0.001	<0.001
Al	0.13 ± 0.01	282 ± 3	0.27 ± 0.01	1129 ± 20	0.08 ± 0.01	14.9 ± 0.1
As	0.0008	0.017	0.0013	0.077	0.0004	0.0012
B	0.023 ± 0.002	0.15 ± 0.01	<0.01	1.16 ± 0.02	0.030 ± 0.001	0.048 ± 0.003
Ba	0.017 ± 0.002	1.34 ± 0.02	0.005 ± 0.002	7.23 ± 0.02	0.064 ± 0.001	0.19 ± 0.01
Be	<0.002	0.018 ± 0.002	<0.002	0.067 ± 0.002	<0.002	<0.002
Br	0.16	0.16	0.10	0.08	0.20	0.19
Ca	14.1 ± 0.1	91 ± 0.6	2.91 ± 0.07	1090 ± 10	25.4 ± 0.2	34.1 ± 0.1
Cd	0.0004 ± 0.0002	0.0004 ± 0.0002	0.001 ± 0.0002	0.0053 ± 0.0005	<0.0002	0.0006 ± 0.0002
Cl	29.2	29.5	25.5	26.3	13.2	13.2
ClO_3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.002	0.022 ± 0.002	<0.002	1.11 ± 0.02	<0.002	0.003 ± 0.002
CO_3	0	0	7.0	32.6	0	0
Cr	<0.002	0.12 ± 0.01	0.002 ± 0.002	1.22 ± 0.01	<0.002	0.012 ± 0.002
Cs	<0.002	0.020 ± 0.002	<0.002	0.047 ± 0.002	<0.002	0.002 ± 0.002
Cu	0.004 ± 0.002	0.27 ± 0.02	0.017 ± 0.002	11.3 ± 0.1	<0.002	0.012 ± 0.002
F	0.71	0.67	1.27	1.38	0.74	0.74
Fe	0.06 ± 0.01	142 ± 1	0.19 ± 0.01	1460 ± 30	0.06 ± 0.01	9.76 ± 0.2
HCO_3	78.5	93.0	105	400	110	117
Hg	<0.00005	0.00045	<0.00005	0.00035	<0.00005	<0.00005
I	0.17	0.17	<0.01	e	<0.01	<0.01

a. The data in this table should be used only for screening purposes.
b. ppm
c. CR basalt = Cerros del Rio basalt
d. Puye Fm. = fanglomerate facies of the Puye Formation
e. Not determined

TABLE 5.2-1 (continued)

QUALITY OF GROUNDWATER SAMPLES COLLECTED AT R-9[a,b]

Part 1 (continued)						
Depth (ft)	180	180	275	275	579	579
Geologic Unit	CR basalt[c]	CR basalt	CR basalt	CR basalt	Puye Fm.[d]	Puye Fm.
Sample Treatment	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Date Sampled	10/06/97	10/06/97	10/16/97	10/16/97	12/18/97	12/18/97
K	4.54 ± 0.03	30.6 ± 0.1	5.22 ± 0.02	105 ± 1	2.93 ± 0.02	3.94 ± 0.01
Li	<0.01	0.23 ± 0.01	0.02 ± 0.01	0.68 ± 0.01	0.03 ± 0.01	0.04 ± 0.01
Mg	5.29 ± 0.02	46.2 ± 0.2	1.18 ± 0.01	1083 ± 15	1.24 ± 0.01	4.80 ± 0.06
Mn	0.051 ± 0.001	1.98 ± 0.01	0.013 ± 0.002	31.5 ± 0.3	0.041 ± 0.001	0.33 ± 0.01
Mo	0.025 ± 0.002	0.038 ± 0.002	0.10 ± 0.01	0.34 ± 0.01	0.028 ± 0.002	0.02 ± 0.002
Na	26.1 ± 0.2	51.8 ± 0.1	100 ± 1	400 ± 5	29.8 ± 0.1	29.3 ± 0.1
NH_4	0.03	0.03	0.02	1.34	0.09	0.08
NO_3	<0.02	<0.02	3.61	2.83	10.6	10.7
Pb	<0.002	0.10 ± 0.01	<0.002	0.63 ± 0.01	<0.002	0.01 ± 0.001
PO_4	0.14	0.11	0.61	0.99	<0.05	<0.05
Rb	0.009 ± 0.002	0.27 ± 0.01	0.01 ± 0.002	0.76 ± 0.02	0.005 ± 0.002	0.008 ± 0.002
S_2O_3	<0.01	<0.01	<0.02	e	<0.05	<0.05
Sb	0.0002	0.0013	0.0012	0.0017	0.0002	0.0010
Se	<0.0002	0.0012	0.0015	0.0017	<0.0001	<0.001
Si	14.1 ± 0.3	120 ± 1	10.4 ± 0.1	230 ± 2	17.2 ± 0.2	51.4 ± 0.3
Sn	<0.005	<0.005	<0.005	<0.01	<0.005	<0.005
SO_4	8.09	8.01	53.8	60.2	12.4	12.1
Sr	0.093 ± 0.002	0.91 ± 0.01	0.033 ± 0.002	13.5 ± 0.1	0.29 ± 0.01	0.36 ± 0.01
Ti	<0.002	3.77 ± 0.01	0.006 ± 0.002	24.0 ± 0.1	<0.002	0.64 ± 0.01
Tl	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
U	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

a. The data in this table should be used only for screening purposes.
b. ppm
c. CR basalt = Cerros del Rio basalt
d. Puye Fm. = fanglomerate facies of the Puye Formation
e. Not determined

TABLE 5.2-1 (continued)

QUALITY OF GROUNDWATER SAMPLES COLLECTED AT R-9[a,b]

Part 1 (continued)						
Depth (ft)	180	180	275	275	579	579
Geologic Unit	CR basalt[c]	CR basalt	CR basalt	CR basalt	Puye Fm.[d]	Puye Fm.
Sample Treatment	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Date Sampled	10/06/97	10/06/97	10/16/97	10/16/97	12/18/97	12/18/97
V	<0.002	0.16 ± 0.01	0.004 ± 0.002	1.04 ± 0.01	0.002 ± 0.002	0.009 ± 0.001
Zn	0.01 ± 0.01	0.61 ± 0.01	<0.01	3.17 ± 0.02	0.09 ± 0.01	0.02 ± 0.01
Charge Balance (%)	3.83	N/A[e]	8.44	N/A	-0.35	N/A
Temp. (Laboratory, °C)	12.3	12.3	13.2	13.2	15.7	15.7
Cond. (Laboratory, µS/cm)	250	256	457	512	273	273
TDS[f]	252.2	1557.5	388.8	11821.4	329.7	544.1
TSS[g]	h	med	h	high	h	low
Hardness ($CaCO_3$)	57.0	417	12.1	7182	68.5	105
Alkalinity (Laboratory, $CaCO_3$)	64.3	76.2	97.7	38.2	90.2	95.9
pH (Field, standard units)	8.30	8.30	8.79	8.79	7.9	7.9
pH (Laboratory, standard units)	8.02	7.49	8.79	9.09	8.07	8.07
SiO_2 (Calculated)	30.2	257	22.3	492	36.8	110
Oxalate			3.03	2.74	<0.02	<0.02
Acetate	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Formate	0.02	0.02	0.04	0.08	0.03	0.04

a. The data in this table should be used only for screening purposes.
b. ppm
c. CR basalt = Cerros del Rio basalt
d. Puye Fm. = fanglomerate facies of the Puye Formation
e. N/A = not applicable
f. TDS = total dissolved solids
g. TSS = total suspended solids
h. Not determined

TABLE 5.2-1 (continued)

QUALITY OF GROUNDWATER SAMPLES COLLECTED AT R-9[a,b]

Part 2						
Depth (ft)	615	615	624	624	688	688
Geologic Unit	Puye Fm.[c]	Puye Fm.	Puye Fm.	Puye Fm.	SF basalt[d]	SF basalt
Sample Treatment	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Date Sampled	01/12/98	01/12/98	01/14/98	01/14/98	01/20/98	01/20/98
Ag	<0.001	0.005	<0.001	0.002 ± 0.001	<0.001	0.01 ± 0.002
Al	0.17 ± 0.01	543 ± 1	0.43 ± 0.01	193 ± 5	<0.02	196 ± 2
As	0.0002	0.102	0.0018	0.014	0.0025	0.019
B	0.047 ± 0.001	0.20 ± 0.01	0.041 ± 0.003	0.10 ± 0.01	0.046 ± 0.001	0.064 ± 0.002
Ba	0.060 ± 0.001	5.08 ± 0.03	0.028 ± 0.001	0.90 ± 0.01	0.045 ± 0.001	1.38 ± 0.01
Be	<0.002	0.032 ± 0.001	<0.002	0.008 ± 0.001	<0.002	0.003 ± 0.001
Br	0.25	0.24	0.15	0.15	0.05	0.04
Ca	25.1 ± 0.1	611 ± 1	16.6 ± 0.1	139 ± 2	27.1 ± 0.6	132 ± 1
Cd	<0.0002	0.0061 ± 0.0002	<0.0002	0.0008 ± 0.0002	<0.0002	0.012 ± 0.001
Cl	177	180	20.2	20.3	7.67	7.57
ClO_3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co	<0.002	0.24 ± 0.01	<0.002	0.052 ± 0.002	<0.002	0.11 ± 0.01
CO_3	0	0	0	0	9.2	9.8
Cr	<0.002	1.65 ± 0.03	<0.002	0.13 ± 0.01	<0.002	0.24 ± 0.01
Cs	<0.002	0.029 ± 0.004	<0.002	0.003 ± 0.002	<0.002	0.003 ± 0.002
Cu	0.010 ± 0.002	1.38 ± 0.03	0.003 ± 0.002	0.14 ± 0.01	0.003 ± 0.002	0.82 ± 0.01
F	0.42	0.42	0.56	0.56	0.30	0.32
Fe	0.18 ± 0.01	1051 ± 13	0.43 ± 0.01	121 ± 2	0.01 ± 0.01	170 ± 2
HCO_3	133	910	76.0	177	118	117
Hg	0.00005	0.00038	<0.00005	0.00008	<0.00005	<0.00005
I	0.011	0.015	<0.005	0.005	<0.005	<0.005

a. The data in this table should be used only for screening purposes.
b. ppm
c. Puye Fm. = fanglomerate facies of the Puye Formation
d. SF basalt = Santa Fe Group basalt

TABLE 5.2-1 (continued)

QUALITY OF GROUNDWATER SAMPLES COLLECTED AT R-9[a,b]

Part 2 (continued)						
Depth (ft)	615	615	624	624	688	688
Geologic Unit	Puye Fm.[c]	Puye Fm.	Puye Fm.	Puye Fm.	SF basalt[d]	SF basalt
Sample Treatment	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Date Sampled	01/12/98	01/12/98	01/14/98	01/14/98	01/20/98	01/20/98
K	24.2 ± 0.1	92.4 ± 2.0	2.95 ± 0.01	12.2 ± 0.1	3.87 ± 0.01	10.8 ± 0.1
Li	0.03 ± 0.01	0.44 ± 0.01	<0.01	0.12 ± 0.01	0.03 ± 0.01	0.10 ± 0.01
Mg	1.06 ± 0.01	147 ± 1	0.26 ± 0.01	46.1 ± 0.5	4.09 ± 0.06	60.3 ± 0.5
Mn	0.24 ± 0.01	21.5 ± 0.1	0.03 ± 0.01	2.83 ± 0.02	0.05 ± 0.01	2.88 ± 0.02
Mo	0.05 ± 0.01	0.39 ± 0.01	0.04 ± 0.004	0.04 ± 0.01	0.007 ± 0.002	0.007 ± 0.002
Na	167 ± 3	215 ± 1	41 ± 0.1	45 ± 0.2	20.1 ± 0.5	46.3 ± 0.1
NH_4	0.23	0.94	0.04	0.04	0.06	0.14
NO_3	3.41	<0.02	8.66	7.36	3.42	3.31
Pb	<0.002	2.05 ± 0.01	0.006 ± 0.002	0.12 ± 0.03	<0.002	0.14 ± 0.02
PO_4	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Rb	0.011 ± 0.002	0.37 ± 0.02	0.004 ± 0.002	0.077 ± 0.005	0.004 ± 0.002	0.006 ± 0.002
S_2O_3	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01
Sb	0.0003	0.0007	0.0003	0.0003	0.0003	0.0010
Se	<0.0001	0.0007	<0.0001	<0.0001	<0.0001	<0.0001
Si	4.23 ± 0.03	117 ± 1	9.44 ± 0.07	176 ± 4	31.6 ± 0.1	219 ± 2
Sn	<0.005	<0.005	<0.005	<0.005	0.005 ± 0.005	0.034 ± 0.005
SO_4	64.7	65.8	27.2	29.4	6.37	6.34
Sr	0.28 ± 0.01	4.78 ± 0.04	0.19 ± 0.01	1.52 ± 0.01	0.21 ± 0.01	1.32 ± 0.01
Ti	0.003 ± 0.001	1.99 ± 0.02	0.005 ± 0.001	1.96 ± 0.01	<0.002	4.76 ± 0.10
Tl	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
U	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

a. The data in this table should be used only for screening purposes.
b. ppm
c. Puye Fm. = fanglomerate facies of the Puye Formation
d. SF basalt = Santa Fe Group basalt

TABLE 5.2-1 (continued)

QUALITY OF GROUNDWATER SAMPLES COLLECTED AT R-9[a,b]

Part 2 (continued)						
Depth (ft)	615	615	624	624	688	688
Geologic Unit	Puye Fm.[c]	Puye Fm.	Puye Fm.	Puye Fm.	SF basalt[d]	SF basalt
Sample Treatment	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Date Sampled	01/12/98	01/12/98	01/14/98	01/14/98	01/20/98	01/20/98
V	<0.002	0.40 ± 0.01	0.003 ± 0.002	0.12 ± 0.01	0.005 ± 0.001	0.14 ± 0.01
Zn	0.03 ± 0.01	3.85 ± 0.01	<0.01	0.35 ± 0.01	<0.01	0.76 ± 0.01
Charge Balance (%)	6.77	N/A[e]	8.46	N/A	0.63	N/A
Temp. (Laboratory,°C)	17.2	17.2	15.3	15.3	17.9	17.9
Cond. (Laboratory, µS/cm)	987	1068	281	321	259	266
TDS[f]	550.5	4684.1	276.9	1740.5	386.7	2082.6
TSS[g]	h	high	h	med	h	med
Hardness ($CaCO_3$)	67.0	2131	42.5	537	84.5	578
Alkalinity (Laboratory, $CaCO_3$)		746		145		
pH (Field, standard units)	6.95	6.95	8.32	8.32	8.07	8.07
pH (Laboratory, standard units)	7.53	7.66	9.16	9.16	8.01	8.04
SiO_2 (Calculated)	9.1	250	20.2	377	67.6	469
Oxalate	2.85	2.71	0.48	0.47	0.30	0.41
Acetate	i	i	i	i	i	i
Formate	i	i	i	i	i	i

a. The data in this table should be used only for screening purposes.
b. ppm
c. Puye Fm. = fanglomerate facies of the Puye Formation
d. SF basalt = Santa Fe Group basalt
e. N/A = not applicable
f. TDS = total dissolved solids
g. TSS = total suspended solids
h. Not determined
i. Present, but in concentrations too low to quantify

TABLE 5.2-2

FIELD-MEASURED PARAMETERS FOR GROUNDWATER SAMPLES COLLECTED AT R-9

Geologic Unit	Depth (ft)	Date Sampled	pH	Temperature (°C)	Specific Cond. (µSi/cm)	Turbidity (NTU)[a]
Cerros del Rio basalt	180	10/06/97	8.30	9.2	223	17
	275	10/16/97	8.79	13.2	443	b
Puye Formation	579	12/18/97	7.90	15.7	385	142
	615	01/12/98	6.95	17.2	1080	b
	624	01/14/98	8.32	15.2	219	190
Santa Fe Group basalt	688	01/20/98	8.07	17.9	222	b

a. NTU = nephelometric turbidity unit

b. Off the scale because of very high turbidity values for open borehole groundwater samples

TABLE 5.2-3

RADIONUCLIDE ACTIVITIES IN SAMPLES OF NONFILTERED GROUNDWATER FROM R-9[a,b]

Depth (ft)	180	275	579	615	624	688
Geologic Unit	CR basalt[c]	CR basalt	Puye Fm.[d]	Puye Fm.	Puye Fm.	SF basalt[e]
Date Sampled	10/6/97	10/16/97	12/18/97	01/12/98	01/14/98	01/20/98
Tritium[f]	347 ± 25	106 ± 7	2.71 ± 0.58	30.3 ± 1.9	13.93 ± 0.90	14.43 ± 0.96
Strontium-90	0.47 ± 0.28	0.52 ± 0.64	-0.42 ± 0.66	-0.23 ± 0.68	-0.17 ± 0.64	0.36 ± 0.67
Cesium-137	-0.381 ± 2.420	1.39 ± 2.44	-0.322 ± 2.680	-0.045 ± 2.130	-0.826 ±2.420	-0.381 ± 2.030
Plutonium-238	0.037 ± 0.044	0.76 ± 0.26	0.0156 ± 0.0194	0.006 ± 0.022	-0.0010 ± 0.0156	0.020 ± 0.028
MDA[g]	0.084	0.23	0.034	0.051	0.039	0.052
Plutonium-239, 240	0.031 ± 0.030	0.011 ± 0.062	-0.0074 ± 0.0130	0.000 ± 0.0154	0.0058 ± 0.0156	-0.0058 ± 0.0158
MDA	0.050	0.110	0.041	0.014	0.035	0.039
Americium-241	0.092 ± 0.046	0.106 ± 0.094	0 .029 ± 0.030	0.013 ± 0.024	0.010 ± 0.032	0.042 ± 0.034
MDA	0.047	0.160	0.052	0.051	0.074	0.051
Uranium-234	1.54 ± 0.28	7.94 ± 1.14	1.35 ± 0.22	5.06 ± 0.68	2.14 ± 0.32	2.05 ± 0.32
MDA	0.038	0.096	0.044	0.048	0.043	0.075
Uranium-235	0.043 ± 0.036	0.361 ± 0.158	0.055 ± 0.038	0.132 ± 0.056	0.120 ± 0.054	0.033 ± 0.034
MDA	0.038	0.074	0.05	0.041	0.046	0.058
Uranium-238	1.36 ± 0.26	6.60 ± 0.98	0.949 ± 0.180	2.81 ± 0.40	1.74 ± 0.028	1.47 ± 0.26
MDA	0.057	0.11	0.068	0.053	0.054	0.07
Total Uranium[h,j]	5.45 ± 0.75	112[i]	2.81 ± 0.38	25.08 ± 3.40	4.13 ± 0.57	2.03 ± 0.28
MDC[k]	0.10	0.1	0.10	0.10	0.10	0.10
Gross Alpha	304 ± 56	447 ± 98	1.9 ± 1.7	580 ± 180	270 ± 120	34 ± 35
Gross Beta	351 ± 58	730 ± 120	3.7 ± 1.8	820 ± 230	310 ± 100	113 ± 42
Gross Gamma	212 ± 23	266 ± 16	274 ± 21	340 ± 25	351 ± 25	237 ± 19
MDA	31	18	20	19	18	18

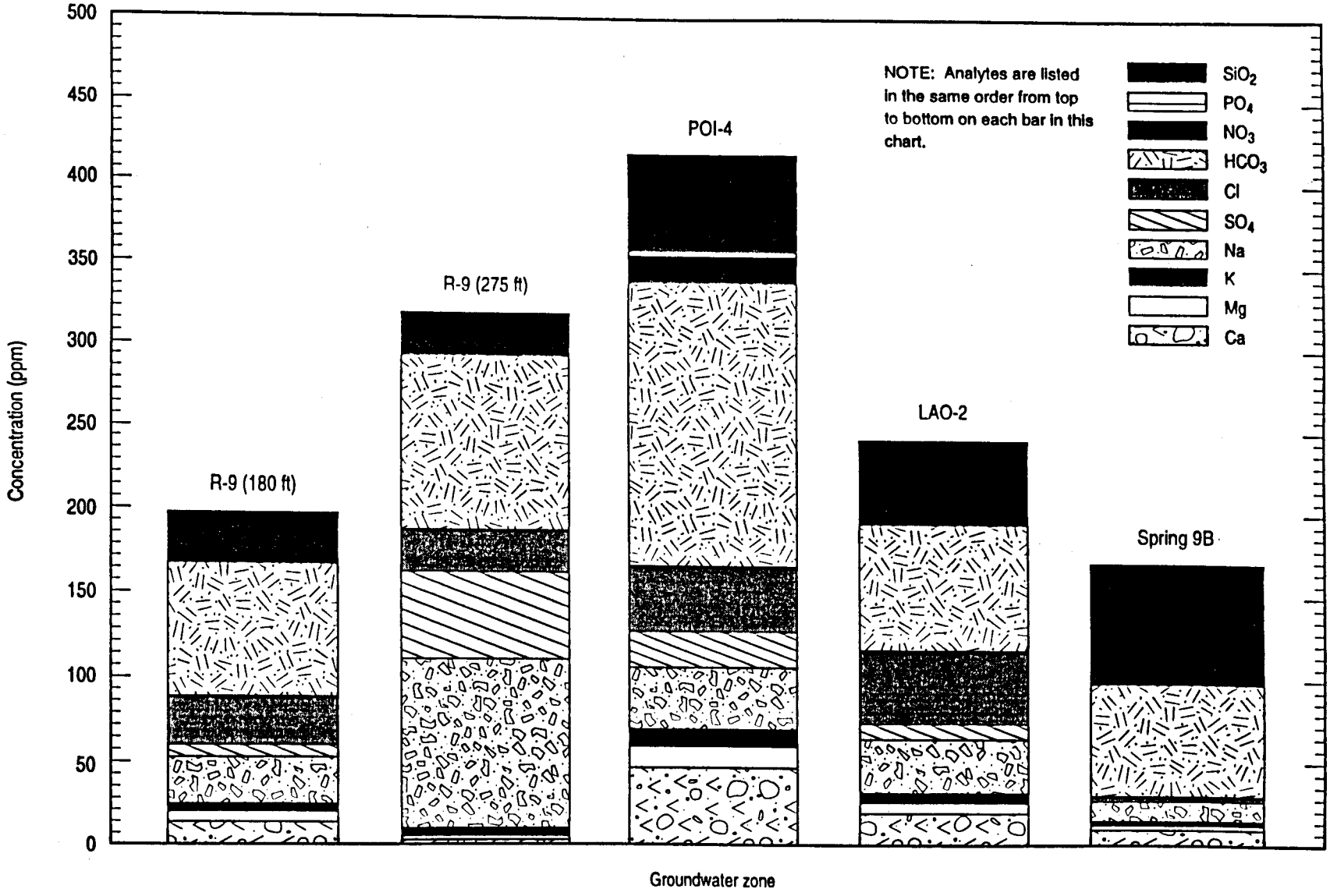
a. pCi/L
b. Error of two standard deviations is reported.
c. CR basalt = Cerros del Rio basalt
d. Puye Fm. = fanglomerate facies of the Puye Formation
e. SF basalt = Santa Fe Group basalt
f. Tritium analyzed by University of Miami; other radionuclides and parameters analyzed by Paragon Analytics, Inc.
g. MDA = minimum detectable activity
h. µg/L (KPA)
i. Samples were analyzed for uranium by LIKPA except for the sample collected from the 275-ft perched zone, which was analyzed by TIMS.
j. Analyzed by TIMS
k. MDC = minimum detectable concentration

TABLE 5.2-4

RADIONUCLIDE ACTIVITIES IN SAMPLES OF FILTERED GROUNDWATER FROM R-9[a,b]

Depth (ft)	180	275	579	615	624	688
Geologic Unit	CR basalt[c]	CR basalt	CR basalt	Puye Fm.[d]	Puye Fm.	SF basalt[e]
Date Sampled	10/6/97	10/16/97	12/18/97	01/12/98	01/14/98	01/20/98
Tritium[f]	(See Table 5.2-3 for results of tritium analyses for the six saturated zones.)					
Strontium-90	0.11 ± 0.25	No sample[g]	-0.14 ± 0.69	-0.21 ± 0.87	0.13 ± 0.63	-0.02 ± 0.84
Cesium-137	-0.176 ± 2.070	No sample	-0.837 ± 2.31	-0.688 ± 2.11	-1.43 ± 1.20	0.598 ± 2.180
Plutonium-238	0.039 ± 0.048	No sample	-0.001 ± 0.040	0.009 ± 0.024	0.000 ± 0.024	-0.025 ± 0.024
MDA[h]	0.093	No sample	0.086	0.058	0.062	0.065
Plutonium-239, 240	0.012 ± 0.024	No sample	-0.0015 ± 0.0134	0.028 ± 0.026	0.0080 ± 0.0162	0.0127 ± 0.0180
MDA	0.055	No sample	0.038	0.017	0.03	0.013
Americium-241	0.037 ± 0.030	No sample	0.0111 ± 0.0180	0.012 ± 0.022	0.019 ± 0.034	0.0135 ± 0.0182
MDA	0.037		0.036	0.044	0.069	0.031
Uranium-234	0.529 ± 0.142	No sample	1.018 ± 0.192	1.30 ± 0.22	0.688 ± 0.154	1.26 ± 0.22
MDA	0.070		0.052	0.050	0.068	0.038
Uranium-235	0.014 ± 0.028	No sample	0.042 ± 0.032	0.016 ± 0.026	0.030 ± 0.028	0.067 ± 0.040
MDA	0.064		0.037	0.052	0.036	0.032
Uranium-238	0.628 ± 0.156	No sample	0.870 ± 0.172	0.698 ± 0.146	0.449 ± 0.118	0.691 ± 0.148
MDA	0.060		0.055	0.047	0.048	0.042
Total Uranium[i,j]	1.22 ± 0.17	48.4[k]	2.08 ± 0.28	2.17 ± 0.30	1.41 ± 0.19	1.63 ± 0.22
MDC[l]	0.10	0.1	0.10	0.10	0.10	0.10
Gross Alpha	0.57 ± 0.65	No sample	0.7 ± 1.0	1.4 ± 1.3	1.20 ± 0.93	-0.1 ± 1.3
Gross Beta	3.9 ± 1.0	No sample	4.2 ± 1.7	17.2 ± 2.5	3.3 ± 1.5	2.0 ± 1.5
Gross Gamma	188 ± 30	No sample	274 ± 21	280 ± 21	178 ± 13	252 ± 19
MDA	45		18	17	12	18

a. pCi/L
b. Error of two standard deviations is reported.
c. CR basalt = Cerros del Rio basalt
d. Puye Fm. = fanglomerate facies of the Puye Formation
e. SF basalt = Santa Fe Group basalt
f. Tritium analyzed by University of Miami; other radionuclides and parameters analyzed by Paragon Analytics, Inc.
g. No sample = not enough water available for analysis
h. MDA = minimum detectable activity
i. µg/L (KPA)
j. Samples were analyzed for uranium by LIKPA except for the sample collected from the 275-ft perched zone, which was analyzed by TIMS.
k. Analyzed by TIMS
l. MDC = minimum detectable concentration



F5.2-1 / R-9 WELL COMPLETION RPT / 090898

Figure 5.2-1. Comparison of major ion and nutrient chemistry of Cerros del Rio basalt groundwater in R-9 with alluvial groundwater (well LAO-2) and intermediate-depth perched groundwater in basalt (well POI-4 and Spring 9B).

Water quality data for Spring 9B in White Rock Canyon is provided in Figure 5.2-1 as a point of reference for evaluating the water quality data collected from perched water zones in basalt. Spring 9B, which yields water with a calcium-sodium-bicarbonate ionic composition, is the only known spring on the Pajarito Plateau discharging water from basalt that does not contain elevated concentrations or activities of anthropogenic chemicals including chloride, nitrate, tritium, sulfate, and uranium. For example, activities of tritium are less than 1 pCi/L at Spring 9B. Concentrations of chloride are 1.93 ppm in Spring 9B (Longmire, unpublished data). Although perched groundwater in the basalts of R-9 and Spring 9B water have similar sodium and calcium bicarbonate ionic compositions, concentrations of chloride, sulfate, oxalate, and nitrate are higher in the R-9 groundwater (Figure 5.2-1).

The major-ion chemistry of the upper perched zone within the basalt is chemically similar to alluvial groundwater in well LAO-2 (Environmental Surveillance and Compliance Programs 1997, 56684) (Figure 5.2-1) which is located at the confluence of Los Alamos Canyon and DP Canyon (Figure1-1). The two perched groundwater zones within the Cerros del Rio basalt appear to contain a component of alluvial groundwater (LAO-2) based on the presence of above-background concentrations of chloride (29 ppm or mg/L) and tritium (347 pCi/L in the upper zone and 106 pCi/L in the lower zone). Stable isotope data also suggest that basalt groundwater is derived from a meteoric source(s) that recharges through the canyon floor (Table 5.2-5).

TABLE 5.2-5

STABLE ISOTOPIC DATA FOR NONFILTERED GROUNDWATER SAMPLES COLLECTED FROM R-9*

Saturated Zone (depth in ft)	δD (per mil)	$\delta^{18}O$ (per mil)
Basalt		
180	-73	-10.1
275	-74	-10.9
Puye Formation		
579	-70	-9.8
615	-72	-9.8
624	-90	-12.3
Santa Fe Group Basalt		
688	-75	-10.5

* The local meteoric line for the Jemez Mountains is $\delta D = 8 \times (\delta^{18}O) + 12$ (Blake et al. 1995, 49931). Precision values for D and ^{18}O are ± 1 per mil and ± 0.1 per mil, respectively. Isotopic analyses for δD and $\delta^{18}O$ are performed by Geochron Laboratories, Cambridge, Massachusetts.

The perched groundwater in the Cerros del Rio basalt in R-9 is chemically distinct from that found in a similar geologic setting in well POI-4 located in lower Pueblo Canyon (Figures 1-1 and 5.2-1). This suggests that the occurrences of perched groundwater in basalts found in Pueblo and Los Alamos Canyons are probably not hydraulically connected. Perched intermediate groundwater beneath Pueblo Canyon probably flows to the east-southeast and partially discharges at Basalt Spring.

5.2.2.2 Quality of Groundwater within the Puye Formation

The uppermost saturated zone within the Puye Formation at a depth of 579 ft is characterized by a calcium-sodium-bicarbonate ionic composition with a TDS content of 329.7 ppm (Table 5.2-1). The

second saturated zone at a depth of 615 ft is characterized by an overall sodium-chloride ionic composition with a TDS content of 550.5 ppm (Table 5.2-1). This second saturated zone has unique chemistry as evidenced by elevated dissolved sodium (167 ppm) and chloride (177 ppm) concentrations. Calcium and bicarbonate are present in lower concentrations in the second saturated zone. The third saturated zone at a depth of 624 ft is characterized by a sodium-calcium-bicarbonate ionic composition with a TDS content of 276.9 ppm (Table 5.2-1). Sulfate and chloride are also present in this groundwater zone (Table 5.2-1 and Figure 5.2-2), and concentrations of these two solutes are greater than those found in water supply wells PM-1 and PM-3 (Environmental Surveillance and Compliance Programs 1997, 56684). The major ion chemistry of the three perched zones in the Puye Formation differs from the characteristic calcium-sodium-bicarbonate compositions found in PM-1 and PM-3. Sodium is the dominant cation in the Puye Formation groundwater at R-9, whereas calcium is the dominant cation in PM-1 and PM-3 waters (Figure 5.2-2).

Presence of elevated nitrate, chloride, and sulfate within the Puye Formation waters (Figure 5.2-2) suggests a pathway from the surface to the regional aquifer up-canyon from R-9 (Table 5.2-1). The concentration of dissolved nitrate (as nitrate) in water from the uppermost saturated zone within the Puye Formation is 10.6 ppm (Figure 5.2-2 and Table 5.2-1). Concentrations of this solute decrease with depth ranging from 3.41 to 8.66 ppm.

5.2.2.3 Quality of Groundwater within the Santa Fe Group Basalt

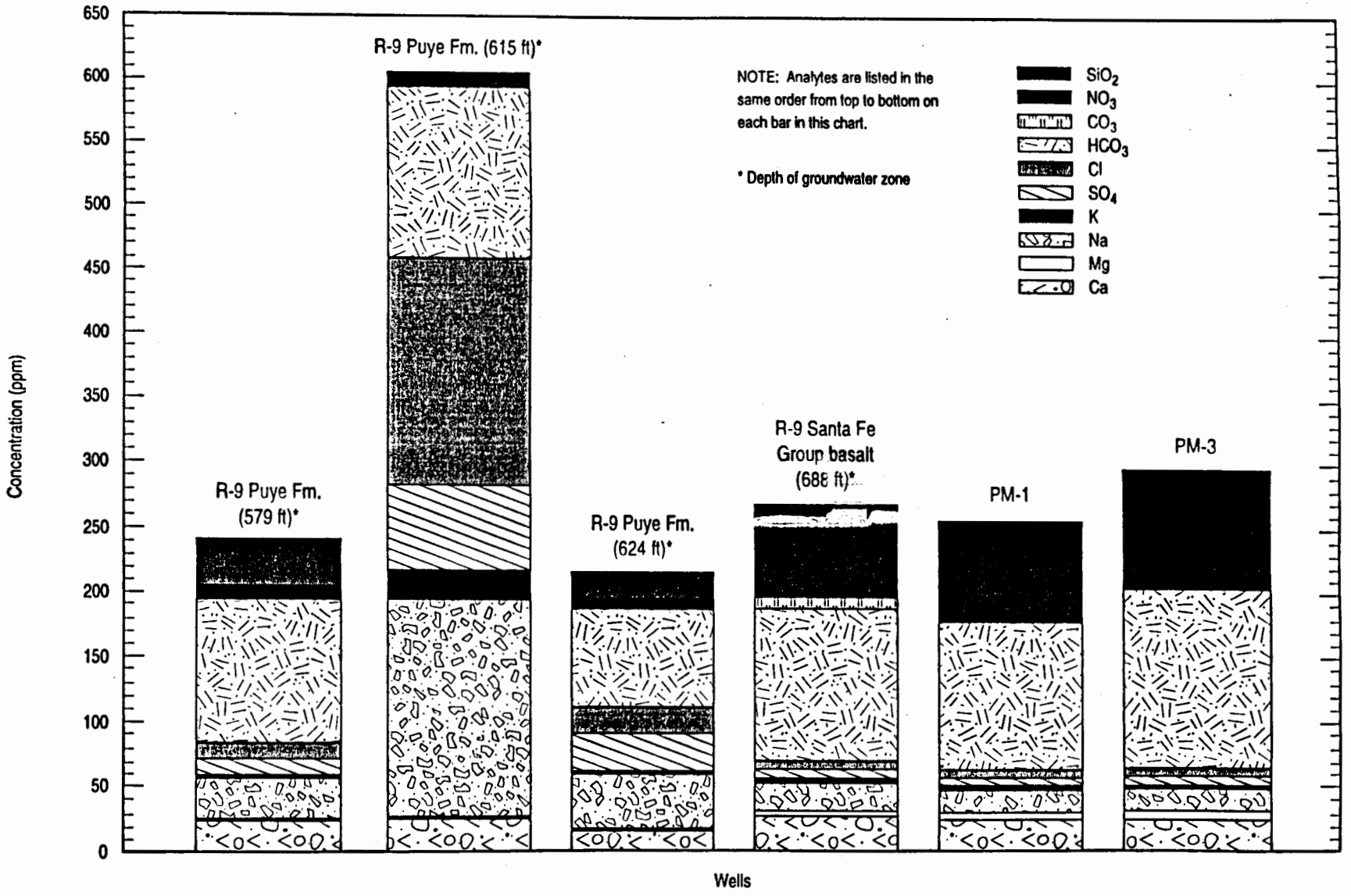
Water in the saturated zone in Santa Fe Group basalt at a depth of 688 ft is characterized by a calcium-sodium-bicarbonate ionic composition with a TDS content of 387 ppm and a pH of 8.0 (Table 5.2-1). This groundwater is chemically similar to regional aquifer water in wells PM-1 and PM-3 (Figure 5.2-2).

5.2.2.4 Radionuclide Distributions in Groundwater

Activities of total and dissolved radionuclides (americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; and tritium), gross alpha, gross beta, and gross gamma in groundwater samples collected at R-9 are summarized in Tables 5.2-2 and 5.2-3. Activities of most radionuclides, excluding tritium and uranium, are at less than detectable levels in all saturated zones. Natural and anthropogenic isotopes contribute to gross alpha, gross beta, and gross gamma values measured in the basalt perched zones. Natural radioactivity (potassium-40, thorium-232, uranium-234, uranium-235, and uranium-238) found in silicate rocks (Brookins 1984, 12453) contributes to these parameters measured in waters from the Puye Formation and Santa Fe Group basalt.

Activities of measurable tritium are present in all zones, suggesting that there is a component of groundwater less than 50 years old (Blake et al. 1995, 49931; Adams et al. 1995, 47192) within the Cerros del Rio basalt, Puye Formation, and Santa Fe Group basalt (Table 5.2-2). The sources of tritium include both atmospheric and Laboratory-derived tritium. This demonstrates that there is a pathway for surface water/alluvial groundwater for recharging perched zones and the regional aquifer within the past 50 years.

Plutonium-238 was detected at 0.76 $\pm$ 0.26 pCi/L (two standard deviations) in a nonfiltered groundwater sample collected from the lower perched zone at a depth of 275 ft (Table 5.2-3). This activity is above the detection limit for the sample. However, the dominant isotope of plutonium in Los Alamos Canyon is plutonium-239,240 derived from weapons research conducted at TA-21. This sample was reanalyzed by Paragon Analytics Inc. confirming the analytical results. Plutonium-238 was used at TA-21 for heat source experiments.



F5.2-2 / R-9 WELL COMPLETION RPT / 090898

Figure 5.2-2. Comparison of major ion and nutrient chemistry of Puye Formation and Santa Fe Group groundwater in R-9 with regional aquifer groundwater in nearby water supply wells PM-1 and PM-3.

5.2.2.5 Uranium and Oxalate Distributions in Groundwater

Dissolved uranium concentration in the upper perched zone within the Cerros del Rio basalt (180 ft deep) is 1.22 ppb or µg/L (Table 5.2-4). Dissolved uranium concentration in the lower perched zone within the Cerros del Rio basalt (275 ft deep) is 48.4 ppb. Under oxidizing conditions for the lower perched zone within the basalt, uranium is predicted to occur predominantly as $UO_2(CO_3)_3^4$ based on model simulations using the computer code MINTEQA2 (Allison et al. 1991, 49930). This uranyl carbonato complex does not completely adsorb onto mineral surfaces at a pH value of 8.79 (Langmuir 1997, 56037), which probably accounts for its elevated concentration in the lower perched zone water. The total (dissolved and suspended) uranium concentration is 112 ppb for the lower perched zone (Table 5.2-3). The turbidity value for this zone exceeded the maximum readable value for the instrument, suggesting a high particulate content, which likely accounts for a significant portion of the uranium in the unfiltered sample.

Background concentrations of dissolved uranium in alluvial groundwater and surface water at the Los Alamos Reservoir in upper Los Alamos Canyon are less than 1 µg/L (Longmire, unpublished data; Longmire et al. 1996, 54168; Environmental Surveillance and Compliance Programs 1997, 56684). Concentrations of uranium in alluvial groundwater are below the proposed EPA maximum contaminant level of 20 µg/L and the New Mexico Water Quality Control Commission standard of 5 mg/L. Above-background concentrations of uranium are observed in groundwater samples collected from observation wells LAO-0.7, LAO-1, LAO-2, LAO-3, LAO-3, LAO-4, and LAO-4.5 (Longmire et al. 1996, 54168; Environmental Protection Group 1990, 6995; Environmental Protection Group 1992, 7004; Environmental Protection Group 1993, 23249; Environmental Protection Group 1994, 45363; Environmental Protection Group 1995, 50285; Environmental Surveillance Program 1996, 55333; Environmental Surveillance and Compliance Programs 1997, 56684) and in surface water (LANL 1981, 6059). Former TA-1 and TA-21 are likely sources of uranium discharged or released into upper Los Alamos Canyon before the 1950s.

The high uranium content of the Bandelier Tuff, particularly the Guaje Pumice Bed, is an alternative source of the uranium found in this groundwater. However, perched groundwater in the Guaje Pumice Bed in well LAOI(A)1.1 typically has uranium concentrations less than 1 ppb (Longmire, unpublished data). In addition, uranium occurs as a trace element in glass, zircon, and other trace minerals (Broxton et al. 1995, 50121). Although glass has a much higher solubility than the other mineral phases at near-neutral pH values, leaching of uranium from glass and other phases is unlikely.

Statistical distributions of uranium within 65 groundwater and spring samples collected on the Pajarito Plateau and surrounding areas are shown in Table 5.2-6. The mean uranium concentration for this sample population is 1.86 µg/L with a standard deviation of 3.78 µg/L. The median uranium concentration is 0.68 µg/L. This distribution is characterized by a right-sided tail (skewness = 3.69). Laboratory test wells, supply wells, springs (west of the Rio Grande), and ER Project groundwater samples typically contain uranium concentrations of less than 2 µg/L.

San Ildefonso Pueblo wells and La Mesita Spring (east of the Rio Grande) contain uranium concentrations ranging from 0.05 to 19.64 µg/L. Uranium concentrations in the La Mesita Spring sample are 10.01 µg/L (Environmental Surveillance and Compliance Programs 1997, 56684). The San Ildefonso Pueblo wells are completed within the Santa Fe Group sediments; groundwater discharging from La Mesita Spring is associated with the Santa Fe Group sediments. Higher uranium concentrations in groundwater are observed near the Rio Grande in the regional aquifer (Santa Fe Group sediments).

TABLE 5.2-6

STATISTICAL DISTRIBUTION OF URANIUM IN GROUNDWATER FROM THE PAJARITO PLATEAU AND SURROUNDING AREAS

Statistic	Value (µg/L)
Number	65
Mean	1.86
Standard error	0.47
Median	0.68
Standard deviation	3.78
Kurtosis	14.15
Skewness	3.69
Minimum	0.05
Maximum	19.64
Confidence level (95%)	0.94

Sources: Environmental Surveillance and Compliance Programs, 1991, 56684; Laboratory background groundwater investigation (spring 1998 sampling round)

Oxalate is present in groundwater samples collected from the lower perched zone in the Cerros del Rio basalt at 3.03 ppm (Table 5.2-1). However, oxalate was not detected in the uppermost perched zone. Oxalate was detected within the saturated zones in the Puye Formation and Santa Fe Group basalt (Table 5.2-1). Oxalate is a mobile anion ($C_2O_4^{2-}$), similar to sulfate (SO_4^{2-}), above pH values of 5.

The source of the oxalate is not known with certainty. The oxalate detected in R-9 may be derived from natural sources through bacterial activity in soils and rocks, specifically through the oxidation of carbohydrates to carbon dioxide gas. However, the oxalate detected may be derived from anthropogenic sources. Oxalate and oxalic acid were used during the processing and purification of natural uranium, or tubaloy, to precipitate uranyl oxalate at former TA-1 in the early 1940s. Oxalate was also used in the processing and purification of plutonium ($Pu_2(C_2O_4)_3$) at former TA-1 and TA-21.

5.2.2.6 Summary of Groundwater Chemistry

Solute chemical data show the presence of anthropogenic anions (chloride, nitrate, oxalate, and sulfate) derived from alluvial groundwater in upper Los Alamos Canyon within the six saturated zones identified during the drilling of R-9. Measurable activities of tritium within the Puye Formation and Santa Fe Group suggest that a component of groundwater in these saturated zones is less than 50 years old. The source of this tritium may be atmospheric fallout (Adams et al. 1995, 47192) and/or from Laboratory discharges (Blake et al. 1995, 49931).

Dissolved uranium (48.4 ppb) measured within the lower perched zone (basalt) of R-9 is a statistical outlier with respect to uranium concentrations for 65 groundwater and spring samples (mean value of 1.86 µg/L) collected on the Pajarito Plateau and surrounding areas. R-9 is downgradient from former TA-1 and TA-21, which are sites known to have used uranium during refining and purification and research activities. Dissolved uranium distributions within the groundwater of the Puye Formation and Santa Fe Group are generally less than 2 ppb.

5.3 Anion Profiles

5.3.1 Methods

Anion concentrations (chloride, nitrate, nitrite, oxalate, phosphate, and sulfate) for pore water in samples of core and cuttings were determined and plotted with depth. Samples were collected and analyzed at approximately 10-ft intervals. A few samples were collected on more closely spaced intervals to examine behavior at stratigraphic contacts or changes in moisture content. Anion concentrations were determined by leaching the samples with deionized water and analyzing the leachate using ion chromatography following Newman (1996, 59118). The leaching and analyses were performed at the EES-1 geochemistry laboratory. For each sample, approximately 50 g of rock was crushed using a mortar and pestle. The crushed rock was then oven dried for at least 12 hours at 100°C. The dry sample was weighed and added to an Erlenmeyer flask along with approximately 75 g of deionized water. The flask was agitated for 24 hours on a rotary mixer. After the mixer was turned off and the solid material settled, the supernatant was filtered and analyzed using a Dionex ion chromatograph. Analytical precision of the ion chromatograph is better than 5%.

Pore water chloride concentrations were calculated using leachate concentrations, gravimetric moisture contents, and bulk densities. Moisture content data are reported in Section 5.2. Bulk densities have not been measured for R-9 samples, so estimates were used that are representative of typical values for the kinds of rock and sediments encountered. The bulk density estimates increase the uncertainty in the pore water concentrations. However, comparisons of calculated pore water concentrations from saturated zone samples with those reported in Section 5.1 show reasonable agreement, indicating that the bulk density estimates are close to the actual values.

5.3.2 Results

Analysis of the vertical variations in geochemistry of Los Alamos Canyon waters is one of the best ways to understand flow and transport in the subsurface. One important component of the subsurface hydrochemistry is the distribution of anions. Samples of core and cuttings obtained from R-9 were analyzed as explained above to obtain the vertical distributions of chloride, nitrate, nitrite, oxalate, phosphate, and sulfate. Bromide was also measured, but concentrations were too low for quantification. In addition, several samples had nitrate, nitrite, and phosphate concentrations below the detection limit. The lack of detection does not mean that these species are not present in the samples. Instead, the leaching procedure results in substantial dilution, and if an anion has a low concentration, the dilution can lower the concentration beyond the detection limit. In general, the anions all showed similar behavior with multipeaked profiles, and the peaks and valleys of the various anion distributions tend to occur at similar depths (Figure 5.3-1). The multipeaked profile is consistent with multiple flow paths and changes in vertical recharge through time. Given the hydrologic contrast between units and the chemical differences between saturated zones (Section 5.1), the multiple flow path explanation appears to be the most likely. Pore water concentrations for all the anions are shown in Table 5.3-1.

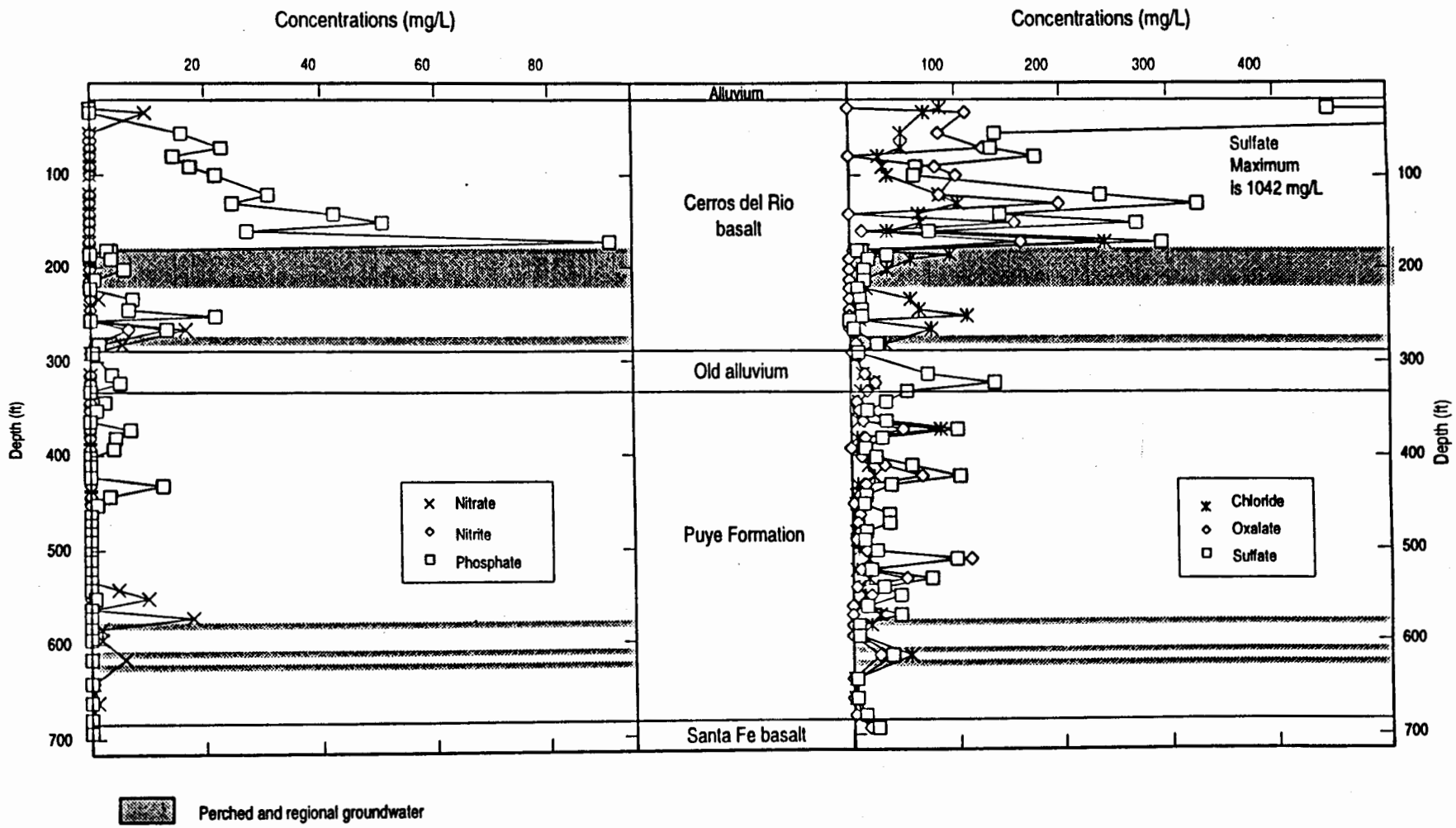


Figure 5.3-1. Pore water anion profiles for R-9.

TABLE 5.3-1

ESTIMATES OF R-9 PORE WATER ANION CONCENTRATION[a]

Average Depth (ft) of Sample	Chloride	Nitrate	Nitrite	Oxalate	Phosphate	Sulfate
26.75	87	BD[b]	BD	BD	BD	449
32.50	72	10	BD	112	BD	1042
54.25	50	BD	BD	85	16	139
71.0	50	BD	BD	126	23	134
81.0	27	BD	BD	BD	14	175
91.0	32	BD	BD	81	17	63
101.0	36	BD	BD	101	22	61
121.50	85	BD	BD	85	31	237
131.0	102	BD	BD	198	25	328
141.0	65	BD	BD	BD	42	142
150.5	68	BD	BD	157	51	270
161.0	36	BD	BD	12	27	74
171.0	240	BD	BD	161	91	295
181.0	15	BD	BD	4	4	12
181.4	7	BD	BD	4	3	8
184.65	95	BD	BD	20	BD	36
189.15	58	BD	BD	BD	4	18
201.35	36	BD	BD	BD	6	14
213.15	14	BD	BD	BD	1	14
222.75	15	BD	BD	BD	BD	8
234.40	57	1	BD	BD	7	10
243.98	64	BD	BD	BD	7	11
252.50	111	BD	BD	BD	22	12
255.25	9	BD	BD	BD	BD	BD
266.48	77	17	7	BD	13	5
281.65	33	6	1	6	2	26
290.60	6	BD	BD	1	0	7
312.75	12	BD	BD	13	4	73
322.75	22	BD	BD	23	5	136
332.75	10	BD	BD	16	BD	54
342.75	8	BD	BD	5	2	33
352.75	5	BD	BD	8	1	17
362.75	8	BD	BD	12	BD	33
372.75	85	BD	BD	49	7	102
382.75	6	BD	BD	14	4	30
392.75	6	BD	BD	BD	4	14
402.75	20	BD	BD	10	BD	24
412.75	16	BD	BD	31	BD	58

a. mg/L

b. BD = below detection

TABLE 5.3-1 (continued)

ESTIMATES OF R-9 PORE WATER ANION CONCENTRATION[a]

Average Depth (ft) of Sample	Chloride	Nitrate	Nitrite	Oxalate	Phosphate	Sulfate
422.75	21	BD[b]	BD	67	BD	103
432.75	6	BD	BD	15	12	38
443.5	4	BD	BD	8	3	14
453.5	3	BD	BD	3	1	12
463.5	6	BD	BD	7	BD	35
472.75	5	BD	BD	6	BD	35
482.75	3	BD	BD	8	BD	14
492.75	3	BD	BD	3	BD	12
502.75	6	BD	BD	13	BD	23
512.75	15	BD	BD	113	BD	99
522.75	5	BD	BD	9	BD	19
532.75	17	BD	BD	52	BD	75
541.75	5	5	BD	3	BD	30
551.9	11	10	BD	18	1	46
561.95	7	BD	BD	BD	BD	14
572.95	26	18	BD	BD	BD	46
584.15	17	2	BD	BD	BD	6
595.5	8	2	BD	BD	BD	6
616	56	6	BD	25	BD	37
639.7	3	0	0	BD	BD	5
660.9	2	1	0	BD	BD	4
678.9	8	BD	BD	2	BD	12
692.3	24	BD	BD	16	BD	23

a. mg/L

b. BD = below detection

5.4 Moisture Content of Core and Cuttings

5.4.1 Methods

Moisture content was determined on samples of both core and cuttings. Core was collected from 34.4% of the borehole, including all the saturated intervals. Therefore, collecting a vertical profile of moisture content for the entire borehole requires that moisture content analyses be performed on drill cuttings. The drill cuttings were collected from a port that was installed in the cuttings return line at a location before the cuttings entered the cyclone. This was done to prevent the moisture loss that occurs when cuttings are in the cyclone. After core or cuttings were screened for radioactivity, samples were immediately placed in preweighed and prelabeled jars with tightly fitting lids. The moisture content was determined gravimetrically by drying the samples in an oven in accordance with the American Society for Testing and Materials (ASTM) method D2216-90. Samples collected for moisture content are listed in Appendix C.

5.4.2 Results

The moisture content in core and cuttings for unsaturated intervals of the borehole are shown in Figure 5.4-1. Consistent results were obtained for analyses on both core and cuttings. The moisture content data are necessary to calculate the transport of water and contaminants through the thick, unsaturated intervals. The moisture content data are also necessary to calculate the pore water anion concentrations over vertical profiles (see Section 5.3) and to prepare water retention curves.

Moisture contents are lowest in the Cerros del Rio basalt above the first perched zone at a depth of 180 ft (Figure 5.4-1). Moisture contents are also low in Cerros del Rio basalt in the unsaturated interval separating the upper two perched zones. A marked increase in moisture contents occurs in the Puye Formation below the second perched zone. The highest moisture contents occur in the clay-rich tuffaceous sediments in the lower part of the Puye Formation.

5.5 Matric Potential

5.5.1 Methods

Matric potential was measured using a chilled-mirror water activity meter as described by Gee et al. (1992, 58717). Samples were placed in resealable plastic bags and wrapped with packing tape immediately after the core or cuttings were screened for radioactivity. Storage time ranged between 3 and 57 days. Splits of samples were transferred to plastic vials with tightly fitting lids. The sample vials were loaded into the water activity meter within 10 minutes, and measurements were made in triplicate. Core was crushed into mm-sized fragments, and sample splits were placed in the plastic vials as quickly as possible after breaking the seal on the plastic bags. Repeat measurements demonstrated that samples produced the same results even if the measurements were made more than two hours after filling the vials and securing the lids. All analytical runs were bracketed by measurements of standards, which demonstrate a two-sigma reproducibility better than 0.002 activity units.

5.5.2 Results

Matric potential results are currently being evaluated and are not included in this report. Data quality issues for this data set are being evaluated, and matric potential results will be summarized in a future report.

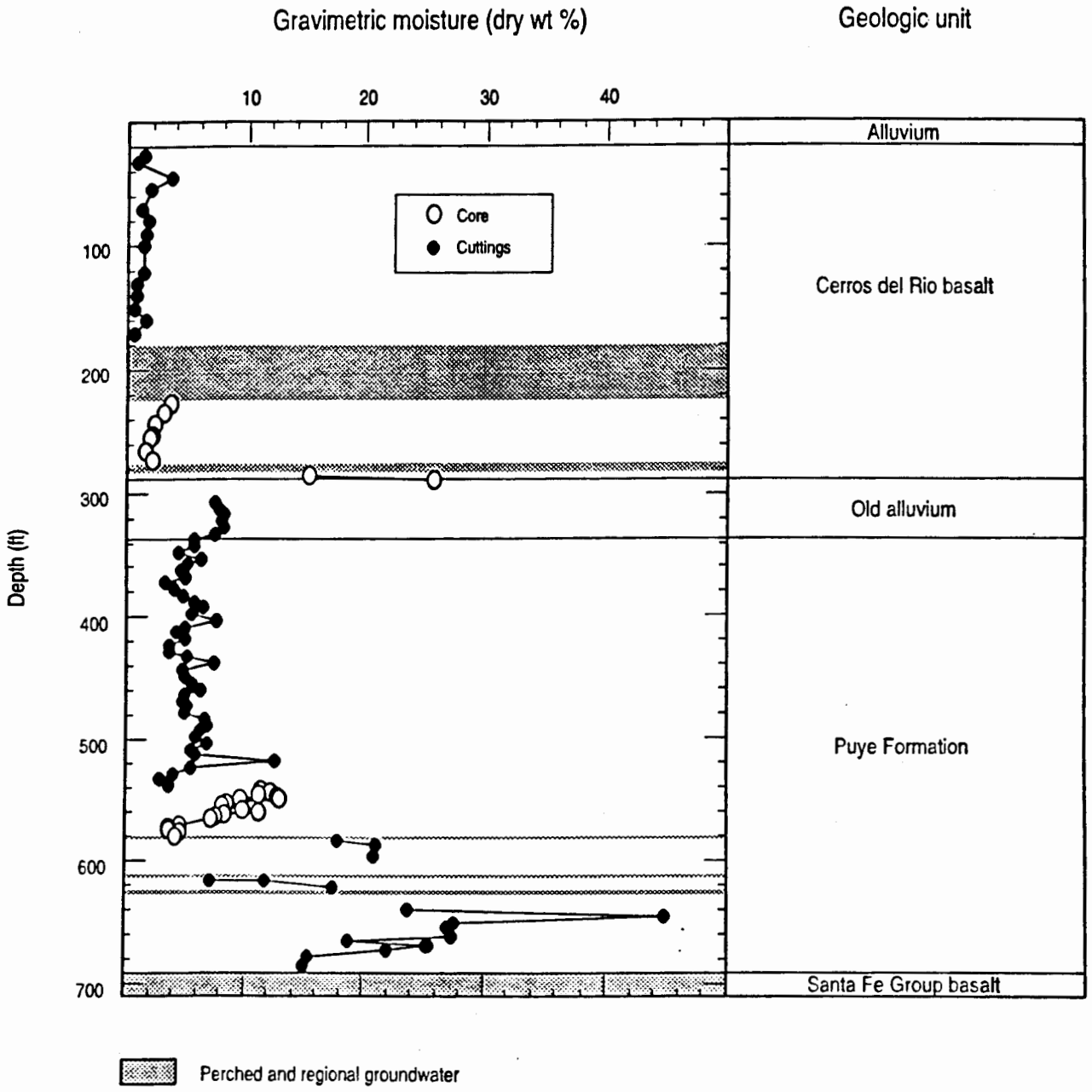
5.6 Hydraulic Properties

A total of 39 core samples were collected and preserved for potential hydraulic property testing and are currently stored at the FSF. Samples will be selected for testing based on data needs identified for numerical flow and transport modeling. Potential hydraulic property testing may include, but is not limited to, porosity, particle density, bulk density, saturated hydraulic conductivity, and determination of water retention curves.

5.6.1 Methods

Samples for hydraulic properties were collected as soon as possible after core extraction and were protected from moisture loss by the following methods.

- Samples for hydraulic property testing were collected in 6-in.-diameter Lexan plastic or stainless steel liners loaded into the core tube.
- If a core collected without a liner was deemed to warrant hydraulic testing, it was quickly inserted into a liner, intact if possible.



F5.4-1 / R-9 WELL COMPLETION RPT / 091198

Figure 5.4-1. Moisture content for core and cuttings from R-9.

The ends of the Lexan plastic or stainless steel liners containing core to be preserved were capped with tight-fitting plastic caps and sealed with Teflon nonstick-coated tape.

- The capped ends of the liner were wrapped with clear packing tape.
- The footage interval of the core sample as well as the time and date of collection were recorded on the liner with indelible ink.
- The capped and labeled liner was inserted into a Coreprotec aluminized sleeve labeled with the same sampling information.
- The ends of the Coreprotec sleeve were closed with an electric heat sealer creating an air-tight seal.
- The protected cores were documented as samples for hydrologic testing, stored to prevent freezing, and transported to the FSF as soon as possible after they were collected.
- Custody of the samples was transferred from the Canyons Focus Area field support team to the FSF using a PC-based Access database and electronic chain-of-custody form.

A listing of samples collected and preserved for hydraulic properties testing is given in Appendix C.

5.6.2 Results

Samples are currently being evaluated by the Canyons Focus Area technical team, the Groundwater Integration Team, and members of the groundwater modeling team. Samples will be submitted for testing by November 1998.

5.7 Air Permeability and Borehole Anemometry

SEA performed a series of *in situ* air measurements during the drilling of R-9. These measurements were performed during periods of open borehole access to determine unsaturated permeability characteristics of the basalt formations.

5.7.1 Methods

The straddle packer permeability measurements were performed within intervals of Cerros del Rio basalt after open borehole drilling or in intervals where the drill casing was retracted to expose open borehole. Air was injected into a 28-in. interval isolated by two pneumatic packers, and the resulting air-flow rate and injection pressure were used to infer an air permeability using a steady-state, one-dimensional, spherical flow model. The measurement system had been used previously at TA-54 to support environmental restoration characterization of the Bandelier Tuff. R-9 was the system's first application in basaltic rocks.

Two borehole regions were available for measurements. The first was an open region in the upper part of the Cerros del Rio basalt, where individual measurements were made at the depths of 39, 43, 60, and 64 ft. The second region was located in the lower part of the Cerros del Rio basalt where individual measurements were made at depths of 245, 250, and 255 ft.

Straddle packer permeability measurements have historically been performed to conduct air and water permeability measurements in porous media. For this application, a steady-state spherical flow model is used. If the air injection (or extraction) source can be approximated as a sphere, then the steady-state air

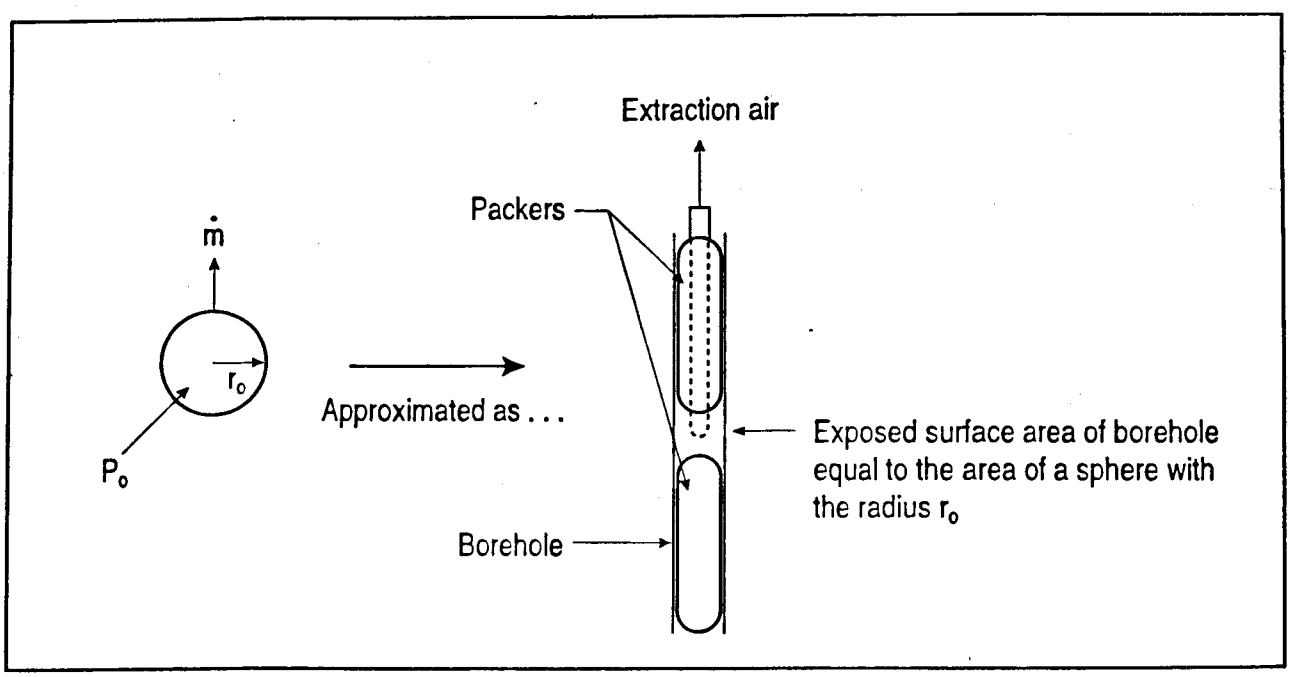
flow into the source, the source equivalent radius, the source pressure, and the ambient soil gas pressure can be used to infer the effective air permeability, k (as shown in the equation below) (Keller et al. 1973, 59119; Lowry and Narbutovskih 1991, 59120).

$$k = \frac{\mu R T \dot{m}}{2\pi M\left(P_o^2 - P^2\right)} \cdot \left(\frac{1}{r_o}\right)$$

where:

μ = dynamic gas viscosity
R = universal gas constant
T = absolute temperature
$\dot{m}$ = gas mass flow into soil
M = gas molecular weight
P_o = absolute pressure of source
P = ambient absolute soil gas pressure
r_o = source radius

This model is applied in straddle packer measurements by setting r_o to be the radius of the sphere whose surface area is equal to the area of the exposed borehole wall (Figure 5.7-1).



F5.7-1 / R-9 WELL COMPLETION RPT / 073198

Figure 5.7-1. Approximation of a spherical air-flow geometry with a conventional straddle packer design for *in situ* soil gas permeability measurements.

The packer system is depicted in Figure 5.7-2. Packers are located above and below the injection zone, and their separation distance is variable. Each packer is 6 ft long, is fabricated of a lightweight packer material, and is operated at 5 pounds per square inch (psi) or above internal pressure during the permeability measurement. The primary measurements recorded are the pressure difference between the injection zone and ambient atmospheric pressure (the temperature of the air being injected and the air-flow rate during the injection [measured with an orifice plate flowmeter]). All the sensors are located in an electronics package situated above the packer system, and the data are transmitted uphole to a laptop computer for averaging and recording. The air permeability system schematic is shown in Figure 5.7-3.

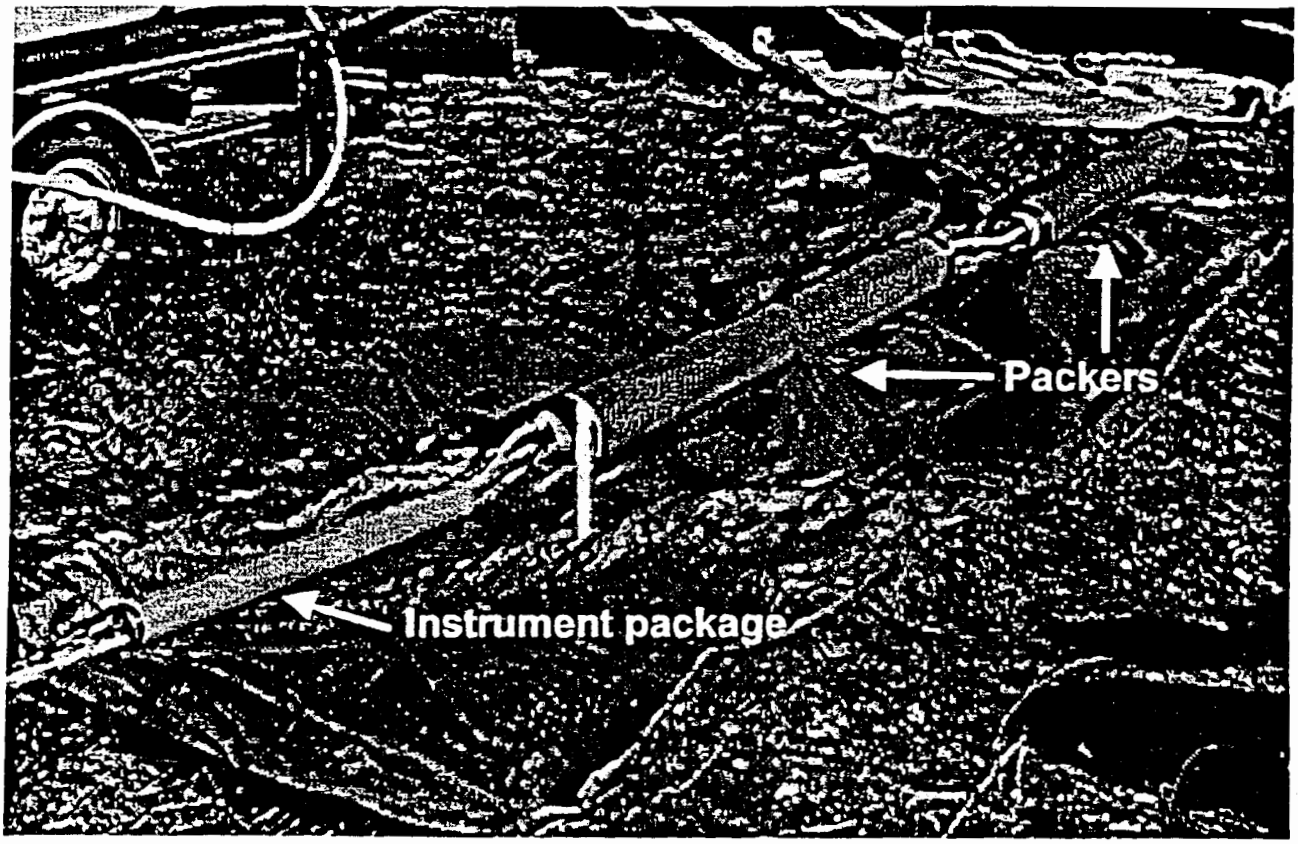


Figure 5.7-2. Downhole instrument package and packers.

5.7.2 Results

Data from the upper region (39 to 64 ft) showed the higher of the measured values: 2.4 Darcies at 39 ft and 1.2 Darcies at 64 ft. The measurements at 43 and 60 ft indicated permeability higher than the system could sense, probably in excess of several hundred Darcies. This could be due to either a highly fractured and conductive zone or a borehole wall so rough that the packers could not form an adequate seal. Measurements in the lower region of the borehole indicated notably lower permeabilities, all at 0.3 Darcies (245-, 250-, and 255-ft depths). Results are summarized in Table 5.7-1.

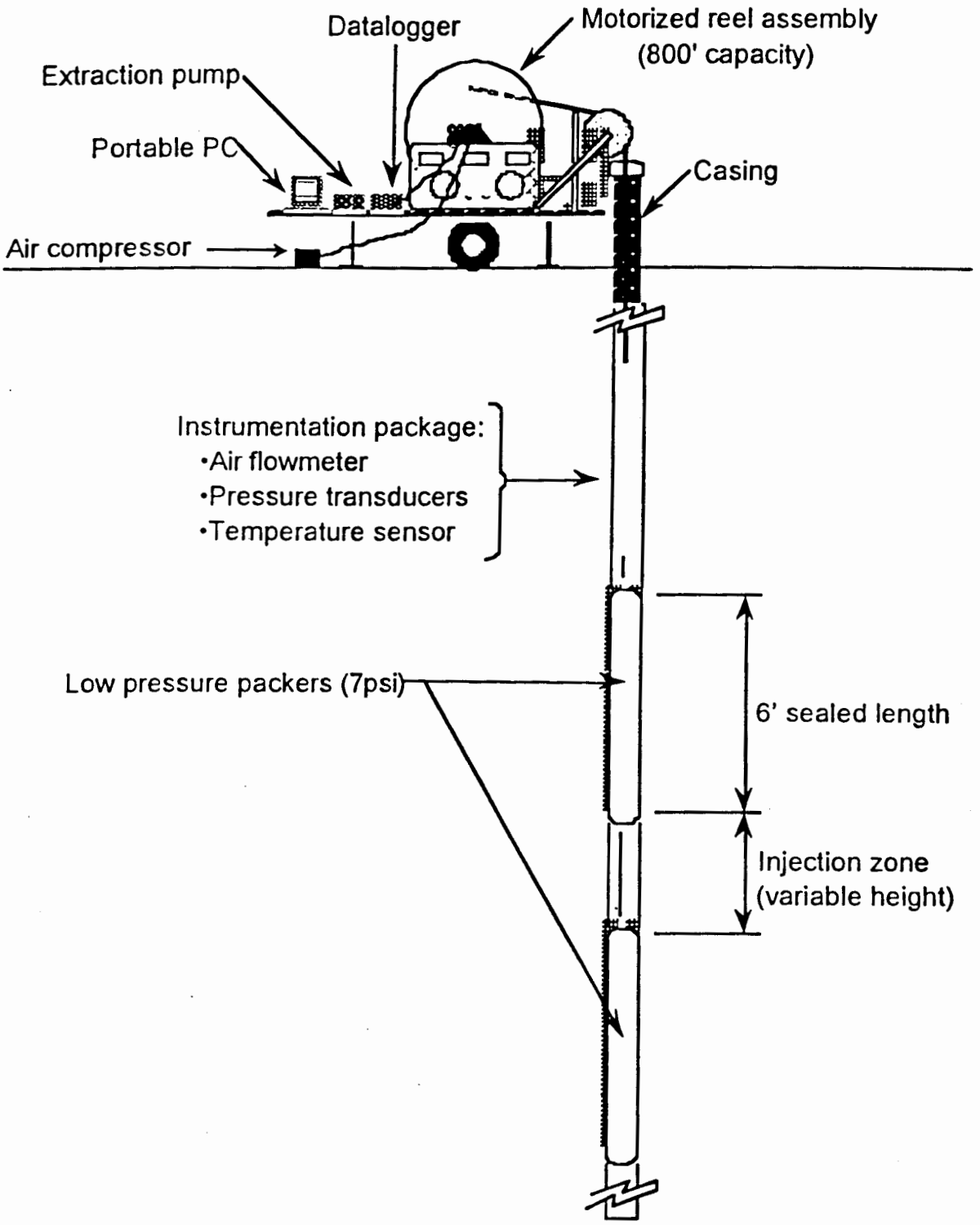


Figure 5.7-3. Air permeability measurement system.

TABLE 5.7-1

R-9 PACKER PERMEABILITY RESULTS FOR CERROS DEL RIO BASALT[a]

Date	Depth (ft)	Borehole Diameter (in.)	Air Temp (°C)	Packer Pressure (psi)[b]	Atmospheric Pressure (psia)[c]	Injection Overpress (psia)	Flow Rate (SCFM)[d]	Permeability (Darcies)
9/27/97	39	5.25	14.8	13.0	12.10	0.95	3.0	2.4
9/27/97	43	5.25				e		$>10^2$
9/27/97	60	5.25				e		$>10^2$
9/27/97	64	5.25	13.5	11.0	12.10	1.4	2.2	1.2
10/19/97	245	4.5	18.4	5.4	12.08	1.4	0.5	0.3
10/19/97	250	4.5	18.7	5.7	12.08	1.4	0.5	0.3
10/19/97	255	4.5	18.6	5.7	12.08	1.4	0.5	0.3

a. Injection zone height was 28 in. in all cases

b. psi = pounds per square inch

c. psia = pounds per square inch, absolute

d. SCFM = standard cubic feet per minute

e. Injection zone overpressure too low to measure, hence very high inferred permeability

5.8 Borehole Geophysics

5.8.1 Methods

The borehole geophysical methods that were used for measurements during the drilling of R-9 include color videotape, borehole digital image processing system (BIPS), natural gamma radiation (NGR), caliper, electromagnetic induction (EM), magnetic susceptibility (MS), gamma-gamma density (density), thermal neutron (TN), and epithermal neutron (EN). Most measurements were taken in the open borehole, and some measurements were taken inside the drill casing. The borehole geophysical measurements were performed by the borehole geophysics company COLOG, Inc., and by the environmental contractor SEA. SEA performed measurements using a portable Mt. Sopris geophysical logging system rented from COLOG. The record of borehole measurements is archived at the Facility for Information Management, Analysis, and Display (FIMAD). Borehole measurements were collected according to the schedule presented in Table 5.8-1.

The borehole video camera and BIPS records are recorded on VHS tape. A preliminary viewing of these records from R-9 established that they identify changes in basalt lithology from massive to vesicular and they show the presence of fractures. The BIPS videotape record can be processed to calculate the strike and dip of the fractures. Determining the aperture of the fractures would require computer processing of the digital BIPS record.

The neutron borehole measurements include records of two types: TN and EN. The radioactivity source for these measurements was americium-beryllium with a strength of 3 Ci. The EN measurements were collected by placing a cadmium foil shield on the source.

TABLE 5.8-1

BOREHOLE MEASUREMENTS AT R-9

Date	Depth (ft)[a]	Operator	Borehole Status	Video Camera	BIPS	Caliper	EM	MS	NGR	TN	EN	Density
9/27/97	10–98	COLOG	Open	X	X	X	X	X	X	X	X	X
9/27/97	10–98	COLOG	RC[b] rods						X	X	X	
10/19/97	239–278	SEA	Open				X	X	X			
10/20/97	6–239	COLOG	Cased[c]	X								
10/20/97	239–264	COLOG	Open	X	X							
10/20/98	239–282	COLOG	Open			X			X	X	X	X
10/21/97	119-138	COLOG	Open	X	X							
10/21/97	119–235	COLOG	Open			X			X	X	X	X
10/21/97	7–119	COLOG	Cased[c]							X		
10/21/97	119-225	SEA	Open			X	X	X				

a. See Figure 2.3-1 for geologic units.

b. Reverse circulation dual-wall drill casing

c. 6-5/8-in.-diameter drill casing

The gamma-gamma density measurements were performed using a cesium-137 radioactive source with a strength of 100 mCi. The borehole probe was a focused design that was decentralized and side collimated. A single caliper arm pressed the probe against the borehole wall. The probe was a compensated design with two detectors (near and far from the radioactive source) to correct for changes in borehole diameter.

The NGR measurements provide a borehole record of the total gamma radiation. The most significant naturally-occurring gamma-emitting radioisotopes are potassium-40 and daughter products of the uranium and thorium decay series. NGR measurements in boreholes are used for stratigraphic correlation and for identification of rocks and sediments that have a high abundance of clay. Uranium and thorium are concentrated in clay by the process of adsorption and ion exchange.

The MS measurements are a record of the magnetic susceptibility of the rock matrix, which is related to iron content and importantly, the iron chemistry. Ferromagnetic materials exhibit a very high magnetic susceptibility. The objective of MS measurements is stratigraphic correlation.

Caliper measurements are a record of the diameter of the borehole. The caliper record identifies features such as fractures, joints, collapse zones, and rubbly zones. The caliper record is important to the interpretation of other borehole measurements, such as neutron, density, and air and water permeability (measured with straddle packer systems).

EM measurements are collected in saturated and unsaturated boreholes. The EM probe used for measurements in R-9 is designed to measure the electrical conductivity of the rocks 8 to 39 in. from the borehole axis. The EM measurements are sensitive to the electrical properties of the rocks and the quantity and quality of contained groundwater.

5.8.2 Results

Figures 5.8-1 through 5.8-6 present borehole measurements taken with NGR, caliper, EM, and TN. The measurements were collected as digital records. The figures were generated with the ViewLog software package for interpretation and display of borehole geophysical measurements. The figures also show the borehole stratigraphy and the presence of saturation.

Figures 5.8-1 and 5.8-2 present results for borehole measurements in a 5-in.-diameter open borehole that was drilled in unsaturated rock. The measurements were taken in the depth interval from land surface to 98 ft. Surface casing was present to a depth of 4 ft.

Figures 5.8-3, 5.8-4a, and 5.8-4b present the results of measurements in an open borehole in the depth interval of 199 to 235 ft. At the time of these measurements, the borehole was cased from land surface to 119 ft with 6-5/8-in.-diameter drill casing. The results of TN measurements that were collected in the cased interval are also presented in Figure 5.8-4. During the geophysical measurements, the borehole was unsaturated to a depth of 137 ft and saturated at greater depths. During drilling of the borehole, saturated materials were first encountered at a depth of 180 ft. The groundwater quickly rose to an SWL at a borehole depth of 137 ft.

Figures 5.8-5 and 5.8-6 present the results of measurements in an open borehole in the depth interval of 239 to 282 ft. In this interval the borehole was drilled with coring systems and had a diameter of 4.5 in. The borehole was unsaturated to a depth of 264 ft and saturated at greater depths. During the coring operations, saturated materials were first encountered at a depth of 275 ft. Groundwater then rose in the borehole to a SWL at a depth of 264 ft.

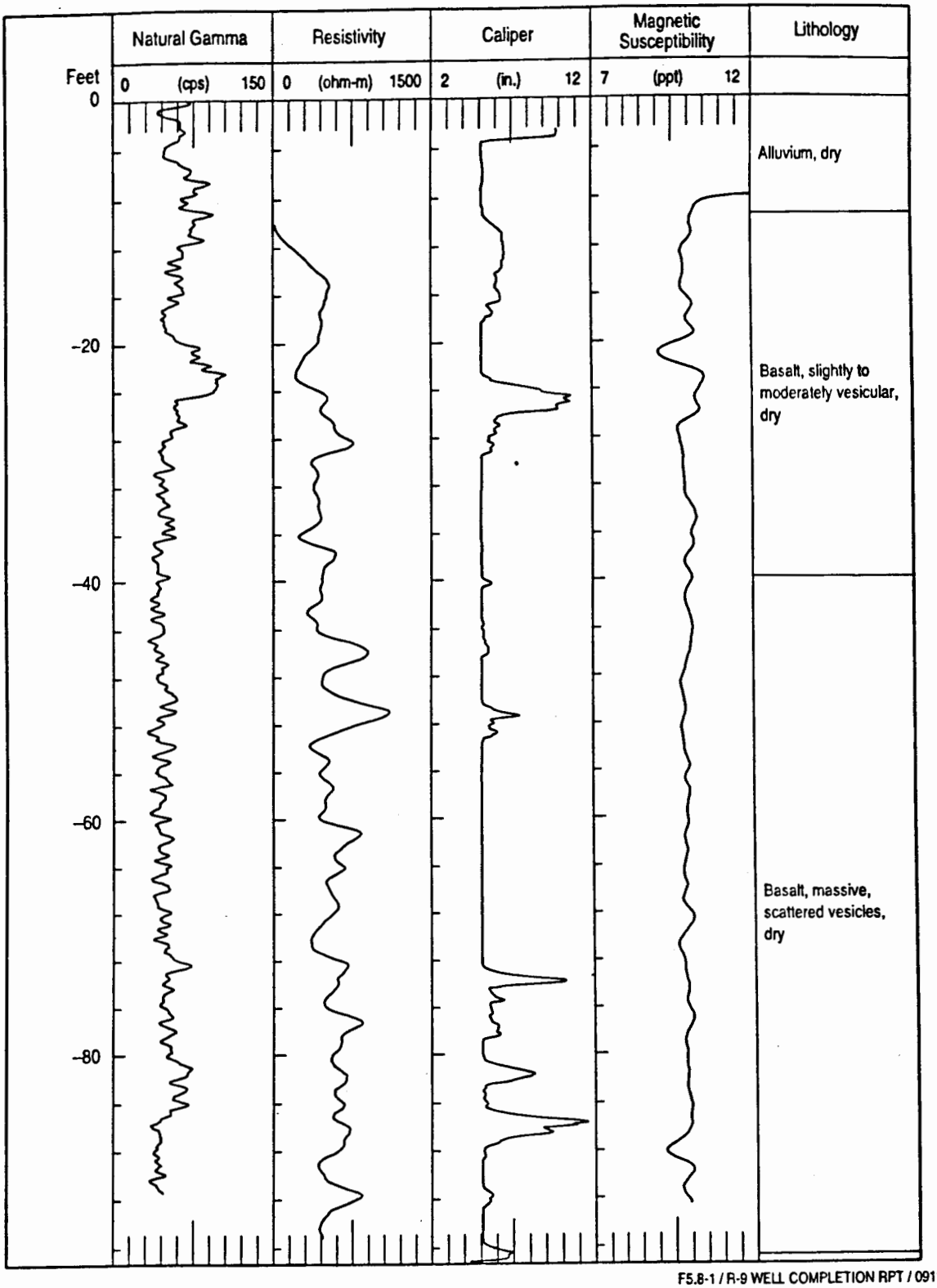
The figures show that the caliper record is important in identifying massive, competent intervals of basalt; the presence of fractures; and vesicular, rubbly intervals in the basalt.

The NGR measurements generally range in abundance from 40 to 75 counts per second. The local variation to higher abundance in the depth interval of 20 to 25 ft is probably caused by a higher clay content. The general increase in NGR abundance that occurs at depths greater than 238 ft may reflect a mineralogic change in the basalt.

The EM measurements collected in R-9 range in value from 20 to 1200 ohm-meters. The low values are measured in saturated intervals; the high values are measured in massive basalt that has a low moisture content. In the unsaturated borehole intervals, the EM measurements vary because of moisture content and clay content.

The MS measurements range in value from 4 to 10 parts per thousand; the highest values were measured in the upper 100 ft of basalt. The application of MS measurements for stratigraphic correlation cannot be determined from the limited measurements performed in R-9.

The compensated density measurements show the effect of borehole rugosity on the measured values. It is important that the density measurements are compared with caliper measurements. Unrealistic low values for density correlate with depth intervals where the borehole exhibits a great change in diameter over a short distance. In competent sections of the borehole, the density measurements range from 2.3 gm/cm^3 to 2.7 gm/cm^3. The lower values of density were measured in highly vesicular basalt, and the higher values were measured in dense, massive basalt. The highest density values were measured in the dense, massive basalt that forms the perching horizon below the first perched zone of saturation.



F5.8-1 / R-9 WELL COMPLETION RPT / 091198

Figure 5.8-1. Borehole geophysical measurements in an open borehole with nonradioactive source tools in R-9 for the depth interval of 10 to 96 ft.

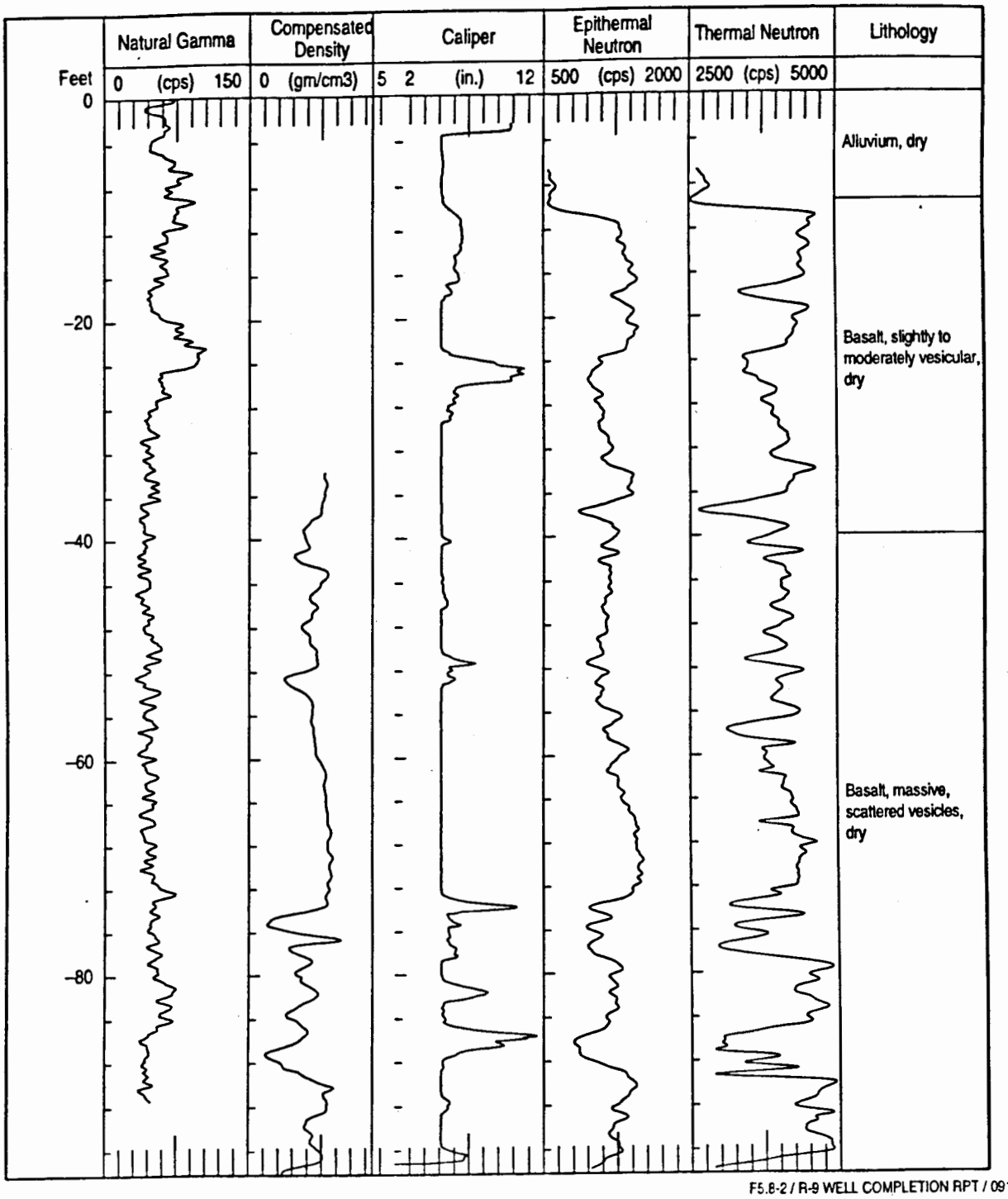


Figure 5.8-2. Borehole geophysical measurements in an open borehole with nonradioactive source tools in R-9 for the depth interval of 10 to 96 ft.

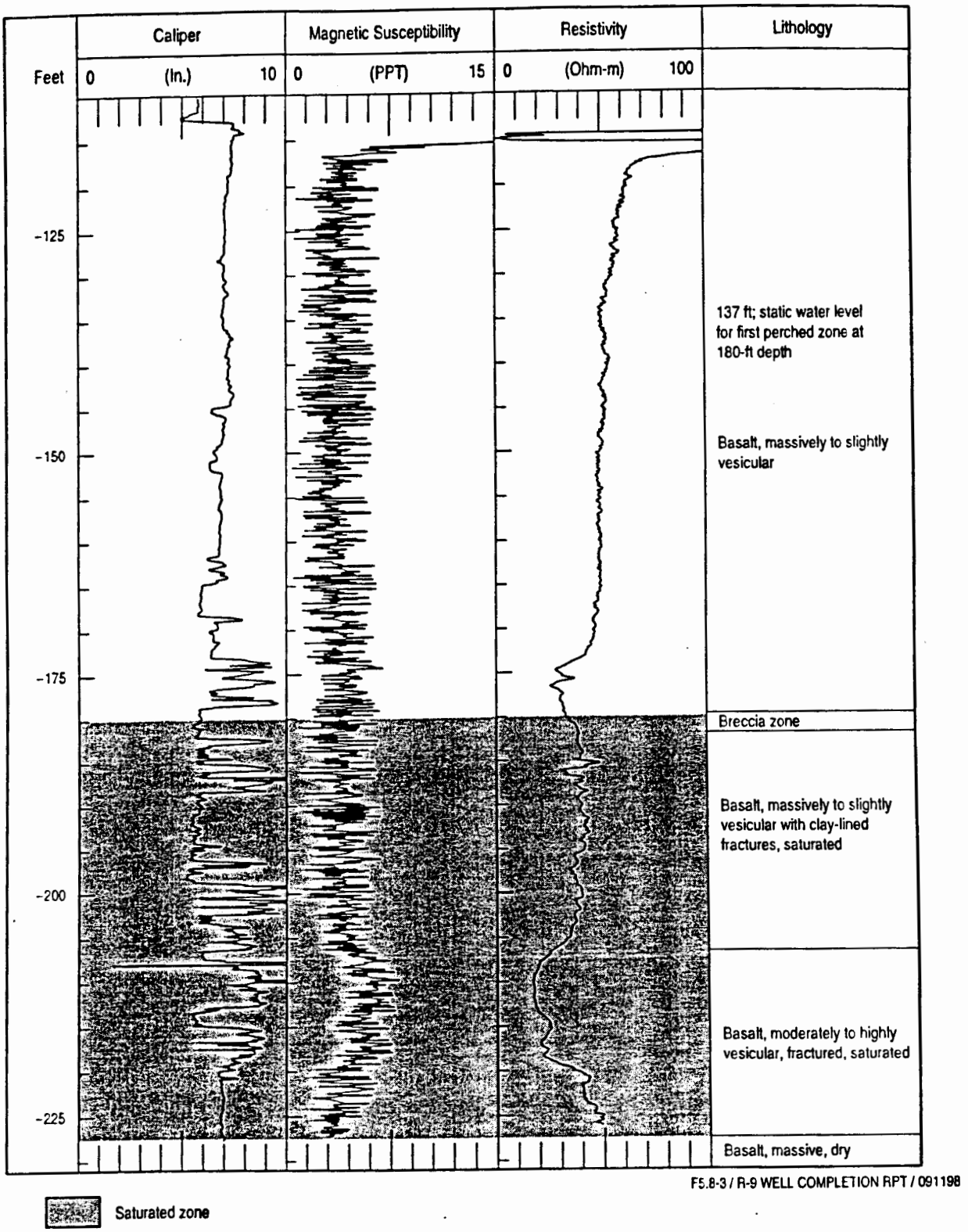
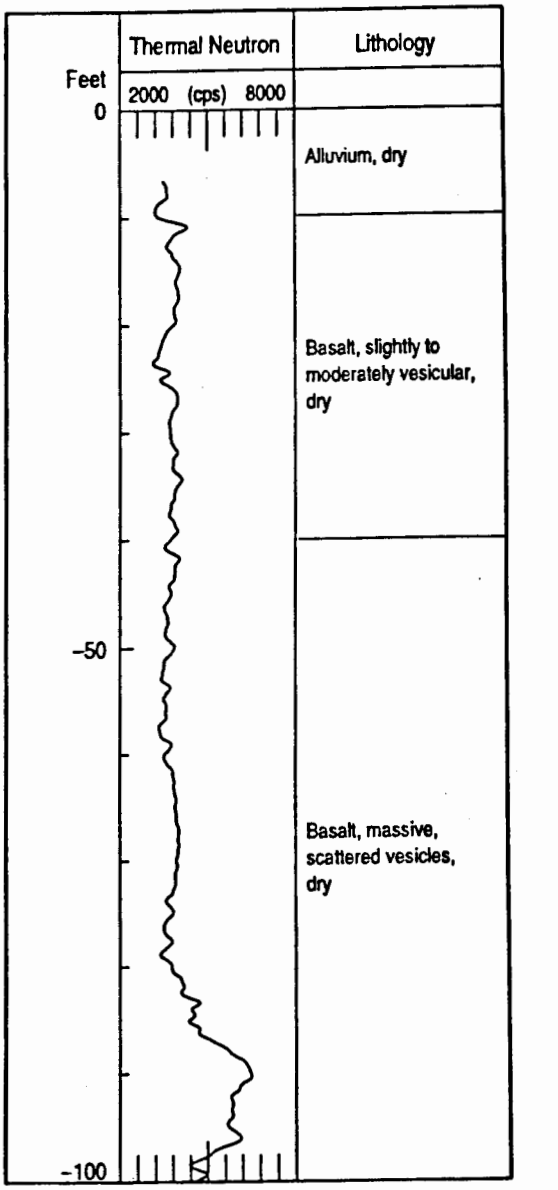


Figure 5.8-3. Borehole geophysical measurements in an open borehole with nonradioactive source tools in R-9 for the depth interval of 120 to 225 ft.



F5.8-4a / R-9 WELL COMPLETION RPT / 091198

Figure 5.8-4a. Borehole geophysical measurements through steel casing with radioactive source tools in R-9 for the depth interval of 5 to 100 ft.

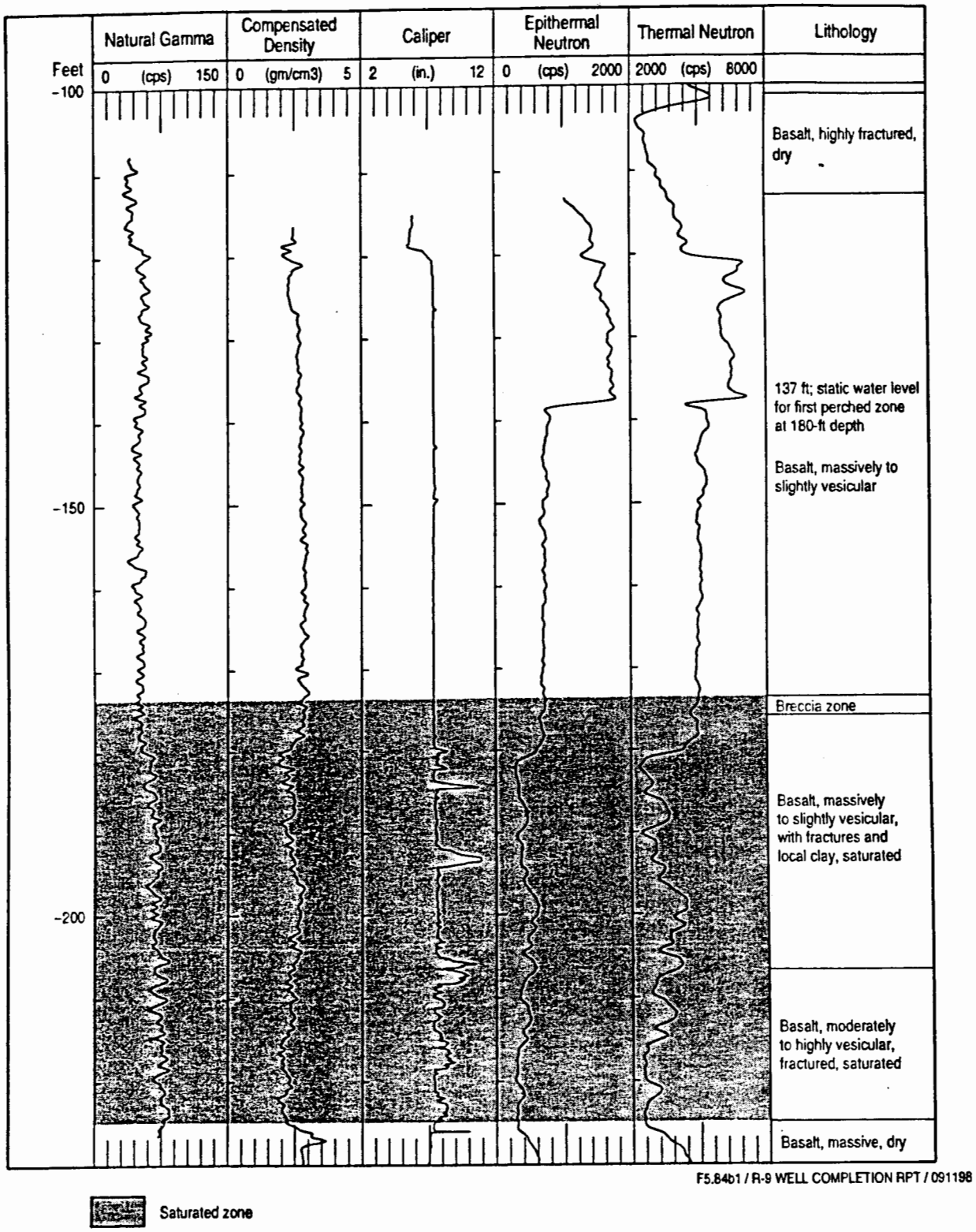


Figure 5.8-4b. Borehole geophysical measurements in an open borehole with radioactive source tools in R-9 for the depth interval of 120 to 226 ft.

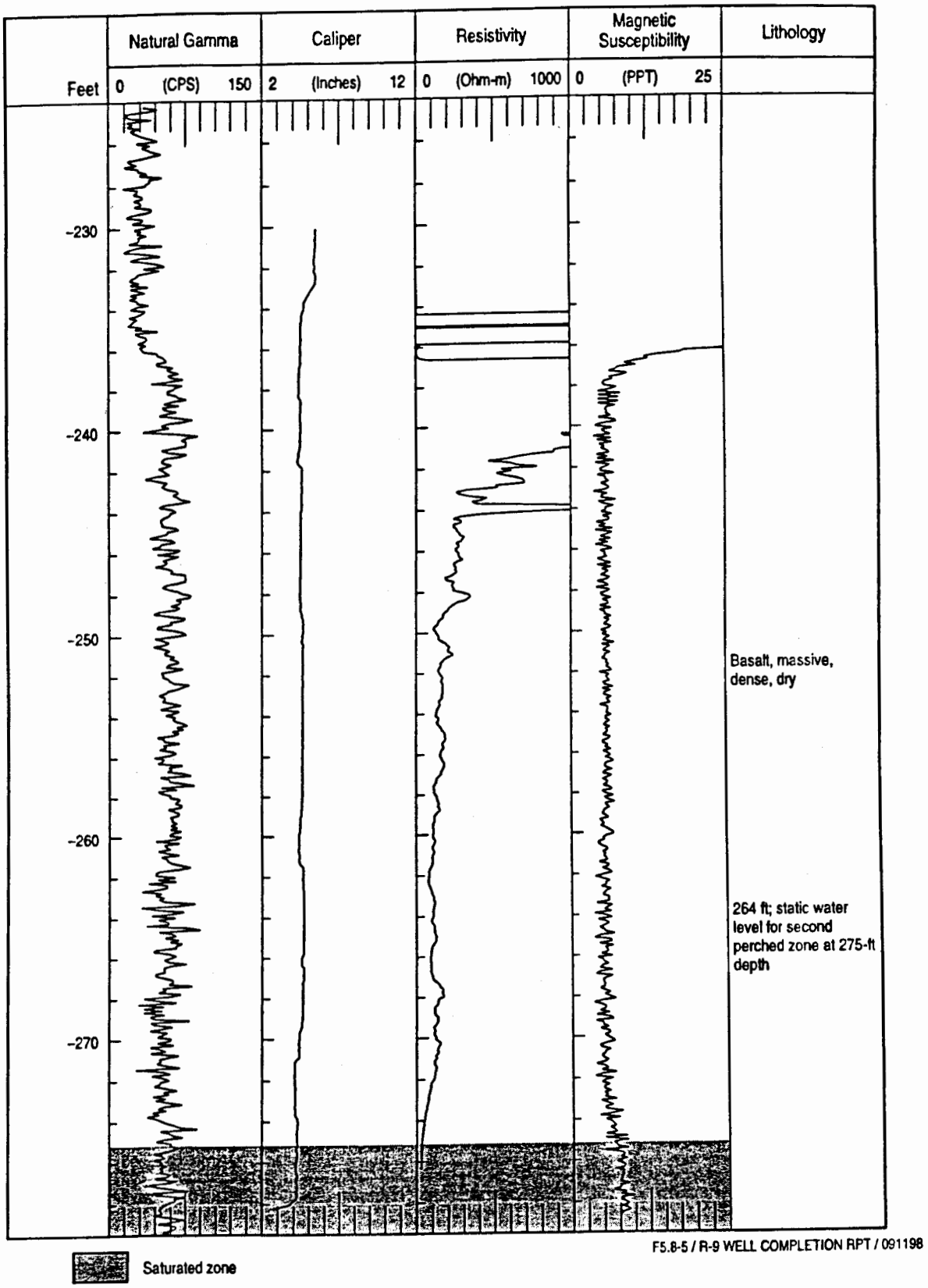


Figure 5.8-5. Borehole geophysical measurements in an open borehole with nonradioactive source tools in R-9 for the depth interval of 224 to 278 ft.

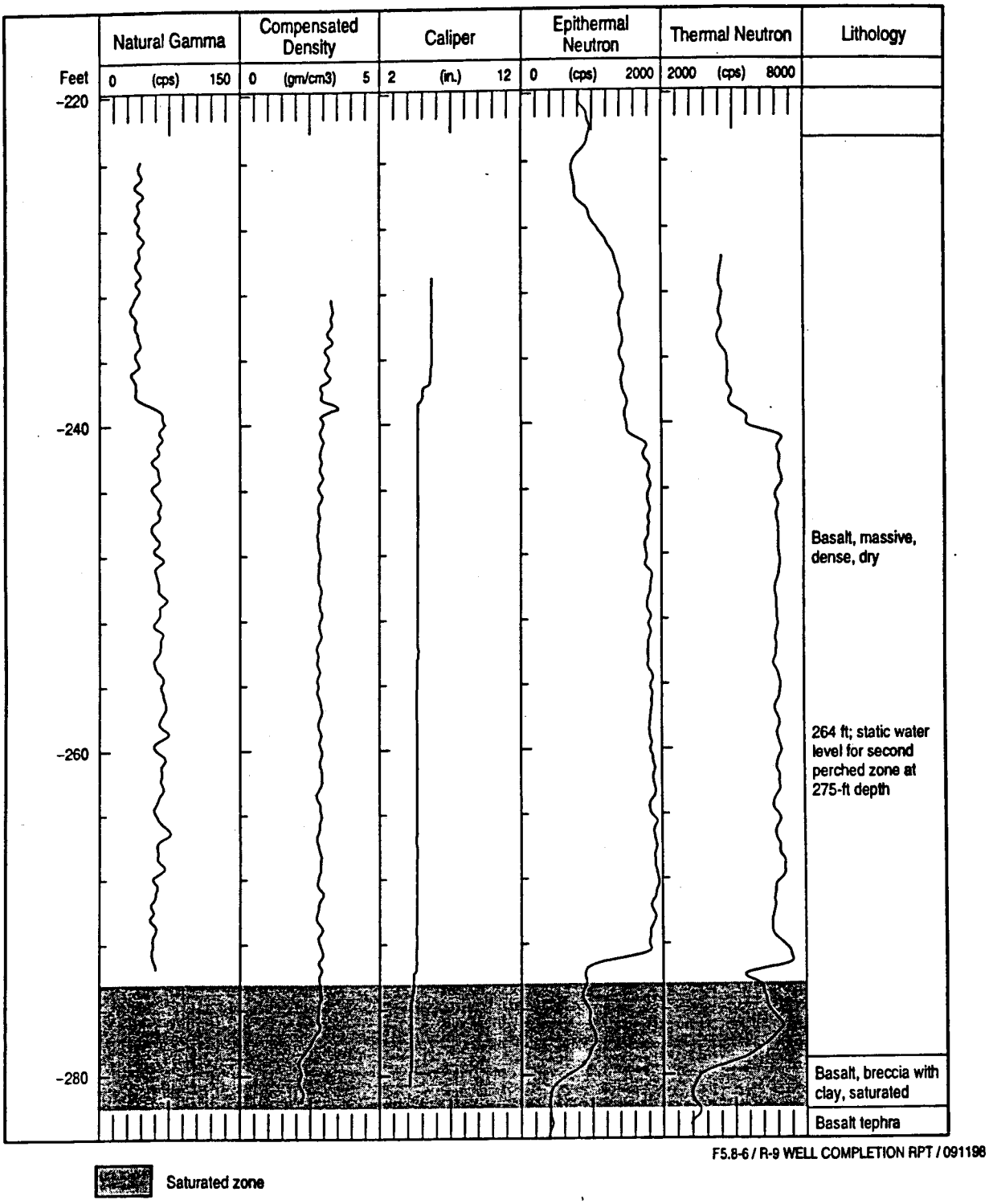


Figure 5.8-6. Borehole geophysical measurements in an open borehole with radioactive source tools in R-9 for the depth interval of 220 to 280 ft.

The EN and TN measurements exhibit an important relationship to moisture content. The neutron measurements trend to higher values as moisture content drops. This trend is illustrated in Figure 5.8-6 at the base of the first perched zone of saturation and at the top of the second perched zone of saturation (273 to 280 ft).

6.0 WASTE MANAGEMENT

The waste generated during R-9 drilling activities included drill cuttings, purge water, decontamination water, personal protective equipment, absorbent pads used beneath the drill rig, and miscellaneous waste. Drill cuttings were stored in 55-gal. drums and transferred daily to a roll-off bin. A total of two roll-off bins were generated from the drilling of R-9. When the bins were full, a sample was collected in accordance with the approved Waste Characterization Strategy Form (WCSF) and analyzed for metals, gross alpha, gross beta, gross gamma, and tritium. The analytical results for the cuttings samples were reviewed and found to be below acceptable levels as stated in the WCSF. Using the waste minimization strategy identified in the WSCF, the cuttings were taken by Parker Brothers Construction to be used as backfill.

Purge water generated during drilling activities was stored in five 3000-gal. tanks. The first zone of saturation encountered at a depth of 180 ft generated 7300 gal. of purge water. In accordance with the approved WCSF, the groundwater analytical results from this zone were reviewed and found to be below acceptable levels. The water was then discharged though a sprinkler system at the rate of 500 gal. per day in accordance to the approved Notice of Intent to Discharge (NOI). Table 6-1 indicates dates and volumes of NOI discharges at R-9.

TABLE 6-1

R-9 NOI DISCHARGES

Date	Volume (gal.)
10/6/97	500
10/7/97	500
10/9/97	200
10/10/97	500
10/10/97	500
10/11/97	500
10/12/97	500
10/13/97	200
10/26/97	500
10/28/97	500
10/29/97	500
10/30/97	500
10/31/97	500
11/1/97	500
11/2/97	500
11/3/97	500
11/4/97	500
11/5/97	400
Total volume discharged to date	7300

The second zone of saturation was encountered at a depth of 275 ft, and approximately 3000 gal. of the purge water was generated and contained in two tanks. When the groundwater analytical results were reviewed, it was decided that, based on elevated uranium results from the second perched zone, the water will be transported to TA-50 for disposal.

The regional aquifer was encountered at a depth of 688 ft , and approximately 2400 gal. of purge water was generated and contained in two tanks. When the groundwater analytical results were reviewed, the results were below acceptable levels, as stated in the WCSF, and the water will be discharged in accordance with the approved NOI.

Decontamination water (less than 6 gal. per day) was generated when the sampling equipment was decontaminated at TA-50. Since no contamination was encountered based on field screening or visual observation, the water was discharged to the site in accordance with "Decontamination Water Discharge Procedure: Containerized Decon Water" (LANL 1996, 58716) and in accordance with the approved WCSF.

Miscellaneous waste included nitrile gloves, paper towels, plastic bags, plastic sheeting, and drum liners. A resealable plastic bag was kept at the entrance of the access control zone to contain the miscellaneous waste. When the bag was full, it was sealed and labeled with the well designation and contents. Approximately four 55-gal. drum liners of miscellaneous waste were generated during drilling. A Waste Profile Form was prepared for this waste stream, and the miscellaneous waste was disposed of on November 11, 1997, and March 18, 1998, at the Los Alamos County landfill in accordance with the approved WCSF.

Other miscellaneous waste included approximately 12 drums of soil mixed with diesel fuel from a generator that leaked. Also, 8 drums of bentonite and 6 drums of absorbent pads were generated during drilling activities The pads were used to absorb any liquids that leaked from beneath the drill rig. The drums were profiled in accordance with the approved WCSF and disposed of accordingly.

7.0 SURVEY ACTIVITIES

7.1 Geodetic Survey

The location and elevation of R-9 were surveyed on April 2, 1998, by Surv-Tek, Inc., after the temporary well casing was installed. The survey point is the center of the top of the protective box installed on the well head. The FIMAD location ID for R-9 is LA-0168; it was designated as Field Point No. 169 by Surv-Tek, Inc. Based on this survey, the location and elevation of R-9 are as follows: X = 1648239.91, Y = 1770845.91, and Z = 6383.93. The X, Y, and Z designations represent easting, northing, and elevation, respectively. The location was also surveyed after borehole LAOI-7 was completed, which was the pilot hole for R-9. The coordinates recorded for LAOI-7 are X = 1648239.896, Y = 1770845.839, and Z = 6383.990. The elevation of LAOI-7 was recorded at the ground surface; therefore, it represents the ground surface elevation of R-9. Location coordinates are based on New Mexico State Plane Grid Coordinates, Central Zone (North American Datum [NAD] 83) and are expressed in feet. Elevation is recorded in feet above mean sea level (ft MSL). Horizontal and vertical data are based on Laboratory global positioning system (GPS) monument B0001, which has the coordinates of X = 1645399.117, Y = 1773039.676, and Z = 6731.68, as provided by the Laboratory central point (combined scale factor [CSF] = 0.999580833). After the permanent well is completed, the exact location of R-9 and the elevation of the north side top-of-casing and the surface monument will be resurveyed for the permanent record.

7.2 Surface Radiological Survey

A surface radiological survey was conducted by a radiological control technician before drilling activities began at LAOI-7. This predrilling radiation survey consisted of collecting alpha, beta, and gamma background measurements and conducting statistical analysis to calculate action levels that suggest radioactivity elevated above background values. The survey consisted of 15 points on a grid projected over the work area. Each point was surveyed using direct reading alpha, beta/gamma, and dose rate meters. Alpha was measured using a Ludlum 139 with an air proportional probe; beta/gamma was measured using a Ludlum 12 with a 44-9 probe; dose rate was measured using a Ludlum 19 µR/hr meter. Calculated background values for the drill site are 0.4 counts per minute (cpm) for alpha, 152 cpm for beta/gamma, and 16.2 µR/hr for dose rate.

8.0 WELL DESIGN, CONSTRUCTION, AND DEVELOPMENT

The permanent well design, construction, and development will be included in the final report for R-9. The temporary well completion for R-9 is shown in Figure 8-1. The temporary well at R-9 was constructed in the following manner.

- The 8-5/8-in.-diameter casing was landed at 679 ft and sealed with bentonite to prevent water from flowing downhole and mixing with water in the productive zone at 688 ft.
- A 6-in.-diameter hole was drilled to a total depth of 710 ft.
- A temporary 4-in.-diameter schedule 40 polyvinyl chloride casing was hung inside the existing casing strings.
- A 20-ft screen was positioned from 684 to 704 ft, and a 2-ft sump was installed.
- A sand pack (20-40) was tremied in the hole from 6 ft above to 6 ft below the screened interval.
- A pressure transducer was installed to monitor water table fluctuations because of atmospheric effects, seasonal effects, earth tides, and pumping of nearby water supply well PM-1.

9.0 MODIFICATIONS TO WORK PLANS

Table 9-1 compares the planned characterization activities in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290), the *Hydrogeologic Workplan* (LANL 1996, 55430), the core document (LANL 1997, 55622), and the *Field Implementation Plan for the Drilling and Testing of LANL Regional Characterization Well, R-9* ("the field implementation plan"; LANL 1997, 59163) with characterization activities performed in R-9. The characterization activities in the *Hydrogeologic Workplan* and the core document are the same; therefore, planned characterization activities for these two documents are shown together in Table 9-1.

The most significant modification of planned versus actual activities at R-9 was the redesign of R-9 from an intermediate-depth well to a regional aquifer well. In the work plan, R-9 (as LAOI-7) was originally designed to detect and characterize the highest intermediate-depth perched groundwater zone near the eastern Laboratory boundary in Los Alamos Canyon. The original depth was not to exceed 150 ft. In the *Hydrogeologic Workplan*, the core document, and the field implementation plan, the well was redesigned to penetrate the regional aquifer. R-9, which is presently at a depth of 710 ft, successfully penetrated the top of the regional aquifer. The final depth and completion design of R-9 will be based on evaluation of hydrogeologic data collected from both R-9 and R-12, other hydrology data from existing wells, and discussions with the Groundwater Integration Team and the regulators.

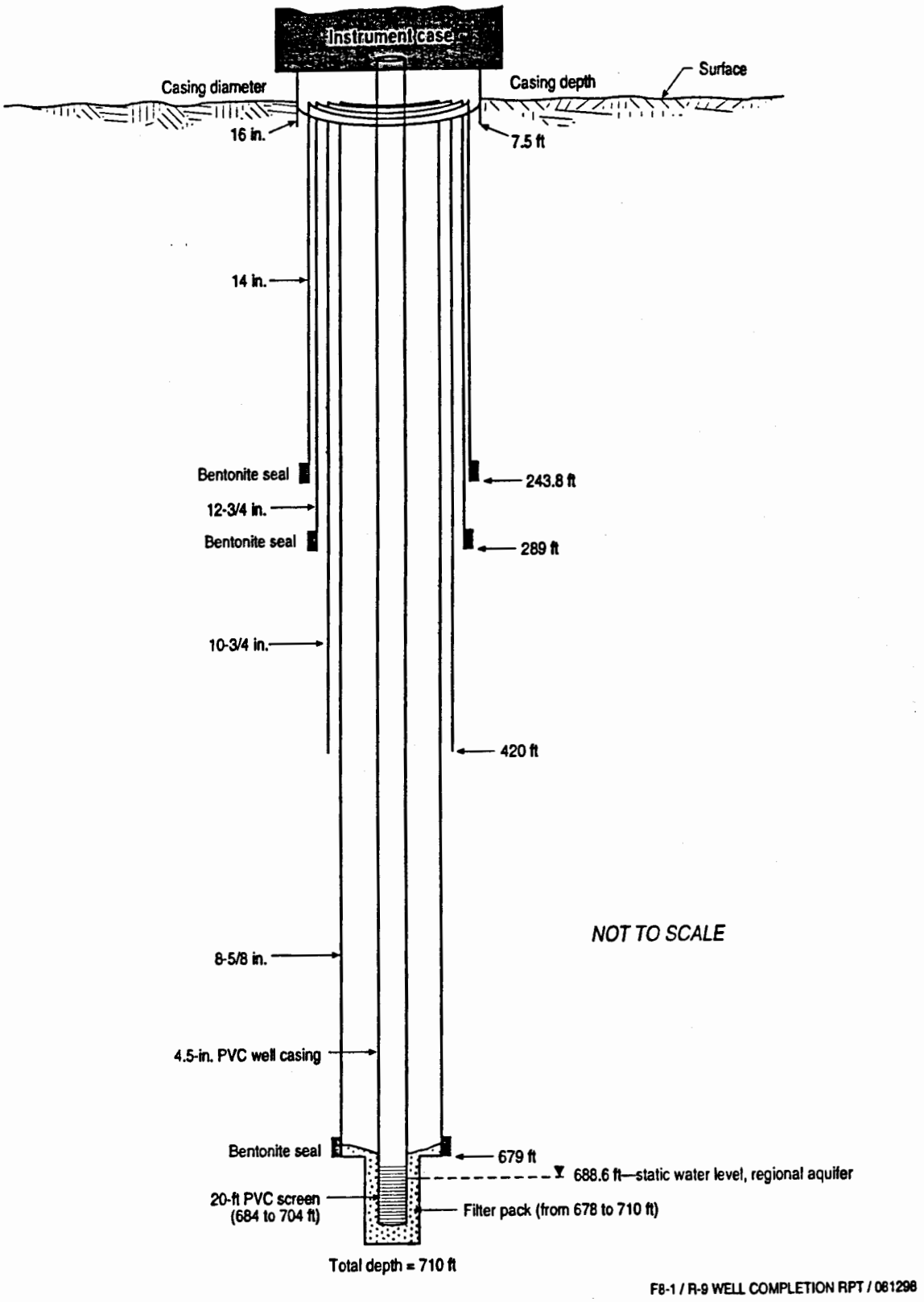


Figure 8-1. Configuration of the temporary well for R-9.

TABLE 9-1

ACTIVITIES PLANNED FOR R-9 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeologic Workplan and Core Document for Canyons Investigations	R-9 Field Implementation Plan	R-9 Actual Work
Planned Depth (ft)	Maximum 150	100 to 500 into the regional aquifer	750	Currently 710
Drilling Method	Auger or rotary drilling	Methods may include, but are not limited to, hollow-stem auger, air-rotary/Odex/Stratex, air-rotary/Barber rig, mud-rotary drilling	Air-rotary methods including downhole percussion hammers on 4.5-in. and 7-in. O.D. dual-wall casings to drill open hole; air-rotary 101-mm Geobarrel system to collect continuous core; air-rotary Holte and Stratex casing advance systems and downhole percussion hammers to simultaneously drill and advance casing in the borehole	Same as field implementation plan
Amount of Core	Not specified	10% of the borehole	Approximately 38% of the borehole	34.4% of the borehole
Lithologic Log	Log to be prepared from core, cuttings, and drilling performance	Log to be prepared from core, cuttings, and drilling performance	Log to be prepared from core, cuttings, and drilling performance	Log was prepared from core, cuttings, and drilling performance
Number of Water Samples Collected for Contaminant Analysis	A water sample will be collected from each saturated zone. Well will be sampled at completion and after six months.	A water sample will be collected from each saturated zone. The number of sampling events after well completion are not specified.	A water sample will be collected from each saturated zone. The geochemistry project leader and technical team will determine the number and locations of samples based on conditions encountered. The number of sampling events after well completion are not specified. Up to seven water samples are planned.	A total of 13 water samples were collected from saturated zones. Of these, 6 were duplicate water samples.
Water Sample Analytes	**Trace Elements/Metals:** Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Tl, Tl, U, V, Zn **Anions:** Br, ClO_3, Cl, F, NO_3, PO_4, HCO_3, SO_4 **Other Inorganic Chemicals:** Si, cyanide **Radionuclides:** ^{3}H, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am **Organic Compounds:** pesticides, PCBs, VOCs, SVOCs **Other Analyses:** ^{14}C, ^{13}C, $^{18}O/^{16}O$, D/H, DOC	Radiochemistry I, II, and II analytes; ^{3}H; gamma spectroscopy scan; general inorganic chemicals; metals; stable isotopes	**Trace Elements/Metals:** Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Tl, U, V, Zn, NH_4 **Anions:** Br, ClO_3, Cl, F, NO_3, NO_2, PO_4, HCO_3, SO_4 **Other Inorganic Chemicals:** Si, cyanide, total organic carbon **Radionuclides:** ^{3}H, ^{90}Sr, ^{137}Cs, ^{241}Am, ^{234}U, ^{235}U, ^{236}U, ^{238}Pu, $^{239,240}Pu$, gamma spectroscopy, gross alpha, gross beta, gross gamma **Organic Compounds:** VOCs, SVOCs **Other Analyses:** ^{14}C, ^{13}C, $^{18}O/^{16}O$, D/H, DOC	Same as field implementation plan with additions of Mo, ^{236}U, $^{15}N/^{14}N$

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-9 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeologic Workplan and Core Document for Canyons Investigations	R-9 Field Implementation Plan	R-9 Actual Work
Water Sample Field Measurements	Alkalinity, dissolved oxygen, pH, specific conductance, temperature, turbidity	Alkalinity, pH, specific conductance, temperature, turbidity	Alkalinity, dissolved oxygen (completed well only), pH, specific conductance, temperature, turbidity	Alkalinity, pH, specific conductance, temperature, turbidity
Number of Core/Cuttings Samples Collected for Contaminant Analysis	Collect and preserve seven cores to represent major hydrogeologic units and zones above and below major hydrogeologic contacts	Twenty samples of core or cuttings to be analyzed for contaminants in each borehole	Up to 21 core/cuttings samples planned	To date, 15 samples of cores/cutting have been collected for contaminant analysis.
Core Sample Analytes	**Trace Elements/Metals:** Al, Sb, As, Ba, Be, Br, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Tl, Ti, U, V, Zn **Anions:** B, Cl, F, SO_4 **Other Inorganic Chemicals:** Si, cyanide **Radionuclides:** ^{3}H, ^{90}Sr, ^{137}Cs, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, gamma spectroscopy, gross alpha, gross beta, gross gamma	Uppermost sample to be analyzed for a full range of compounds; deeper samples to be analyzed for Radiochemistry I, II, and II analytes; ^{3}H; and metals; four samples to be analyzed for VOCs	**Trace Elements/Metals:** Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Tl, Ti, U, V, Zn **Anions:** Br, Cl, F, SO_4, NO_3 **Other Inorganic Chemicals:** Cyanide **Radionuclides:** ^{3}H, ^{90}Sr, ^{137}Cs, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, gamma spectroscopy, gross alpha, gross beta, gross gamma VOAs and SVOCs collected only at depths of 33 and 43 ft, and where PID detects occur	Same as field implementation plan
Hydraulic Property Analyses	Bulk density, dry density, Kd, porosity, mineralogy, moisture content, moisture potential, saturated hydraulic conductivity	Physical properties will be determined on 5 samples and will typically include moisture content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics. Approximately 10 samples of core or cuttings will be collected for mineralogy, petrography, and rock chemistry.	The following physical properties will be determined in each of the major stratigraphic units: particle size (sedimentary units), moisture content, matric potential, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics. In addition, approximately 10 samples of core or cuttings will be selected by the geology project leader for mineralogy, petrography, and rock chemistry.	To date, 39 cores have been collected and preserved for potential use as samples for hydrological property testing. Selection of samples for testing will be based on characterization requirements identified during development of groundwater flow and transport models. A total of 105 samples were collected for moisture content and 104 samples for matric potential. Samples were also collected for mineralogy (22), petrography (27), and rock chemistry (12).

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-9 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeologic Workplan and Core Document for Canyons Investigations	R-9 Field Implementation Plan	R-9 Actual Work
Geophysics	Natural gamma, neutron moisture, and density logs may be collected.	In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptibility, borehole color videotape, fluid temperature (saturated), fluid resistivity (saturated), single-point resistivity (saturated), and spontaneous potential (saturated). In general, cased-hole geophysics includes gamma-gamma density, natural gamma, and thermal neutron.	In stable open borehole environments, geophysics measurements will include caliper, electromagnetic induction, natural gamma, magnetic susceptibility, color camera, borehole digital camera, gamma-gamma, and thermal/epithermal neutron logs. In the cased borehole, geophysics measurements will include gamma-gamma density, natural gamma, and thermal neutron logs.	Same as field implementation plan
Water-Level Measurements			Water levels will be determined for each saturated zone by water-level meter or by pressure transducer.	Water levels were determined for each saturated zone by water-level meter or by pressure transducer.
Slug Tests			Slug tests planned for all zones of saturation encountered.	Slug tests were conducted at the static water levels for the upper two perched zones, but the applicability of the results is questionable because the tests were conducted at the static water level for confined systems. Because of their questionable utility, slug test data are not reported.
Air Permeability/ Borehole Anemometry		Conducted in Bandelier Tuff at 10-ft intervals after removing the hollow-stem auger and/or Odex/Stratex casing	In unsaturated environments, borehole anemometry and straddle packer air permeability measurements will be made in stable open borehole environments at locations determined in the field.	Air permeability was measured in two borehole regions in the Cerros del Rio basalt. Four measurements were made in the upper region, and three measurements were made in the lower region.
Surface Casing		Approximately 20 in. O.D.; extends from land surface to 10 ft depth in underlying competent layer and grouted in place	10-in.-diameter low carbon steel casing set to a minimum depth of 20 ft with a 3 ft stickup	Permanent well not completed

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-9 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeologic Workplan and Core Document for Canyons Investigations	R-9 Field Implementation Plan	R-9 Actual Work
Minimum Well Casing Size	4 in.	6-5/8-in. O.D.	5-in. I.D.	Permanent well not completed
Well Screen	10-ft stainless steel with top at top of static water level	Machine-slotted (0.01-in.) stainless steel screen(s) with flush-jointed threads; number and length of screens to be determined on a site-specific basis and proposed to NMED	60 ft of prepacked, 6.68-in.-diameter, machine-slotted (0.01-in.) stainless steel screen with flush-jointed threads 5 ft of the screen to extend above the static water level; screen specifications based on well life expectancy of 50 years and on discussions with NMED	Permanent well not completed
Filter Material		>90% silica sand, properly sized for the 0.010-in. slot size of the well screen; extends 2 ft above and below the well screen	>98% silica sand, properly sized for the 0.010-in. slot size of the well screen; extends 2 ft above and below the well screen	Permanent well not completed
Conductor Casing		Carbon-steel casing from land surface to top of stainless steel casing	Carbon-steel casing 5.56 in. in diameter extending from land surface to dielectric coupling at top of stainless steel casing; 10 ft of 5.56-in.-diameter stainless steel casing below dielectric coupling	Permanent well not completed
Backfill Materials (exclusive of filter materials)		Uncontaminated drill cuttings below sump and bentonite above sump	Bentonite in borehole below well; fine sand in transition zone 10 ft above and 3 ft below filter pack; bentonite above transition zone to bottom of surface casing; cement grout between surface casing and borehole wall and between surface casing and well casing	Permanent well not completed
Sump		Stainless steel casing	5.56-in.-diameter stainless steel casing 10 ft long	Permanent well not completed
Bottom Seal		Bentonite	Bentonite	Permanent well not completed

Other modifications to R-9 were relatively minor. In some cases, molybdenum, uranium-236, and nitrogen-15/nitrogen-14 were added to the analytical suite for water samples because of groundwater issues that were identified during the drilling program. Also, the percentage of core collected was increased from 10% as planned in the *Hydrogeologic Workplan* and the core document to 34.4% that was actually collected. The additional core was needed to adequately characterize the geologic conditions and perched zones encountered during drilling.

10.0 SUMMARY OF SIGNIFICANT RESULTS

In descending order, geologic units penetrated in R-9 included alluvium, basaltic rocks of the Cerros del Rio volcanic field, old alluvium, the Puye Formation, and basaltic rocks of the Santa Fe Group. The following geologic conditions were unexpected.

- Overall, the Puye Formation was found to be finer grained than expected based on lithologic logs of existing wells in the area. The upper Puye Formation consists primarily of siltstone and sandstone.
- The lower part of the Puye Formation is composed of a thick sequence of diagenetically altered, reworked tuffaceous sandstone and conglomerate. Pervasive diagenesis of the tuffaceous sedimentary deposits resulted from the alteration of volcanic glass to clay minerals. Similar "tuffs" were assigned to the top of the Santa Fe Group in well PM-1, but the dacitic nature of these deposits indicate they are part of the Puye Formation.
- The axial facies of the Puye Formation (Totavi Lentil) was expected in R-9 based on lithologic logs of existing wells in the area; however, these deposits were not present.
- The top of the Santa Fe Group in R-9 is represented by a basalt flow with a minimum eruption age of 8.45 to 8.63 Ma. This basalt probably correlates with basalts in the upper part of the Santa Fe Group in PM-1.

Six saturated zones were encountered during R-9 drilling operations. The tops of the saturated zones occurred at depths of 180, 275, 579, 615, 624, and 688 ft. Five of these zones are believed to be perched groundwater zones, and the sixth is believed to be associated with the regional aquifer.

The perched zone at 180 ft depth occurs in the middle of basaltic rocks of the Cerros del Rio volcanic field. After the top of the zone was first penetrated, water rose quickly in the borehole before it stabilized at a depth of 137 ft, indicating that the zone is relatively permeable and the water is confined. Fractures probably provide the saturated porosity in this perched zone. This groundwater body is perched on massive basalt and is approximately 45 ft thick. Groundwater from this zone has a sodium-calcium-chloride-bicarbonate ionic composition with a pH value of 8.30. This zone contains above background activities/concentrations of tritium (347 pCi/L) and chloride (29.2 ppm).

The perched zone at a depth of 275 ft occurs at the base of the Cerros del Rio basalt. A clay-rich basaltic breccia forms the saturated porosity, and the perching layer is a fine-grained basaltic tephra. Groundwater in this zone is characterized by a sodium-sulfate-bicarbonate ionic composition with a pH value of 8.79. This zone, which is approximately 7 ft thick, contains 106 pCi/L tritium and 48.4 ppb dissolved uranium. The lower zone in the Cerros del Rio basalt has a higher TDS content (330 ppm) than the upper zone (200 ppm), possibly reflecting a longer groundwater residence time. In addition to tritium

and possibly dissolved uranium, other possible anthropogenic constituents include chloride, nitrate, and oxalate.

Three thin zones of saturation were also encountered in the Puye Formation at depths of 579 , 615, and 624 ft. These zones, which are of uncertain origin, occur in transmissive zones intercalated in clay-rich tuffaceous sedimentary deposits. They appear to be hydraulically connected, confined systems in which water levels rose rapidly to a depth of 524 ft after the tops of the zones were penetrated. Groundwater within the Puye Formation varies from calcium-sodium-bicarbonate to sodium-chloride-bicarbonate compositions. Tritium concentrations in groundwater of the Puye Formation range from 2.71 to 30.3 pCi/L. Concentrations of chloride, nitrate, and oxalate appear to be elevated relative to background values in all three zones.

The deepest groundwater system was encountered at a depth of 688 ft near the top of basalt in the Santa Fe Group. This deep system is unconfined, and it is almost certainly associated with the regional aquifer. The depth of the top of the regional water table is 28 to 84 ft lower than what was predicted based on water levels in nearby water supply wells and water-level maps for the regional aquifer. Groundwater from this zone is characterized by a calcium-sodium-bicarbonate ionic composition with a TDS content of 275 ppm. This groundwater is chemically similar to regional aquifer water in wells PM-1 and PM-3; it has a tritium concentration of 14.43 pCi/L.

11.0 ACKNOWLEDGMENTS

The authors of this report had the following responsibilities. Broxton was the principal compiler of the report and was the technical team leader for the drilling program. Gilkeson was responsible for the design, planning, and technical oversight of drilling operations and for coordinating borehole testing activities. Longmire was the geochemistry principal investigator who coordinated the collection, analysis, and interpretation of chemical data collected for core, cuttings, and groundwater. Marin was the well-site geologist who prepared preliminary lithologic logs; collected and preserved samples for geologic, moisture, and hydrologic characterization; and compiled drilling statistics. Warren was the geology principal investigator who collected petrographic, chemical, and mineralogic data to determine the geologic characteristics of rock units; he also coordinated moisture and matric potential analyses. Crowder was the field team leader who provided oversight of the site geologist, site safety officer, sampling, waste management activities, and health and safety; he provided the description of survey activities in this report. Newman provided information on anion profiles from samples of core and cuttings. Lowry and Wycoff were responsible for the air permeability measurements and interpretation; Wycoff also assisted with geophysical measurements. Daymon was field team manager and provided the waste management section of this report.

In addition to the authors, numerous individuals contributed to this investigation.

Tonto Environmental Drilling Company provided drilling services under the direction of John Eddy, the drilling supervisor. The drilling crew consisted of Larry Thoren, Casy Howe, Gray Rich, Frank Hight, Kelly Dixon, and Glenn Woodward.

Darril Stafford and Ray Wright were the site safety officers and the radiological control technicians for drilling activities. Trung Nguyen provided Laboratory oversight for health and safety; Marty Peifer provided Laboratory oversight for radiological controls.

Steve Bolivar, Joe Skalski, and Willanne Winchester provided contract oversight for drilling activities, field support, sample management and curation, and analytical support. Felicia Aguilar, Candi Chroninger, and Robert Trujillo provided data management support. Jenny Harris and Andy Adams supported water sampling activities.

Dale Counce was the analyst for water chemistry analyses used for screening of groundwaters collected from saturated zones. Emily Kluk was the analyst for x-ray fluorescence of rock samples and for moisture and matric potential determinations. Margaret Snow performed some of the moisture and matric potential determinations. Steve Chipera was the analyst for x-ray diffraction of core and cuttings. Andy Adams prepared thin sections.

The Groundwater Integration Team, led by Charlie Nylander, participated in the planning and evaluation of data collected during this investigation. Steve McLin provided equipment and field support for water-level measurements.

COLOG, Inc., provided borehole geophysics services. Joe Beveridge helped to reduce the geophysical data.

Bonnie Koch provided DOE oversight during the investigation. She was assisted by Bob Enz.

John Young of the New Mexico Environment Department provided regulatory oversight during drilling operations. Michael Dale and Chris Hanlon-Meyer from the DOE Oversight Bureau collected sample splits from groundwater zones and acted as liaisons with the regulators.

Maureen Oakes served as editor for this report, Christy Flāming was the illustrator, and Pam Maestas was the compositor.

David Rogers and Bill Stone provided review comments on this report.

Allyn Pratt supported all phases of this investigation as leader of the Canyons Focus Area.

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Appendix A

Drilling Chronology

APPENDIX A DRILLING CHRONOLOGY

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
1.0	9/22/97	Mon	Day								Mobilized drill rig and support equipment to site
2.0	9/23/97	Tue	Day								Set up drill rig and support equipment
3.0	9/24/97	Wed	Day								Set up completed
	9/24/97	Wed	Day								Cut off existing 10-in. surface casing
4.0	9/25/97	Th	Day	904	918	4.00	10.00	6.00	14.0	25.71	Drilled out cement in surface casing (4 to 10 ft) using RC-44 4-7/8-in. percussion hammer and reverse circulation (RC) rods
	9/25/97	Th	Day	1055	1220	10.00	33.00	23.00	85.0	16.24	Drilled open borehole from 10 to 33 ft using RC-44 4-7/8-in. percussion hammer and RC rods; Cerros del Rio Basalt
	9/25/97	Th	Day	1315	1400	0.00	33.00	33.00	45.0	44.00	Tripped in core tools from surface to 33 ft
	9/25/97	Th	Day	1745	1845	33.00	36.00	3.00	60.0	3.00	Cored 4-1/2-in. hole from 33 to 36 ft; recovery = 6.7% in weathered Cerros del Rio Basalt
5.0	9/26/97	Fri	Day	645	900	36.00	41.00	5.00	135.0	2.22	Cored 4-1/2-in. hole from 36 to 41 ft; recovery = 24% in weathered Cerros del Rio Basalt; abandoned coring at 41 ft because of poor recovery
	9/26/97	Fri	Day	930	1000	0.00	41.00	41.00	30.0	82.00	Tripped out core tools from 41 ft to surface
	9/26/97	Fri	Day	1000	1035	33.00	41.00	8.00	35.0	13.71	Reamed corehole to 7.0-in. from 33 to 41 ft using RC-44 4-7/8-in. percussion hammer and RC rods
	9/26/97	Fri	Day	1122	1542	41.00	182.00	141.00	260.0	32.54	Drilled open borehole from 41 to 182 ft using RC-44 4-7/8-in. percussion hammer and RC rods; Cerros del Rio Basalt
	9/26/97	Fri	Day								Collected cuttings for contaminant characterization samples from 41 to 51 ft and 50.8 to 58 ft
	9/26/97	Fri	Day	1600							**Encountered water from 180 to 182 ft in clay-rich Cerros del Rio Basalt rubble**
	9/26/97	Fri	Day								Collected ~1 gal. of water through drilling circulation system
	9/26/97	Fri	Day								Observed that water rose under artesian head to ~162 ft below ground surface (bgs)
	9/26/97	Fri	Day	1605	1643	182.00	0.00	182.00	38.0	287.37	Tripped out RC-44 4-7/8-in. percussion hammer and RC rods from 182 ft to surface
	9/26/97	Fri	Day	1650							Measuring depth to water (DTW) unsuccessful because borehole caved at 98 ft
	9/26/97	Fri	Day								Observed that water rose to ~140 ft bgs

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	9/27/97	Sat	Day								Conducted geophysical logging from 10 to 98 ft (COLOG); geophysical logs included camera, borehole image processing system (BIPS), gamma density, magnetic susceptibility, and neutron (open borehole and through RC rods)
	9/27/97	Sat	Day								Performed open borehole anemometry and unsaturated zone straddle packer measurements (SEA) with open intervals at 39 to 41 ft, 43 to 45 ft, 60 to 62 ft, and 64 to 66 ft
6.0	9/29/97	Mon	Day	1015							Collected informal water sample from 1 gal. obtained through drilling circulation system
	9/29/97	Mon	Day	1150	1627	0.00	4.00	4.00	277.0	0.87	Tripped in Stratex 6-5/8-in. casing advance system from surface to 4 ft
	9/29/97	Mon	Day	1635	1655	4.00	10.00	6.00	20.0	18.00	Drilled 6-5/8-in. casing from 4 to 10 ft inside the 10-in.-diameter, 10-ft-long surface casing
7.0	9/30/97	Tue	Day	835	845				10.0		Removed 10-in.-diameter, 10-ft-long surface casing, which broke free from cement while installing 6-5/8-in. casing
	9/30/97	Tue	Day	953	1355	10.00	34.00	24.00	242.0	5.95	Drilled 6-5/8-in. casing from 10 to 34 ft; Cerros del Rio Basalt
8.0	10/1/97	Wed	Day								Modified rotating head to minimize dust emissions while drilling
9.0	10/2/97	Th	Day								Collected contaminant characterization cuttings sample of precurated cuttings from 172 to 178.5 ft to comply with the sampling and analysis plan (SAP), which indicated that a contaminant characterization sample be collected from 5 ft above the water
	10/2/97	Th	Day	735	1825	34.00	59.00	25.00	650.0	2.31	Drilled 6-5/8-in. casing from 34 to 59 ft; Cerros del Rio Basalt
10.0	10/3/97	Fri	Day	800	1850	59.00	129.00	70.00	650.0	6.46	Drilled 6-5/8-in. casing from 59 to 129 ft; Cerros del Rio Basalt
10.5	10/4/97	Sat	Day	720	745	129.00	0.00	129.00	25.0	309.60	Tripped out 6-5/8-in. casing advance system from 129 ft to surface
	10/4/97	Sat	Day	755	820	0.00	129.00	129.00	25.0	309.60	Tripped in RC-44 4-7/8-in. percussion hammer and RC rods from surface to 129 ft
	10/4/97	Sat	Day	822	1005	129.00	182.00	53.00	103.0	30.87	Reamed borehole from 129 to 182 ft using RC-44 4-7/8-in. percussion hammer and RC rods
	10/4/97	Sat	Day	1020	1055	182.00	0.00	182.00	25.0	436.80	Tripped out RC-44 4-7/8-in. percussion hammer and RC rods from 182 ft to surface
	10/4/97	Sat	Day	1146							Measured DTW at 137.65 ft below ground zero (bgz)
	10/4/97	Sat	Day	1159		137.65	137.63	0.02	13.0	0.0923	Measured DTW at 137.63 ft bgz
	10/4/97	Sat	Day	1214		137.63	137.62	0.01	15.0	0.0400	Measured DTW at 137.62 ft bgz
	10/4/97	Sat	Day	1230		137.62	137.61	0.01	16.0	0.0375	Measured DTW at 137.61 ft bgz
	10/4/97	Sat	Day	1425		137.61	137.42	0.19	115.0	0.0991	Measured DTW at 137.42 ft bgz

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	10/4/97	Sat	Day								Conducted borehole geophysics from 129 to 182 ft (SEA) using rented COLOG portable logging system; abandoned geophysical logging when unable to calibrate geophysical logging tools
	10/4/97	Sat	Day	1430							Installed transducer at 148.15 ft to monitor water level with Hermit data collection system; transducer reads 10.69 ft head
	10/5/97	Sun	Day								Performed slug test on water using Hermit data collection system
11.5	10/6/97	Mon	Day	715	750						Collected ~15 gal. of water at 138 ft using 3-in. stainless steel bailer for contaminant characterization water sample
	10/6/97	Mon	Day	910		137.42	137.07	0.35	2565.0	0.0082	Measured DTW at 137.07 ft bgz 80 minutes after water sampling
	10/6/97	Mon	Day	940	1015	0.00	181.00	181.00	35.0	310.29	Tripped in 4-1/2-in. outside diameter (OD) coring system from surface to 181 ft
	10/6/97	Mon	Day								Evacuated water from borehole using drilling circulation air to air-lift water
	10/6/97	Mon	Day	1145	1800	181.00	200.50	19.50	375.0	3.12	Cored 4-1/2-in. hole from 181 to 200.5 ft; recovery = 81.5% in clay-rich Cerros del Rio Basalt
	10/6/97	Mon	Day								Collected two contaminant characterization core samples, five geotechnical core samples, and one hydrologic core sample
	10/6/97	Mon	Day								Facility manager (FMU-80/FSS-8) on site
12.5	10/7/97	Tue	Day	740	1720	200.50	225.50	25.00	580.0	2.59	Cored 4-1/2-in. hole from 200.5 to 225.5 ft; recovery = 81.6% in clay-rich basalt; clay-rich basalt extends from 180 to 225 ft
	10/7/97	Tue	Day								Collected one contaminant characterization core sample and two geotechnical core samples
13.5	10/8/97	Wed	Day	822		137.07	136.92	0.15	1392.0	0.0065	Measured DTW at 136.92 ft bgz
	10/8/97	Wed	Day								Facility manager (FMU-80/FSS-8) on site to deenergize the overhead power lines adjacent to the site
	10/8/97	Wed	Day	904	1156	225.50	236.00	10.50	172.0	3.66	Cored 4-1/2-in. hole from 225.5 to 236 ft; recovery = 100% in massive Cerros del Rio Basalt
	10/8/97	Wed	Day								Collected three contaminant characterization core samples, three geotechnical core samples, and two hydrologic core samples
	10/8/97	Wed	Day	1238		136.92	139.66	2.74	256.0	0.6422	Measured DTW at 139.66 ft bgz
	10/8/97	Wed	Day								Detected bottom of water by 2-ft decline in DTW with corehole at 236 ft in massive, relatively unfractured, clay-poor Cerros del Rio Basalt
	10/8/97	Wed	Day	1311		139.66	139.59	0.07	33.0	0.1273	Measured DTW at 139.59 ft bgz
	10/8/97	Wed	Day	1327	1411	236.00	239.00	3.00	44.0	4.09	Cored 4-1/2-in. hole from 236 to 239 ft; recovery = 86.7% in massive Cerros del Rio Basalt

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	10/8/97	Wed	Day	1417		139.59	138.57	1.02	66.0	0.9273	Measured DTW at 138.57 ft bgz
	10/8/97	Wed	Day	1444							Added bentonite seal (0.65 gal.) through core tools from 236 to 239 ft
	10/8/97	Wed	Day	1454	1530	236.00	0.00	236.00	36.0	393.33	Tripped out core tools from 236 ft to surface
	10/8/97	Wed	Day	1540		138.57	135.14	3.43	83.0	2.48	Measured DTW at 135.14 ft bgz
	10/8/97	Wed	Day	1545	1640	0.00	129.00	129.00	55.0	140.73	Tripped in Stratex 6-5/8-in. casing advance system from surface to 129 ft
14.5	10/9/97	Th	Day	842	1603	129.00	179.00	50.00	441.0	6.80	Drilled 6-5/8-in. casing from 129 to 179 ft; Cerros del Rio Basalt
15.5	10/10/97	Fri	Day	745	1400	179.00	239.00	60.00	375.0	9.60	Drilled 6-5/8-in. casing from 179 to 239 ft; Cerros del Rio Basalt
	10/10/97	Fri	Day	1548	1715	239.00	0.00	239.00	87.0	164.83	Tripped out 6-5/8-in. casing advance system from 239 ft to surface
	10/10/97	Fri	Day	1810	1815	239.00	232.50	6.50	5.0	78.00	Pulled back 6-5/8-in. casing 6.5 ft from 239 to 232.5 ft
	10/10/97	Fri	Day								Added bentonite pellets from 233 to 239 ft; waited 30 minutes for bentonite to self-hydrate with water in corehole
	10/10/97	Fri	Day	1840							Landed 6-5/8-in. casing (temporarily) at 239 ft; allowed to set during 3-day weekend
16.5	10/14/97	Tue	Day	725	845	0.00	239.00	239.00	80.0	179.25	Tripped in core tools from surface to 239 ft
	10/14/97	Tue	Day	1050	1800	239.00	265.00	26.00	430.0	3.63	Cored 4-1/2-in. hole from 239 to 265 ft; recovery = 93.5% in massive Cerros del Rio Basalt
	10/14/97	Tue	Day								Collected three geotechnical core samples
17.5	10/15/97	Wed	Day	725	820	239.00	0.00	239.00	80.0	179.25	Tripped out core tools from 265 ft to surface
	10/15/97	Wed	Day	820	830						Cleaned bit and coring system
	10/15/97	Wed	Day	830	916	0.00	265.00	265.00	46.0	345.65	Tripped in core tools from surface to 265 ft
	10/15/97	Wed	Day	916	1735	265.00	280.50	15.50	499.0	1.86	Cored 4-1/2-in. hole from 265 to 280.5 ft; recovery = 94.2% in massive basalt to 279 ft and clay-rich basalt rubble to 280.5 ft
	10/15/97	Wed	Day								Encountered water at ~275 ft
	10/15/97	Wed	Day								Collected two contaminant characterization core samples
	10/15/97	Wed	Day	1747							Measured DTW at 280.41 ft bgz
	10/15/97	Wed	Day	1800	1806	280.50	281.50	1.00	6.0	10.00	Cored 4-1/2-in. hole from 280.5 to 281.5 ft; recovery = 100% in clay-rich basalt rubble to 281.5 ft
18.5	10/16/97	Th	Day	735	815	281.50	0.00	281.50	40.0	422.25	Tripped out core tools from 281.5 ft to surface
	10/16/97	Th	Day	825		280.41	273.65	6.76	878.0	0.46	Measured DTW at 273.65 ft bgz
	10/16/97	Th	Day	940	1025						Collected ~2.5 gal. of water at 273 ft using 3-in. stainless steel bailer for contaminant characterization water sample

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	10/16/97	Th	Day	1025		273.65	279.03	5.38	120.0	2.69	Measured DTW at 279.03 ft bgz; 2.5 ft of standing water in corehole
	10/16/97	Th	Day	1045	1200	0.00	281.50	281.50	75.0	225.20	Tripped in core tools from surface to 281.5 ft
	10/16/97	Th	Day	1251	1605	281.50	286.00	4.50	194.0	1.39	Cored 4-1/2-in. hole from 281.5 ft to refusal at 286 ft; recovery = 75.5% in basalt rubble to 282.4 ft; basalt tephra to 283.7 ft; basaltic tephra/sandstone mixture to 284.4 ft; and crossbedded sandstone to 286 ft
	10/16/97	Th	Day								Collected one geotechnical core sample
	10/16/97	Th	Day	1725		279.03	285.63	6.60	420.0	0.94	Measured DTW at 285.63 ft bgz
	10/16/97	Th	Day	1800	1805						Added bentonite seal in corehole from 285 to 286 ft
	10/16/97	Th	Day	1810	1815	285.00	250.00	35.00	5.0	420.00	Pulled back core rods from 285 to 250 ft
19.5	10/17/97	Fri	Day	810	855	286.00	0.00	286.00	45.0	381.33	Tripped out core tools from 286 ft to surface
	10/17/97	Fri	Day	907		285.63	267.43	18.20	942.0	1.16	Measured DTW at 267.43 ft bgz
	10/17/97	Fri	Day	1035	1420	0.00	7.50	7.50	225.0	2.00	Drilled 16-in. washover surface casing from surface to ~7.5 ft bgs
	10/17/97	Fri	Day								Removed excess 16-in. washover casing
	10/17/97	Fri	Day	1425	1730						Excavated cellar for casing jacks (start)
20.0	10/18/97	Sat	Day								Excavated cellar for casing jacks (complete); 3 ft X 4 ft X 5 ft bgs
	10/19/97	Sun	Day	1040		267.43	263.74	3.69	2973.0	0.0745	Measured DTW at 263.74 ft bgz
	10/19/97	Sun	Day	1045	1455						Conducted downhole geophysics in open hole from 232 to 282 ft (SEA), including caliper, EM, magnetic susceptibility, and natural gamma; SEA also ran caliper log inside 6-5/8-in. casing from 6 to 232 ft to determine no disruption in casing
	10/19/97	Sun	Day	1502		263.74	263.58	0.16	262.0	0.0366	Measured DTW at 263.58 ft bgz
	10/19/97	Sun	Day	1505	1745						Performed borehole anemometry (SEA) from 232 to 282 ft and straddle packer measurements from the following open intervals: 245 to 247 ft, 250 to 252 ft, and 255 to 257 ft
	10/19/97	Sun	Day	1810		263.58	264.17	0.59	188.0	0.1883	Measured DTW at 264.17 ft bgz
	10/19/97	Sun	Day	1850	1855						Installed transducer and slug into water at 264.17 ft bgz using Hermit data collection system
21.0	10/20/97	Mon	Day	500	700						Performed slug test on water using Hermit data collection system
	10/20/97	Mon	Day	750		264.17	264.14	0.03	820.0	0.0022	Measured DTW at 264.14 ft bgz following slug test
	10/20/97	Mon	Day	800	855						Collected ~15 gal. of water at 264 ft using 3-in. stainless steel bailer for contaminant characterization water sample

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	10/20/97	Mon	Day	1000	1700						Conducted borehole geophysics (COLOG) through 6-5/8-in. casing to 239 ft and in open hole from 239 to 275 ft. Logs included camera, BIPS, neutron, and gamma density
22.0	10/21/97	Tue	Day	715	845	0.00	239.00	239.00	90.0	159.33	Cleaned out 6-5/8-in. casing to 239 ft using RC-44 4-7/8-in. percussion hammer and RC rods
	10/21/97	Tue	Day	845	925	239.00	0.00	239.00	40.0	358.50	Tripped out RC-44 4-7/8-in. percussion hammer and RC rods from 239 ft to surface
	10/21/97	Tue	Day	950	1025	0.00	244.00	244.00	35.0	418.29	Tripped in core rods from surface to 244 ft
	10/21/97	Tue	Day	1025							Installed wooden bridge plug at 244 ft bgs using wireline overshot to knock bridge plug from core rods
	10/21/97	Tue	Day	1045	1055						Added bentonite seal above wooden bridge plug from 236 to 244 ft using core rods
	10/21/97	Tue	Day	1100							Added deionized (DI) water (5 gal.) to hydrate bentonite pellets
	10/21/97	Tue	Day	1115	1137	236.00	0.00	236.00	22.0	643.64	Tripped out core rods from 236 ft to surface
	10/21/97	Tue	Day	1140	1430	239.00	119.00	120.00	170.0	42.35	Pulled back 6-5/8-in. casing from 239 to 119 ft
	10/21/97	Tue	Day	1450	2015						Conducted open borehole geophysics (COLOG) from 119 to 137.5 ft, including camera, BIPS, gamma density, and neutron
	10/21/97	Tue	Day	2020	2220						Conducted borehole geophysics (SEA) from 119 to 137.5 ft, including caliper, EM, natural gamma, and magnetic susceptibility
23.0	10/22/97	Wed	Day	615		135.14	136.79	1.65	19595.0	0.0051	Measured DTW at 136.79 ft bgz
	10/22/97	Wed	Day	620	650						Collected ~5 gal. of water at 137 ft using 3-in. stainless steel bailer for contaminant characterization water sample
	10/22/97	Wed	Day	920	1115	119.00	0.00	119.00	115.0	62.09	Pulled back 6-5/8-in. casing from 119 ft to surface
24.0	10/22/97	Wed	Evening	1905	2117	0.00	5.00	5.00	132.0	2.27	Tripped in Holte 14-in. casing advance system from surface to 5 ft
	10/22/97	Wed	Evening	2230	2400	5.00	10.00	5.00	90.0	3.33	Drilled 14-in. casing from 5 to 10 ft; alluvium
	10/23/97	Th	Morning	140	547	10.00	30.00	20.00	247.0	4.86	Drilled 14-in. casing from 10 to 30 ft; Cerros del Rio Basalt
25.0	10/23/97	Th	Day	855	915						Investigated lubricants used in drilling operations and collected samples of lubricants for analysis
	10/23/97	Th	Day	915	930						Repaired rotating head
	10/23/97	Th	Day	945	1800						Improved seal in floor of casing jack cellar with hydrated bentonite, and later, Quick Crete cement to stop dust emissions
26.0	10/23/97	Th	Evening	1846	2030	30.00	40.00	10.00	104.0	5.77	Drilled 14-in. casing from 30 to 40 ft; Cerros del Rio Basalt
	10/24/97	Fri	Morning	0	600	40.00	65.00	25.00	360.0	4.17	Drilled 14-in. casing from 40 to 65 ft; Cerros del Rio Basalt
27.0	10/24/97	Fri	Day	725	1525	65.00	80.00	15.00	480.0	1.88	Drilled 14-in. casing from 65 to 80 ft; Cerros del Rio Basalt

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
28.0	10/24/97	Fri	Evening	1915	2148	80.00	100.00	20.00	153.0	7.84	Drilled 14-in. casing from 80 to 100 ft; Cerros del Rio Basalt
	10/25/97	Sat	Morning	9	220	100.00	120.00	20.00	131.0	9.16	Drilled 14-in. casing from 100 to 120 ft; Cerros del Rio Basalt
29.0	10/25/97	Sat	Day	705	1720	120.00	160.00	40.00	615.0	3.90	Drilled 14-in. casing from 120 to 160 ft; Cerros del Rio Basalt
30.0	10/25/97	Sat	Evening	1914	2120	160.00	170.00	10.00	126.0	4.76	Drilled 14-in. casing from 160 to 170 ft; Cerros del Rio Basalt
	10/26/97	Sun	Morning	10	555	170.00	180.00	10.00	345.0	1.74	Drilled 14-in. casing from 170 to 180 ft; Cerros del Rio Basalt
31.0	10/27/97	Mon	Day	815	1610	180.00	202.00	22.00	475.0	2.78	Drilled 14-in. casing from 180 to 202 ft; Cerros del Rio Basalt
32.0	10/27/97	Mon	Evening	1955	2045	202.00	205.00	3.00	50.0	3.60	Drilled 14-in. casing from 200 to 205 ft; Cerros del Rio Basalt
	10/28/97	Tue	Morning	0	545	205.00	227.00	22.00	345.0	3.83	Drilled 14-in. casing from 205 to 227 ft; Cerros del Rio Basalt
33.0	10/28/97	Tue	Day	730	1800	227.00	239.00	12.00	630.0	1.14	Drilled 14-in. casing from 227 to 239 ft; Cerros del Rio Basalt
34.0	10/28/97	Tue	Evening	1800	2015	238.00	243.00	5.00	135.0	2.22	Drilled 14-in. casing from 238 to 243 ft; Cerros del Rio Basalt
	10/28/97	Tue	Evening	2015	2300	243.00	0.00	243.00	165.0	88.36	Tripped out Holte 14-in. casing advance system from 243 ft to surface
	10/28/97	Tue	Evening	2300	2315	243.00	238.00	5.00	15.0	20.00	Pulled 14-in. casing back 5 ft from 243 to 238 ft
	10/28/97	Tue	Evening	2325							Added bentonite pellets (eight buckets = 40 gal.) in 14-3/4-in. casing borehole (fast-yield bentonite pellet volume = 0.75 ft three 5-gal. buckets)
	10/29/97	Wed	Morning	0	30	238.00	243.00	5.00	30.0	10.00	Pushed 14-in. casing from 238 to 243 ft in bentonite seal using RC-44 4-7/8-in. percussion hammer on drive plate atop casing
	10/29/97	Wed	Morning	30							Landed 14-in. casing at 243 ft in bentonite seal (first time)
	10/29/97	Wed	Morning	410	500	0.00	243.00	243.00	50.0	291.60	Tripped in 4-7/8-in. tricone bit and RC rod from surface to 243 ft to clean out hole from 243 to 286 ft to minimize the introduction of drilling lubricant before resampling the water
	10/29/97	Wed	Morning	500	600						Located 4-1/2-in. hole at base of 14-in. casing with 4-7/8-in. tricone bit; the tricone bit "walked" around and "found" the former hole backfilled with soft bentonite in the massive-basalt ledge
	10/29/97	Wed	Morning	600							Positioned tricone bit atop wooden bridge plug at 244 ft
35.0	10/29/97	Wed	Day	700	1045		244.00	244.00	225.0	65.07	Tripped in 6-5/8-in. casing over RC rods to 244 ft as guide to land casing atop hole in center of 14-in. casing; 6-5/8-in. casing to provide a guide to 3-in. stainless steel bailer for resampling water
	10/29/97	Wed	Day	1100							Added bentonite pellets (one bucket = 5 gal.) between 6-5/8-in. and 14-in. casings
	10/29/97	Wed	Day	1245	1640	243.00	277.00	34.00	235.0	8.68	Reamed 4-1/2-in. hole using 4-7/8-in. tricone bit and RC rods from 243 to 277 ft

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	10/29/97	Wed	Day	1640							Detected surge of water in drilling circulation system at 277 ft in tricone bit reaming operation; seal probably ruptured on 14-in. casing below water at 243 ft
	10/29/97	Wed	Day	1740							Measured DTW through RC rods at 197.07 ft bgz confirming that seal ruptured on 14-in. casing below water at 243 ft (first time)
36.0	10/30/97	Th	Day	620							Measured DTW through RC rods at 191.61 ft bgz
	10/30/97	Th	Day	800							Measured DTW between 6-5/8-in. and 14-in. casings at 190.87 ft bgz
	10/30/97	Th	Day	810	820						Evacuated water inside 6-5/8-in. casing by air-lifting water using drilling circulation system
	10/30/97	Th	Day	820							Measured DTW through RC rods at 248.60 ft bgz
	10/30/97	Th	Day	830							Measured DTW between 6-5/8-in. and 14-in. casings at 189.56 ft bgz
	10/30/97	Th	Day	845							Measured DTW through RC rods at 248.64 ft bgz
	10/30/97	Th	Day	850	900	239.00	274.50	35.50	10.0	213.00	Tripped in RC rods from 239 to 274.5 ft
	10/30/97	Th	Day	915	925						Evacuated water inside 6-5/8-in. casing by air-lifting water using drilling circulation system
	10/30/97	Th	Day	930							Measured DTW between 6-5/8-in. and 14-in. casings at 199.55 ft bgz
	10/30/97	Th	Day	940							Measured DTW through RC rods at 199.66 ft bgz
	10/30/97	Th	Day	955							Added bentonite chips (five bags) between 6-5/8-in. and 14-in. casings to improve seal (bentonite chip volume = 1.0 ft three 50-lb. bags)
	10/30/97	Th	Day	1025	1045						Evacuated water inside 6-5/8-in. casing by air-lifting water using drilling circulation system
	10/30/97	Th	Day	1053							Measured DTW through RC rods at 203.1 ft bgz
	10/30/97	Th	Day	1100							Measured DTW between 6-5/8-in. and 14-in. casings at 199.56 ft bgz
	10/30/97	Th	Day	1110	1140	277.00	260.00	17.00	30.0	34.00	Pulled back tricone bit and RC rods from 277 to 260 ft
	10/30/97	Th	Day	1225							Measured DTW between 6-5/8-in. and 14-in. casings at 184.16 ft bgz
	10/30/97	Th	Day	1235	1410	260.00	0.00	260.00	95.0	164.21	Tripped out tricone bit and RC rods from 260 ft to surface
	10/30/97	Th	Day	1415							Measured DTW inside 6-5/8-in. casing at 209.4 ft bgz
	10/30/97	Th	Day	1500	1530						Backfilled borehole from 275 to 243 ft with eight bags of 8/12 silica sand through 6-5/8-in. casing

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	10/30/97	Th	Day	1535	1540	244.00	239.00	5.00	5.0	60.00	Pulled back 6-5/8-in. casing from 244 to 239 ft
	10/30/97	Th	Day	1540							Added bentonite pellets (two buckets = 10 gal.) atop sand
	10/30/97	Th	Day	1541	1640	239.00	60.00	179.00	59.0	182.03	Pulled back 6-5/8-in. casing from 239 to 60 ft
36.5	10/30/97	Th	Evening	1830	1900	60.00	0.00	60.00	30.0	120.00	Pulled back 6-5/8-in. casing from 60 ft to surface
	10/30/97	Th	Evening	1900	1910	243.00	242.50	0.50	10.0	3.00	Pulled back 14-in. casing 0.5 ft from 243 to 242.5 ft
	10/30/97	Th	Evening	1910							Added bentonite chips (four bags) inside 14-in. casing
	10/30/97	Th	Evening	1930	2005	0.00	218.50	218.50	35.0	374.57	Tripped in 14-in. plunger on RC rods inside 14-in. casing from surface to bentonite at 218.5 ft
	10/30/97	Th	Evening	2010	2110	218.50	243.00	24.50	60.0	24.50	Pushed 14-in. casing and plunger from 218.5 to 243 ft using RC-44 hammer on drive plate atop casing
	10/30/97	Th	Evening	2110							Landed 14-in. casing at 243 ft in bentonite seal (second time)
	10/30/97	Th	Evening	2130							Placed downhole pressure on plunger and left overnight
37.5	10/31/97	Fri	Day	845							Observed water ~40 ft and bentonite ~20 ft above plunger
	10/31/97	Fri	Day	800	930	243.00	0.00	243.00	90.0	162.00	Tripped out RC rods, plunger, and 20 ft of bentonite from 243 ft to surface inside 14-in. casing
	10/31/97	Fri	Day	945							Measured DTW inside 14-in. casing as nondetect (dry)
											Measured depth to bottom (DTBot) inside 14-in. casing at ~244 ft bgz
	10/31/97	Fri	Day	1015	1100						Shoveled three 55-gal. drums of hydrated bentonite extracted with plunger back into 14-in. casing for resealing
	10/31/97	Fri	Day	1105	1150	243.00	238.00	5.00	45.0	6.67	Pulled back 14-in. casing 5 ft from 243 to 238 ft
	10/31/97	Fri	Day	1255							Measured DTW inside 14-in. casing at 137.89 ft bgz
	10/31/97	Fri	Day	1435	1450	0.00	225.00	225.00	15.0	900.00	Tripped in redesigned plunger and RC rods to bentonite resistance at 225 ft
	10/31/97	Fri	Day	1620							Measured DTW inside 14-in. casing at ~125 ft bgz; no bentonite above plunger at 225 ft
	10/31/97	Fri	Day	1625	1700	238.00	230.00	8.00	35.0	13.71	Pulled back 14-in. casing 8 ft from 238 to 230 ft
	10/31/97	Fri	Day	1700	1800	230.00	236.00	6.00	60.0	6.00	Pushed 14-in. casing and plunger from 230 to 236 ft
	10/31/97	Fri	Day	1810	1845	236.00	243.00	7.00	35.0	12.00	Pushed 14-in. casing and plunger from 236 to 243 ft
	10/31/97	Fri	Day	1845							Landed 14-in. casing at 243 ft in bentonite seal (third time)
	10/31/97	Fri	Day								Placed downhole pressure on plunger and left over weekend
38.5	11/3/97	Mon	Day	730	835	243.00	0.00	243.00	65.0	224.31	Tripped out RC rods and 14-in. plunger with slow rotation during extraction; no water or bentonite extracted

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/3/97	Mon	Day	840							Measured DTW inside 14-in. casing at ~142 ft bgs
	11/3/97	Mon	Day	840							Measured depth to bentonite (DTBent) inside 14-in. casing at 226.44 ft bgz
	11/3/97	Mon	Day	855							Measured DTW inside 14-in. casing at 141.92 ft bgz
	11/3/97	Mon	Day	910	1150						Removed 160 gal. of water from inside 14-in. casing using 3-in. stainless steel bailer
	11/3/97	Mon	Day	1201							Measured DTW inside 14-in. casing at 166.39 ft bgz. Monitored DTW inside 14-in. casing on 15-minute intervals; measurements were 166.29 ft, +0.10 ft; 166.22 ft, +0.07 ft; 166.14 ft, +0.02 ft; and after 40-minute interval, 166.02 ft, +0.10 ft
	11/3/97	Mon	Day	1455	1520						Tightened threads on 14-in. casing string to minimize potential water leakage through threads
	11/3/97	Mon	Day	1620							Measured DTW inside 14-in. casing at 164.49 ft bgz
	11/3/97	Mon	Day	1630	1740	0.00	200.00	200.00	70.0	171.43	Tripped in 6-5/8-in. casing from surface to 200 ft
	11/3/97	Mon	Day	1750							Measured DTW between 6-5/8-in. and 14-in. casings at 160.65 ft bgz
39.5	11/4/97	Tue	Day	720							Measured DTW between 6-5/8-in. and 14-in. casings at 159.51 ft bgz
	11/4/97	Tue	Day	725	800	200.00	219.00	19.00	35.0	32.57	Tripped in 6-5/8-in. casing from 200 to 219 ft
	11/4/97	Tue	Day	800	840	0.00	219.00	219.00	40.0	328.50	Tripped in Stratex 6-5/8-in. casing advance system from surface to 219 ft
	11/4/97	Tue	Day	840							Evacuated bentonite inside 14-in. casing using drilling circulation system
	11/4/97	Tue	Day	900	930	219.00	227.00	8.00	30.0	16.00	Tripped in 6-5/8-in. casing advance system from 219 to 227 ft
	11/4/97	Tue	Day	1039							Measured DTW between 6-5/8-in. and 14-in. casings at 191.08 ft bgz
	11/4/97	Tue	Day	1052	1150	227.00	239.00	12.00	62.0	11.61	Tripped in 6-5/8-in. casing advance system from 227 to 239 ft through bentonite
	11/4/97	Tue	Day	1208							Measured DTW between 6-5/8-in. and 14-in. casings at 191.08 ft bgz
	11/4/97	Tue	Day	1232							Measured DTW between 6-5/8-in. and 14-in. casings after 24 minutes at 191.48 ft bgz
	11/4/97	Tue	Day	1240	1320	239.00	243.00	4.00	40.0	6.00	Tripped in 6-5/8-in. casing advance system from 239 to 243 ft through bentonite; operation plugged bit
	11/4/97	Tue	Day	1345	1420	243.00	0.00	243.00	35.0	416.57	Tripped out 6-5/8-in. casing advance system from 243 ft to surface to unplug

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/4/97	Tue	Day	1425							Measured DTW between 6-5/8-in. and 14-in. casings at 202.53 ft bgz
	11/4/97	Tue	Day	1440	1520	0.00	243.00	243.00	40.0	364.50	Tripped in 6-5/8-in. casing advance system from surface to 243 ft
	11/4/97	Tue	Day	1535	1715	243.00	249.00	6.00	100.0	3.60	Drilled 6-5/8-in. casing from 243 to 249 ft; Cerros del Rio Basalt
40.5	11/5/97	Wed	Day	730							Measured DTW between 6-5/8-in. and 14-in. casings at 90.62 ft bgz
	11/5/97	Wed	Day	730							Measured DTBent between 6-5/8-in. and 14-in. casings at 96.12 ft bgz
	11/5/97	Wed	Day	740	935	249.00	255.00	6.00	115.0	3.13	Drilled 6-5/8-in. casing from 249 to 255 ft; Cerros del Rio Basalt
	11/5/97	Wed	Day	940	1035	255.00	0.00	255.00	55.0	278.18	Tripped out 6-5/8-in. casing advance system from 255 ft to surface to unplug and clean up
	11/5/97	Wed	Day	1055	1120	0.00	255.00	255.00	25.0	612.00	Tripped in 6-5/8-in. casing advance system from surface to 255 ft
	11/5/97	Wed	Day	1135	1725	255.00	279.00	24.00	350.0	4.11	Drilled 6-5/8-in. casing from 255 to 279 ft; Cerros del Rio Basalt
41.5	11/6/97	Th	Day	730	840	279.00	289.00	10.00	70.0	8.57	Drilled 6-5/8-in. casing from 279 to 289 ft; basalt rubble to 282.4 ft, basalt tephra to 283.7 ft, and basalt alluvium to 289 ft
	11/6/97	Th	Day	1030							Measured DTW inside 6-5/8-in. casing as nondetect (dry)
	11/6/97	Th	Day	1030							Measured DTBot inside 6-5/8-in. casing at 287.82 ft bgz
	11/6/97	Th	Day	1030							Measured DTBent between 6-5/8-in. and 14-in. casings at ~76 ft bgs
	11/6/97	Th	Day	1100							Added bentonite pellets (one bucket = 5 gal.) into 1.5-ft open borehole below casing
	11/6/97	Th	Day	1102							Added DI water (5 gal.) to hydrate bentonite pellets
	11/6/97	Th	Day	1110	1215	0.00	286.00	286.00	65.0	264.00	Tripped in 6-5/8-in. plunger and RC rods from surface to bentonite at 286 ft
	11/6/97	Th	Day	1220	1230	289.00	286.00	3.00	10.0	18.00	Pulled back 6-5/8-in. casing 3 ft from 289 to 286 ft
	11/6/97	Th	Day	1240	1300	286.00	287.50	1.50	20.0	4.50	Pushed 6-5/8-in. casing and plunger from 286 ft to refusal 287.5 ft
	11/6/97	Th	Day	1430	1550	287.50	0.00	287.50	80.0	215.63	Tripped out plunger and RC rods from 287.5 ft to surface
	11/6/97	Th	Day	1530							Measured DTW inside 6-5/8-in. casing as nondetect (dry)
	11/6/97	Th	Day	1530							Measured DTBot inside 6-5/8-in. casing at ~286 ft bgs
	11/6/97	Th	Day	1540	1550	287.50	289.50	2.00	10.0	12.00	Pushed 6-5/8-in. casing from 287.5 to 289.5 ft bgs using RC-44 hammer on drive plate atop casing
	11/6/97	Th	Day	1700	1745	0.00	289.50	289.50	45.0	386.00	Tripped in core tools from surface to 289.5 ft
42.5	11/7/97	Fri	Day	730							Measured DTW inside core rods as nondetect (dry)

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/7/97	Fri	Day	850	1500	289.00	306.00	17.00	370.0	2.76	Cored 4-1/2-in. hole from 289 ft to refusal at 306 ft; recovery = 28.2% in Puye Fm clastics
	11/7/97	Fri	Day	1515	1528						Backfilled hole from 306 to 293 ft with 8/12 silica sand
	11/7/97	Fri	Day	1530							Measured depth to backfilled sand at ~293 ft bgs
	11/7/97	Fri	Day	1530	1535						Added bentonite from 293 to 289 ft
	11/7/97	Fri	Day	1535							Added DI water (5 gal.) to hydrated bentonite
	11/7/97	Fri	Day	1540							Measured DTBent at ~289 ft bgs
	11/7/97	Fri	Day	1540	1625	289.00	0.00	289.00	45.0	385.33	Tripped out core tools from 289 ft to surface
	11/7/97	Fri	Day	1625	1710	289.50	258.00	31.50	35.0	54.00	Pulled back 6-5/8-in. casing from 289.5 to 258 ft
	11/7/97	Fri	Day	1715		264.14	278.99	14.85	26485.0	0.0336	Measured DTW at 278.99 ft bgz
43.5	11/10/97	Mon	Day	635		278.99	274.23	4.76	800.0	0.3570	Measured DTW at 274.23 ft bgz
	11/10/97	Mon	Day	840							Collected ~15 gal. of water at 274 ft using 3-in. stainless steel bailer for contaminant characterization water sample
	11/10/97	Mon	Day	845	910						Backfilled from 289 to 260 ft (6-5/8-in. casing borehole) with 8/12 silica sand
	11/10/97	Mon	Day	910	920	258.00	248.00	10.00	10.0	60.00	Pulled back 6-5/8-in. casing from 258 to 248 ft
	11/10/97	Mon	Day								Backfilled from 260 to 249 ft (6-5/8-in. casing hole) with 8/12 silica sand
	11/10/97	Mon	Day	935							Added bentonite seal in 6-5/8-in. casing borehole from 250 to 244 ft
	11/10/97	Mon	Day	940	945	248.00	244.00	4.00	5.0	48.00	Pulled back 6-5/8-in. casing from 248 to 245 ft
	11/10/97	Mon	Day	950							Added bentonite seal in 6-5/8-in. casing borehole from 244 to 242.5 ft; waited ~30 minutes for bentonite to self-hydrate
	11/10/97	Mon	Day	1017	1159	244.00	0.00	244.00	76.0	192.63	Pulled back 6-5/8-in. casing from 244 ft to surface
	11/10/97	Mon	Day	1320	1545	0.00	240.00	240.00	145.0	99.31	Tripped in 14-in. milling bit on 7-in. RC rods from surface to 240 ft for milling 14-in. casing shoe; operation plugged bit and rods with bentonite
	11/10/97	Mon	Day	1545	1650	240.00	0.00	240.00	65.0	221.54	Tripped out 14-in. milling bit and 7-in. RC rods from 240 ft to surface to unplug
	11/10/97	Mon	Day								Cleaned bit and rods
	11/10/97	Mon	Day	1840	2030	0.00	242.00	242.00	110.0	132.00	Tripped in 14-in. milling bit and 7-in. RC rods to casing shoe at ~242.5 ft
44.5	11/10/97	Mon	Evening	2030	2400				3.5 hr		Milled 14-in. casing shoe (first time)
	11/11/97	Tue	Morning	0	430				4.5 hr		Milled the 14-in. casing shoe to completion (first time)

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/11/97	Tue	Morning	20							Detected water burping from 14-in. casing while milling the 14-in. casing shoe indicating that the seal on the 14-in. casing at the base of the water ruptured again (second time)
	11/11/97	Tue	Morning	430	530	242.50	0.00	242.50	60.0	242.50	Tripped out 14-in. milling bit and 7-in. RC rods to assess bit
	11/11/97	Tue	Morning	600		136.79	139.93	3.14	28785.0	0.0065	Measured DTW inside 14-in. casing at 139.93 ft, verifying that seal on 14-in. casing below water ruptured
45.5	11/11/97	Tue	Day	850	910	244.00	242.00	2.00	20.0	6.00	Pulled back 14-in. casing 2 ft from 244 to 242 ft
	11/11/97	Tue	Day	910	1800	0.00	230.00	230.00	530.0	26.04	Tripped in 12-3/4-in. casing from surface to 230 ft
46.5	11/11/97	Tue	Evening	1920							Failed to advanced the 12-3/4-in. casing through the 14-in. casing shoe
	11/11/97	Tue	Evening	2020	2400	240.00	160.00	80.00	220.0	21.82	Tripped out 12-3/4-in. casing from 240 to 160 ft
	11/12/97	Wed	Morning	0	430	160.00	0.00	160.00	270.0	35.56	Tripped out 12-3/4-in. casing from 160 ft to surface
	11/12/97	Wed	Morning	440							Attached 5-ft piece of 14-in. casing to 14-in. casing string to pull it back 2 ft
47.5	11/12/97	Wed	Day	700	840	243.00	241.00	2.00	100.0	1.20	Pulled back 14-in. casing 2 ft from 243 to 241 ft
	11/12/97	Wed	Day	940							Measured circumference and calculated maximum diameter of 14-in. milling bit at 12.752-in.
	11/12/97	Wed	Day	1025							Refaced and built up 14-in. milling bit and 7-in. RC rods with Cuttright carbide pieces
	11/12/97	Wed	Day	1045	1320	0.00	240.00	240.00	155.0	92.90	Tripped in refaced 14-in. milling bit and 7-in. RC rods from surface to 240 ft
	11/12/97	Wed	Day	1320	1817				5 hr		Milled 14-in. casing shoe (second time)
48.5	11/12/97	Wed	Evening	1850	2050	242.00	0.00	242.50	120.0	121.25	Tripped out 14-in. milling bit and 7-in. RC rods from 242 ft to surface
	11/12/97	Wed	Evening	2100							Positioned 14-in. milling bit and 7-in. RC rods inside 5-ft piece of 14-in. casing, and decided to build it up again and remill the 14-in. casing shoe to ensure that the 12-3/4-in. casing would extend past the 14-in. casing shoe
	11/13/97	Th	Morning	115	520				4.1 hr		Milled the 14-in. casing shoe (third time)
	11/13/97	Th	Morning	545	625	242.50	0.00	242.50	40.0	363.75	Tripped out the 14-in. milling bit and 7-in. RC rods from 242 ft to surface
49.5	11/13/97	Th	Day	700	1205	0.00	242.50	242.50	305.0	47.70	Tripped in 12-3/4-in. casing from surface, through the 14-in. casing shoe at 241.5 ft, to 242.5 ft
	11/13/97	Th	Day	1540	1650	0.00	242.50	242.50	70.0	207.86	Tripped in Stratex 12-3/4-in. casing advance system from surface to 242.5 ft
50.5	11/13/97	Th	Evening	1935	2400	242.50	246.00	3.50	265.0	0.79	Drilled 12-3/4-in. casing from 242.5 to 246 ft; Cerros del Rio Basalt

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/14/97	Fri	Morning	0	30	246.00	247.00	1.00	30.0	2.00	Drilled 12-3/4-in. casing from 246 to 247 ft; Cerros del Rio Basalt
	11/14/97	Fri	Morning	35	200	247.00	0.00	247.00	85.0	174.35	Tripped out 12-3/4-in. casing advance system from 247 ft to surface
	11/14/97	Fri	Morning	210							Added bentonite chips (7.5 bags) from 247 to 240 ft
	11/14/97	Fri	Morning	245	410	0.00	246.50	246.50	85.0	174.00	Tripped in plunger inside 12-3/4-in. casing from surface to 246.5 ft
	11/14/97	Fri	Morning								14-in. casing did not drop to 243.5 ft, as predicted
	11/14/97	Fri	Morning	500	600	246.50	0.00	246.50	60.0	246.50	Tripped out plunger inside 12-3/4-in. casing from 246.5 ft to surface
	11/14/97	Fri	Morning	600							Measured DTW inside 12-3/4-in. casing at 236.88 ft bgz
51.5	11/14/97	Fri	Day	815	950	0.00	246.00	246.00	95.0	155.37	Tripped in 12-3/4-in. casing advance system from surface to refusal at 246 ft
	11/14/97	Fri	Day	1115							Observed water inside 12-3/4-in. casing
	11/14/97	Fri	Day	1115							Measured DTW inside 12-3/4-in. casing at ~137.13 ft bgs, indicating that the seal the 14-in. casing ruptured again (third time)
	11/14/97	Fri	Day	1130	1345	236.50	0.00	236.50	135.0	105.11	Tripped out 12-3/4-in. casing advance system from 236.5 ft to surface
	11/14/97	Fri	Day	1535							Added bentonite pellets (10 buckets = 50 gal.) inside 12-3/4 casing
	11/14/97	Fri	Day	1540	1645	0.00	236.00	236.00	65.0	217.85	Tripped in 12-3/4-in. plunger from surface to bentonite/water resistance at 236 ft
	11/14/97	Fri	Day	1645	1740	236.00	246.00	10.00	55.0	10.91	Pushed 12-3/4-in. plunger on bentonite/water from 236 ft, and on 12-3/4-in. casing shoe to 12-3/4-in. casing at 246 ft
52.0	11/14/97	Fri	Evening	1810	1940	241.50	244.50	3.00	90.0	2.00	Pushed 12-3/4-in. casing from 246 to 247 ft and 14-in. casing from 241.5 to 244.5 ft simultaneously using RC-44 hammer atop drive plate; applied pressure from drill rig pull down and left over weekend
53.0	11/17/97	Mon	Day	615							Measured DTW inside 12-3/4-in. casing above plunger at 151.84 ft bgz
	11/17/97	Mon	Day	700	800	246.50	0.00	246.50	60.0	246.50	Tripped out plunger inside 12-3/4-in. casing from 246.5 ft to surface
	11/17/97	Mon	Day	800							Measured DTW inside 12-3/4-in. casing after plunger removed at 164.16 ft bgz
	11/17/97	Mon	Day	805							Measured DTBent inside 12-3/4-in. casing after plunger removed at 237.84 ft bgz
	11/17/97	Mon	Day	950	1400	0.00	247.00	247.00	250.0	59.28	Tripped in 8-5/8-in. casing from surface to 247 ft
	11/17/97	Mon	Day	1435							Measured DTW inside 8-5/8-in. casing at 154.5 ft bgz
	11/17/97	Mon	Day	1615	1815	0.00	247.00	247.00	120.0	123.50	Tripped in Stratex 8-5/8-in. casing advance system from surface to 247 ft
54.0	11/17/97	Mon	Evening	1915	2400	247.00	253.00	6.00	285.0	1.26	Drilled 8-5/8-in. casing from 247 to 253 ft; Cerros del Rio Basalt

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/18/97	Tue	Morning	0	515	253.00	270.00	17.00	315.0	3.24	Drilled 8-5/8-in. casing from 253 to 270 ft; Cerros del Rio Basalt
55.0	11/18/97	Tue	Day	725	1115	270.00	291.00	21.00	230.0	5.48	Drilled 8-5/8-in. casing from 270 to 291 ft; basalt to 282.4 ft, basalt tephra to 283.7 ft, and basalt alluvium to 289 ft
	11/18/97	Tue	Day	1145	1330	291.00	0.00	291.00	105.0	166.29	Tripped out 8-5/8-in. casing advance system from 291 ft to surface
	11/18/97	Tue	Day	1330							Measured DTW inside 8-5/8-in. casing as nondetect (dry)
	11/18/97	Tue	Day	1330							Measured DTBot inside 8-5/8-in. casing at ~290.5 ft bgs
	11/18/97	Tue	Day	1330	1340	291.00	289.00	2.00	10.0	12.00	Pulled back 8-5/8-in. casing from 291 to 289 ft
	11/18/97	Tue	Day	1430							Added granular bentonite (two bags) (granular bentonite volume = 1.0 ft three/bag)
	11/18/97	Tue	Day	1430							Added DI water (10 gal.) to hydrate bentonite
	11/18/97	Tue	Day	1435	1515	0.00	289.00	289.00	40.0	433.50	Tripped in plunger inside 8-5/8-in. casing from surface to 289 ft
	11/18/97	Tue	Day	1515	1540	289.00	291.00	2.00	25.0	4.80	Pushed plunger and 8-5/8-in. casing from 289 to 291 ft
	11/18/97	Tue	Day	1552	1635	291.00	0.00	291.00	43.0	406.05	Tripped out plunger inside 8-5/8-in. casing from 291 ft to surface
	11/18/97	Tue	Day	1635							Measured DTW inside 8-5/8-in. casing as nondetect (dry)
	11/18/97	Tue	Day	1635							Measured DTBot of inside of 8-5/8-in. casing at ~287 ft bgs
	11/18/97	Tue	Day	1640	1730	0.00	20.00	20.00	50.0	24.00	Tripped in 6-5/8-in. casing from surface to 20 ft
56.0	11/18/97	Tue	Evening	1830	2215	20.00	290.00	270.00	225.0	72.00	Tripped in 6-5/8-in. casing from 20 to 290 ft
	11/18/97	Tue	Evening	2216	2400	0.00	290.00	290.00	104.0	167.31	Tripped in Stratex 6-5/8-in. casing advance system from surface to 290 ft
	11/19/97	Wed	Morning	430	600	291.00	295.00	4.00	90.0	2.67	Drilled 6-5/8-in. casing from 291 to 295 ft; alluvium
57.0	11/19/97	Wed	Day	700	815	295.00	299.00	4.00	75.0	3.20	Drilled 6-5/8-in. casing from 295 to 299 ft; alluvium
	11/19/97	Wed	Day	815	920	299.00	0.00	299.00	65.0	276.00	Tripped out 6-5/8-in. casing advance system from 299 ft to surface
	11/19/97	Wed	Day	920							Replaced 6-5/8-in. bit on casing advance system
	11/19/97	Wed	Day	950							Measured DTW inside 8-5/8-in. casing as nondetect (dry)
	11/19/97	Wed	Day	950							Measured DTBot of inside of 8-5/8-in. casing at ~299 ft bgs
	11/19/97	Wed	Day	1000	1040	0.00	299.00	299.00	40.0	448.50	Tripped in 6-5/8-in. casing advance system from surface to 299 ft
	11/19/97	Wed	Day	1040	1720	299.00	399.00	100.00	400.0	15.00	Drilled 6-5/8-in. casing from 299 to 399 ft; alluvium to 329 ft and tuffaceous Puye Fm clastics to 399 ft
58.0	11/19/97	Wed	Evening	1905	2330	399.00	429.00	30.00	265.0	6.79	Drilled 6-5/8-in. casing from 399 to 429 ft; tuffaceous Puye Fm clastics
	11/20/97	Th	Morning	45	530	429.00	499.00	70.00	285.0	14.74	Drilled 6-5/8-in. casing from 429 to 499 ft; tuffaceous Puye Fm clastics

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
59.0	11/20/97	Th	Day	855	1335	499.00	539.00	40.00	280.0	8.57	Drilled 6-5/8-in. casing from 499 to 539 ft; tuffaceous Puye Fm clastics
	11/20/97	Th	Day	1450	1535	539.00	0.00	539.00	45.0	718.67	Tripped out 6-5/8-in. casing advance system from 539 ft to surface
	11/20/97	Th	Day	1545							Measured DTW inside 6-5/8-in. casing as nondetect (dry)
	11/20/97	Th	Day	1620	1710	539.00	519.00	20.00	50.0	24.00	Pulled back 6-5/8-in. casing from 539 to 519 ft
	11/20/97	Th	Day								Measured DTBot in 6-5/8-in. casing borehole at ~538.5 ft bgs
	11/20/97	Th	Day	1715	1810	539.00	479.00	60.00	55.0	65.45	Pulled back 6-5/8-in. casing from 539 to 479 ft
60.0	11/21/97	Fri	Day	835							Measured DTBot inside 6-5/8-in. casing at ~537 ft bgs, indicating 2 ft of slough
	11/21/97	Fri	Day	840	1503	479.00	0.00	479.00	383.0	75.04	Pulled back 6-5/8-in. casing from 479 ft to surface
60.5	11/21/97	Fri	Evening	1620	1718	0.00	295.00	295.00	58.0	305.17	Tripped in wooden bridge plug using core rods from surface to 295 ft
	11/21/97	Fri	Evening	1718							Added granular bentonite and 8/12 sand in 50:50 mixture around and atop wooden bridge plug hung on core rods in open 6-5/8-in. casing borehole at 295 to 296 ft
	11/21/97	Fri	Evening	1720							Positioned wooden bridge plug at 295 to 296 ft by knocking plug from core rods using wireline overshot tool
	11/21/97	Fri	Evening								Pulled back core rods 20 ft from 295 to 275 ft
	11/21/97	Fri	Evening	1725							Measured DTBent/sand mixture atop wooden bridge plug at ~294.5 ft bgs
	11/21/97	Fri	Evening	1744							Added DI water (0.5 gal.) to hydrate bentonite/sand mixture
	11/21/97	Fri	Evening	1810							Added #16 granular bentonite (10 lb) through core rods atop seal at 294.5 ft
	11/21/97	Fri	Evening	1811							Added DI water (1 gal.) to hydrate bentonite
	11/21/97	Fri	Evening	1835							Measured DTBent seal atop wooden bridge plug at 222 ft, indicating core rods plugged with bentonite
	11/21/97	Fri	Evening	1835	1930	275.00	0.00	275.00	55.0	300.00	Tripped out core rods from 275 ft to surface to unplug; rods had bentonite on inner wall but not completely blocked
	11/21/97	Fri	Evening	1945							Measured DTBent seal atop wooden bridge plug at 293.5 ft bgs
	11/21/97	Fri	Evening	1950							Added #16 granular bentonite (30 lb) through core rods atop seal
	11/21/97	Fri	Evening	2005							Added DI water (2 gal.) to hydrate bentonite
	11/21/97	Fri	Evening	2030							Shut down site for Thanksgiving break
	11/24/97	Mon	Day	1155							Measured DTBent between 8-5/8-in. and 12-3/4-in. casings at ~229 ft bgs

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	11/24/97	Mon	Day	1156							Observed bentonite slurry on DTW-meter tape at 8 ft indicating DTW at ~221 ft bgs
	11/24/97	Mon	Day	1210							Measured DTW inside 8-5/8-in. casing as nondetect (dry)
	11/24/97	Mon	Day	1211							Measured DTBot inside 8-5/8-in. casing at ~291 ft bgs
61.5	12/1/97	Mon	Day	730							Measured DTW inside 8-5/8-in. casing as nondetect (dry)
	12/1/97	Mon	Day	731							Measured DTBot inside 8-5/8-in. casing at ~291 ft bgs.
	12/1/97	Mon	Day	735							Measured DTBent between 8-5/8-in. and 12-3/4-in. casings at ~224 ft bgs
	12/1/97	Mon	Day	735							Observed bentonite slurry on DTW-meter tape at 4 ft indicating DTW at ~220 ft bgs
	12/1/97	Mon	Day	750							Pulled back 8-5/8-in. casing 1 ft from 291 to 290 ft
	12/1/97	Mon	Day	815							Added #16 granular bentonite from 291 to 290 ft
	12/1/97	Mon	Day	816							Added DI water (5 gal.) to hydrate bentonite
	12/1/97	Mon	Day	816	840	290.00	278.00	12.00	24.0	30.00	Pulled back 8-5/8-in. casing 12 ft from 290 to 278 ft
	12/1/97	Mon	Day		840						Backfilled 8-5/8-in. casing borehole from 290 to 282 ft with 8/12 silica sand
	12/1/97	Mon	Day	845	915	278.00	258.00	20.00	30.0	40.00	Pulled back 8-5/8-in. casing 20 ft from 278 to 258 ft
	12/1/97	Mon	Day		915						Backfilled 8-5/8-in. casing borehole 27 ft with 8/12 silica sand from 282 to 255 ft
	12/1/97	Mon	Day	1010							Added #16 granular bentonite from 255 to 248 ft
	12/1/97	Mon	Day	1010							Added DI water (20 gal.) to hydrate bentonite
	12/1/97	Mon	Day	1025	1155	258.00	0.00	258.00	90.0	172.00	Pulled back 8-5/8-in. casing from 258 ft to surface
	12/1/97	Mon	Day	1415	1800	247.00	80.00	167.00	165.0	60.73	Pulled back 12-3/4-in. casing from 247 to 80 ft
62.5	12/1/97	Mon	Evening	1914	2120	80.00	0.00	80.00	126.0	38.10	Pulled back 12-3/4-in. casing from 80 ft to surface
	12/1/97	Mon	Evening	2120							Measured DTBent inside 14-in. casing at 238.41 ft bgz
	12/1/97	Mon	Evening	2120							Observed bentonite slurry on DTW-meter tape at 70 ft indicating DTW at ~185.5 ft bgs
	12/1/97	Mon	Evening	2145							Cleaned DTW meter and changed 9-volt battery
	12/2/97	Tue	Evening	2350	2400	243.50	233.50	10.00	10.0	60.00	Pulled back 14-in. casing from 243.5 to 233.5 ft
	12/2/97	Tue	Morning	120	315	233.50	231.50	2.00	115.0	1.04	Pulled back 14-in. casing from 233.5 to 238.0 ft
	12/2/97	Tue	Morning	325		139.93	137.09	2.84	30085.0	0.0057	Measured DTW inside 14-in. casing at 137.09 ft bgz
	12/2/97	Tue	Morning	515	600	0.00	225.00	225.00	45.0	300.00	Tripped in Servco 3-wing under-reamer on 7-in. rods from surface to 225 ft

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
63.5	12/2/97	Tue	Day	745	800	225.00	236.00	11.00	15.0	44.00	Tripped in Servco 3-wing under-reamer from 225 to 236 ft
	12/2/97	Tue	Day	800	1200				4 hr		Opened Servco 3-wing under-reamer arms containing roller bits
	12/2/97	Tue	Day	1200	1755	236.00	243.50	7.50	355.0	1.27	Drilled under-reamer in 14-in. casing borehole from 236 to 243.5 ft; Cerros del Rio Basalt
64.5	12/2/97	Tue	Evening	1935	2100	243.50	0.00	243.50	85.0	171.88	Tripped out Servco 3-wing under-reamer from 243.5 ft to surface
	12/2/97	Tue	Evening	2115		137.09	137.66	0.57	1070.0	0.0320	Measured DTW inside 14-in. casing at 137.66 ft bgz
	12/2/97	Tue	Evening	2235							Added bentonite pellets (eight buckets = 40 gal.) and bentonite chips (11 bags) through 14-in. casing
	12/2/97	Tue	Evening	2245							Measured DTBent inside 14-in. casing at ~232.6 ft bgs.
	12/2/97	Tue	Evening								Allowed time for bentonite to yield
	12/3/97	Wed	Morning								Allowed time for bentonite to yield
65.5	12/3/97	Wed	Day	715	730	231.50	238.00	6.50	15.0	26.00	Tripped in 14-in. casing 6.5 ft from 231.5 to 238 ft
	12/3/97	Wed	Day	945	1310	0.00	233.00	233.00	205.0	68.20	Tripped in 14-in. plunger inside 14-in. casing from surface to top of bentonite at 233 ft
	12/3/97	Wed	Day	1310	1340	238.00	242.00	4.00	30.0	8.00	Pushed 14-in. casing and plunger 4 ft from 238 to 242 ft using RC 44 hammer on drive plate atop casing
66.5	12/3/97	Wed	Evening	2125	2320	241.50	0.00	241.50	115.0	126.00	Tripped out 14-in. plunger from 241.5 ft to surface
	12/3/97	Wed	Evening	2320							Attached 3-ft piece of 14-in. casing to extend back to 243.5 ft; top piece of 14-in. casing was damaged by repeated use
	12/4/97	Th	Morning	52							Modified 14-in. plunger with 2-3/16-in. drill holes
	12/4/97	Th	Morning	220	305	0.00	232.00	232.00	45.0	309.33	Tripped in 14-in. plunger inside 14-in. casing from surface to 232 ft
	12/4/97	Th	Morning	326	348	242.00	243.80	1.80	22.0	4.91	Pushed 14-in. casing and plunger 1.8 ft from 242 to 243.8 ft using RC 44 hammer on drive plate atop casing
	12/4/97	Th	Morning	349							Landed 14-in. casing at 243.8 ft
	12/4/97	Th	Morning	515							Tightened 14-in. casing string in borehole
	12/4/97	Th	Morning	525	600	232.00	0.00	232.00	35.0	397.71	Tripped out 14-in. plunger with slow rotation
67.5	12/4/97	Th	Day	715	750	0.00	232.00	232.00	35.0	397.71	Tripped in bentonite auger inside 14-in. casing from surface to 232 ft
	12/4/97	Th	Day	750	800	232.00	240.00	8.00	10.0	48.00	Drilled auger into bentonite inside 14-in. casing from 232 to 240 ft
	12/4/97	Th	Day	800	830	240.00	0.00	240.00	30.0	480.00	Tripped out auger from 240 ft to surface; 1 ft of bentonite atop auger upon extraction
	12/4/97	Th	Day	835		137.66	139.80	2.14	680.0	0.1888	Measured DTW inside 14-in. casing at ~139.8 ft bgs
	12/4/97	Th	Day	835							Measured DTBent inside 14-in. casing at ~233 ft bgs

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	12/4/97	Th	Day	915	950	0.00	225.00	225.00	35.0	385.71	Tripped in RC rods from surface to 225 ft
	12/4/97	Th	Day	950	1050						Evacuated water inside 14-in. casing by air-lifting water using drilling circulation air
	12/4/97	Th	Day	1050	1140	225.00	0.00	225.00	50.0	270.00	Tripped out RC rods from 225 ft to surface
	12/4/97	Th	Day	1145							Modified auger to improve bentonite extraction
	12/4/97	Th	Day	1350	1440	0.00	243.80	243.80	50.0	292.56	Tripped in auger from surface to 243.8 ft
	12/4/97	Th	Day	1440	1515	243.80	0.00	243.80	35.0	417.94	Tripped out auger from 243.8 ft to surface
	12/4/97	Th	Day	1520							Measured DTW inside 14-in. casing at ~186.2 ft bgs
	12/4/97	Th	Day	1550							Measured DTW inside 14-in. casing at ~185.5 ft bgs
	12/4/97	Th	Day	1550							Measured DTBent inside 14-in. casing at ~233 ft bgs
	12/4/97	Th	Day	1620							Measured DTW inside 14-in. casing at ~184.75 ft bgs
	12/4/97	Th	Day	1650	1800	0.00	20.00	20.00	70.0	17.14	Tripped in 14-in. plunger from surface to 20 ft
68.5	12/4/97	Th	Evening	1800	1845	20.00	233.00	213.00	45.0	284.00	Tripped in 14-in. plunger from 20 to 233 ft
	12/4/97	Th	Evening	1849							Measured DTW inside 14-in. casing atop plunger at 174.66 ft bgz
	12/4/97	Th	Evening	1922							Measured DTW inside 14-in. casing atop plunger at 174.15 ft bgz
	12/4/97	Th	Evening	1952							Measured DTW inside 14-in. casing atop plunger at 173.8 ft bgz
	12/4/97	Th	Evening	2000	2027	233.00	0.00	233.00	27.0	517.78	Tripped out plunger from 233 ft to surface; no water or bentonite atop plunger upon extraction
	12/4/97	Th	Evening	2032							Measured DTW inside 14-in. casing with plunger out at 179.8 ft bgz
	12/4/97	Th	Evening	2105							Measured DTW inside 14-in. casing with plunger out at 179.32 ft bgz
	12/4/97	Th	Evening	2105							Measured DTBent inside 14-in. casing at 228.15 ft bgz
	12/4/97	Th	Evening	2110	2130	0.00	232.00	232.00	20.0	696.00	Tripped in bentonite auger from surface to 232 ft
	12/4/97	Th	Evening	2130	2400	233.00	238.00	5.00	150.0	2.00	Drilled auger into bentonite from 233 to 238 ft
	12/5/97	Fri	Morning	0	15	238.00	243.00	5.00	15.0	20.00	Drilled auger into bentonite from 238 to 243 ft
	12/5/97	Fri	Morning	15	47	243.00	0.00	243.00	32.0	455.63	Tripped out auger from 243 ft to surface; no water or bentonite extracted with auger
	12/5/97	Fri	Morning	57							Measured DTW inside 14-in. casing at 197.21 ft bgz
	12/5/97	Fri	Morning	114							Measured DTW inside 14-in. casing at 197.13 ft bgz
	12/5/97	Fri	Morning	131							Measured DTW inside 14-in. casing at 196.93 ft bgz
	12/5/97	Fri	Morning	149							Measured DTW inside 14-in. casing at 196.92 ft bgz

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	12/5/97	Fri	Morning	210							Measured DTW inside 14-in. casing at 196.93 ft bgz; consistent DTW measurements indicate 14-in. casing seal is holding
	12/5/97	Fri	Morning	230							Added bentonite chips (one bag) through 14-in. casing
	12/5/97	Fri	Morning	235	615	0.00	100.00	100.00	220.0	27.27	Tripped in 12-3/4-in. casing from surface to 100 ft
69.5	12/5/97	Fri	Day	700	1335	100.00	241.00	141.00	395.0	21.42	Tripped in 12-3/4-in. casing from 100 to 241 ft
	12/5/97	Fri	Day	1545	1730	0.00	220.00	220.00	105.0	125.71	Tripped in Stratex 12-3/4-in. casing advance system from surface to 220 ft
70.5	12/5/97	Fri	Evening	2000							Evacuated bentonite and water inside 14-in. casing by air-lifting water using drilling circulation air
	12/6/97	Sat	Morning	0	142	241.00	247.00	6.00	102.0	3.53	Drilled 12-3/4-in. casing from 241.0 to 247.0 ft; plugged casing advance system; Cerros del Rio Basalt
	12/6/97	Sat	Morning	250	620	247.00	0.00	247.00	210.0	70.57	Tripped out 12-3/4-in. casing advance system from 247 ft to surface
71.5	12/6/97	Sat	Day	830							Cleaned bentonite from 12-3/4-in. casing advance system
	12/6/97	Sat	Day	845							Measured DTW as nondetect (dry)
	12/6/97	Sat	Day	845							Measured DTBot at ~247.2 ft bgs
	12/6/97	Sat	Day	920	1040	0.00	247.00	247.00	80.0	185.25	Tripped in Stratex 12-3/4-in. casing advance system from surface to 247 ft
	12/6/97	Sat	Day	1200							Cleaned bentonite from 12-3/4-in. casing advance system
72.5	12/8/97	Mon	Day	700	1720	247.00	259.00	12.00	620.0	1.16	Drilled 12-3/4-in. casing from 247.0 to 259.0 ft; Cerros del Rio Basalt
73.5	12/8/97	Mon	Evening	2030	2400	259.00	266.50	7.50	210.0	2.14	Drilled 12-3/4-in. casing from 259.0 to 266.5 ft; Cerros del Rio Basalt
	12/9/97	Tue	Morning	110	430				1.0		Repaired pull back chain on drill rig
	12/9/97	Tue	Morning	430	600	266.50	270.00	3.50	90.0	2.33	Drilled 12-3/4-in. casing from 266.5 to 270.0 ft; Cerros del Rio Basalt
74.5	12/9/97	Tue	Day	720	1335	270.00	279.00	9.00	375.0	1.44	Drilled 12-3/4-in. casing from 270.0 to 279.0 ft; Cerros del Rio Basalt
75.5	12/9/97	Tue	Evening	1850	2120	279.00	291.00	12.00	150.0	4.80	Drilled 12-3/4-in. casing from 279.0 to 291.0 ft, basalt rubble to 282.4 ft, basalt tephra to 283.7 ft, and basalt alluvium to 291 ft
	12/9/97	Tue	Evening	2310	2400	291.00	0.00	291.00	50.0	349.20	Tripped out 12-3/4-in. casing advance system from 291.0 ft to surface
	12/10/97	Wed	Morning	108							Measured DTW inside 12-3/4-in. casing at 286.37 ft bgz
	12/10/97	Wed	Morning	245							Measured DTW inside 12-3/4-in. casing at 280.30 ft bgz

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	12/10/97	Wed	Morning	300	540	0.00	290.50	290.50	160.0	108.94	Tripped in 12-3/4-in. milling bit on 7-in. RC rods from surface to 290.5 ft
	12/10/97	Wed	Morning	540	600	0.00	0.20	0.20	20.0	0.60	Milled 12-3/4-in. casing shoe (20%)
76.5	12/10/97	Wed	Day	650	1425	0.20	1.00	0.80	455.0	0.11	Milled 12-3/4-in. casing shoe (80%)
	12/10/97	Wed	Day	1425	1540	292.50	0.00	292.50	75.0	234.00	Tripped out 12-3/4-in. milling bit on 7-in. RC rods from 292.5 ft to surface
	12/10/97	Wed	Day	1645	1715	291.00	279.50	11.50	30.0	23.00	Pulled back 12-3/4-in. casing from 291.0 to 279.5
77.5	12/10/97	Wed	Evening	1915							Measured DTW inside 12-3/4-in. casing at 276.57 ft bgz
	12/10/97	Wed	Evening	1925	2050	0.00	279.00	279.00	85.0	196.94	Tripped in Servco 3-wing under-reamer from surface to 279 ft
	12/10/97	Wed	Evening	2150	2245	279.00	285.00	6.00	55.0	6.55	Opened Servco 3-wing under-reamer from 279 to 285 ft
	12/10/97	Wed	Evening	2245	2352	285.00	289.00	4.00	67.0	3.58	Drilled under-reamer in 12-3/4-in. casing borehole from 285 to 289 ft; alluvium
	12/11/97	Th	Morning	105	205	290.00	0.00	290.00	60.0	290.00	Tripped out under-reamer on 7-in. rods from 290 ft to surface
	12/11/97	Th	Morning	218							Measured DTW at 283.5 ft bgz
	12/11/97	Th	Morning	305							Added granular bentonite (six bags) and bentonite chips (six bags) in 50:50 mixture from 285 to 292 ft
	12/11/97	Th	Morning	327							Measured DTBent at 279.55 ft bgz
	12/11/97	Th	Morning	327							Observed bentonite and water on DTW tape at 12 ft, indicating DTW above seal at ~267.5 ft bgs
	12/11/97	Th	Morning	440	540	0.00	282.00	282.00	60.0	282.00	Tripped in 12-3/4 plunger from surface to 282 ft
78.5	12/11/97	Th	Day	715	730	279.00	292.50	13.50	15.0	54.00	Pushed 12-3/4-in. casing from 279 to 292.5 ft using the RC-44 hammer on drive plate atop casing
	12/11/97	Th	Day	730							Landed 12-3/4-in. casing at 292.5 ft
	12/11/97	Th	Day	730	820	292.00	0.00	292.00	50.0	350.40	Tripped out 12-3/4-in. plunger from 292 ft to surface
	12/11/97	Th	Day	820							Measured DTW at ~280.9 ft bgs
	12/11/97	Th	Day	820							Measured DTBent at ~281.7 ft bgs
	12/11/97	Th	Day	835	955	0.00	282.00	282.00	80.0	211.50	Tripped in bentonite auger inside 12-3/4-in. casing from surface to 282 ft
	12/11/97	Th	Day	955	1000	282.00	292.00	10.00	5.0	120.00	Drilled bentonite auger inside 12-3/4-in. casing from 282 to 292 ft
	12/11/97	Th	Day	1000	1015	292.00	0.00	292.00	15.0	1168.00	Tripped out bentonite auger inside 12-3/4-in. casing from 292 ft to surface
	12/11/97	Th	Day	1215	1405	0.00	292.00	292.00	110.0	159.27	Tripped in bucket auger inside 12-3/4-in. casing from surface to 292 ft

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	12/11/97	Th	Day								Evacuated water from inside 12-3/4-in. casing using drilling circulation system
	12/11/97	Th	Day	1415	1440	292.00	295.00	3.00	25.0	7.20	Drilled bucket auger from 292 to 295 ft; alluvium
	12/11/97	Th	Day	1440	1520	295.00	0.00	295.00	40.0	442.50	Tripped out bucket auger from 295 ft to surface
	12/11/97	Th	Day	1615	1710	0.00	292.00	292.00	40.0	438.00	Tripped in 11-3/4-in. hammer bit inside 12-3/4-in. casing from surface to 292 ft
	12/11/97	Th	Day	1710	1800	292.00	297.50	5.50	50.0	6.60	Drilled 11-3/4-in. hammer bit from 292 to 297.5 ft; alluvium
79.5	12/11/97	Th	Evening	1800	1930	297.50	0.00	297.50	90.0	198.33	Tripped out 11-3/4-in. hammer bit from 297.5 ft to surface
	12/11/97	Th	Evening	2145	2400	0.00	20.00	20.00	135.0	8.89	Tripped in 10-3/4-in. casing from surface to 20 ft
	12/12/97	Fri	Morning	0	515	20.00	297.50	277.50	315.0	52.86	Tripped in 10-3/4-in. casing from 20 to 297.5 ft
80.5	12/12/97	Fri	Day	730							Failed to trip in Stratex 10-3/4-in. casing advance system because bit too large for casing
	12/12/97	Fri	Day	800	1752						Machined Stratex 10-3/4-in. casing advance bit to fit inside 10-3/4-in. casing
81.5	12/12/97	Fri	Evening	1825	2000	0.00	297.50	297.50	95.0	187.89	Tripped in Stratex 10-3/4-in. casing advance system from surface to 297.5 ft
	12/12/97	Fri	Evening	2000	2400	297.50	320.00	22.50	240.0	5.63	Drilled 10-3/4-in. casing from 297.5 to 320 ft; alluvium
	12/13/97	Sat	Morning	0	620	320.00	360.00	40.00	380.0	6.32	Drilled 10-3/4-in. casing from 320 to 360 ft; alluvium to 329 ft, tuffaceous Puye Fm clastics to 360 ft
82.5	12/13/97	Sat	Day	620	1800	360.00	400.00	40.00	700.0	3.43	Drilled 10-3/4-in. casing from 360 to 400 ft; tuffaceous Puye Fm clastics
83.5	12/13/97	Sat	Evening	1800	2400	400.00	420.00	20.00	360.0	3.33	Drilled 10-3/4-in. casing from 400 to 420 ft; tuffaceous Puye Fm clastics
	12/14/97	Sun	Morning	0	200	400.00	420.00	20.00	120.0	10.00	Reamed 10-3/4-in. casing borehole from 400 to 420 ft
	12/14/97	Sun	Morning	200							Casing separated (10-3/4-in.) at 400 ft
	12/14/97	Sun	Morning	400	600						Repaired hydraulic leak on drill rig
84.5	12/14/97	Sun	Day	600	1745	400.00	240.00	160.00	705.0	13.62	Tripped out 10-3/4-in. casing from 400 to 240 ft
85.5	12/14/97	Sun	Evening	1745	2400	240.00	0.00	240.00	375.0	38.40	Tripped out 10-3/4-in. casing from 240 ft to surface
	12/15/97	Mon	Morning	15							Measured DTW at 394.52 ft bgz
	12/15/97	Mon	Morning	15							Measured DTBot at 394.62 ft bgz
	12/15/97	Mon	Morning	115							Measured DTW at 394.42 ft bgz
	12/15/97	Mon	Morning	230							Measured DTW at 394.42 ft bgz
	12/15/97	Mon	Morning	515							Measured DTW at 394.42 ft bgz

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
86.5	12/15/97	Mon	Day	640	1340	0.00	380.00	380.00	420.0	54.29	Tripped in 10-3/4-in. casing from surface to 380 ft
	12/15/97	Mon	Day	1405	1515	0.00	380.00	380.00	70.0	325.71	Tripped in Stratex 10-3/4-in. casing advance system from surface to 380 ft
	12/15/97	Mon	Day	1340	1640	380.00	390.00	10.00	180.0	3.33	Drilled 10-3/4-in. casing from 380 to 390 ft; tuffaceous Puye Fm clastics
87.5	12/15/97	Mon	Evening	1830	2400	390.00	420.00	30.00	330.0	5.45	Drilled 10-3/4-in. casing from 390 to 420 ft; tuffaceous Puye Fm clastics
	12/16/97	Tue	Morning	0	130	420.00	0.00	420.00	90.0	280.00	Tripped out 10-3/4-in. casing advance system from 420 ft to surface
88.5	12/16/97	Tue	Day	700	1120	0.00	420.00	420.00	260.0	96.92	Tripped in 8-5/8-in. casing from surface to 420 ft
	12/16/97	Tue	Day	1255							Measured DTW as nondetect (dry)
	12/16/97	Tue	Day	1255							Measured DTBot at ~420 ft bgs
	12/16/97	Tue	Day	1258	1259	420.00	421.00	1.00	1.0	60.00	Pushed 8-5/8-in. casing from 420 to 421 ft to provide room to open Stratex bit
	12/16/97	Tue	Day	1300	1405	0.00	421.00	421.00	65.0	388.62	Tripped in Stratex 8-5/8-in. casing advance system from surface to 421 ft
	12/16/97	Tue	Day	1600	1645	420.00	439.00	19.00	45.0	25.33	Drilled 8-5/8-in. casing from 420 to 439 ft; tuffaceous Puye Fm clastics
89.5	12/16/97	Tue	Evening	1800	2005						Repaired hydraulic leak on drill rig
	12/16/97	Tue	Evening	2010	2400	430.00	459.00	29.00	230.0	7.57	Drilled 8-5/8-in. casing from 430 to 459 ft; tuffaceous Puye Fm clastics
	12/17/97	Wed	Morning	0	600	459.00	518.50	59.50	360.0	9.92	Drilled 8-5/8-in. casing from 459 to 518.5 ft; tuffaceous Puye Fm clastics
90.5	12/17/97	Wed	Day	635	1430	518.50	547.00	28.50	475.0	3.60	Drilled 8-5/8-in. casing from 518.5 to 547 ft; plugged casing advance system; tuffaceous clay-rich Puye Fm clastics
	12/17/97	Wed	Day	1430	1540	547.00	0.00	547.00	70.0	468.86	Tripped out 8-5/8-in. casing advance system from 547 ft to surface to unplug
	12/17/97	Wed	Day	1545							Measured DTW as nondetect (dry)
	12/17/97	Wed	Day	1545							Measured DTBot at ~545.8 ft bgs
	12/17/97	Wed	Day	1600	1730	0.00	547.00	547.00	90.0	364.67	Tripped in 8-5/8-in. casing advance system from surface to 547 ft
91.5	12/17/97	Wed	Evening	1805	2326	547.00	557.00	10.00	321.0	1.87	Drilled 8-5/8-in. casing from 547 to 557 ft; tuffaceous Puye Fm clastics
	12/18/97	Th	Morning	5	625	557.00	575.00	18.00	380.0	2.84	Drilled 8-5/8-in. casing from 557 to 575 ft; tuffaceous Puye Fm clastics
92.5	12/18/97	Th	Day	645	900	575.00	579.00	4.00	135.0	1.78	Drilled 8-5/8-in. casing from 575 to 579 ft; plugged casing advance system; tuffaceous clay-rich Puye Fm clastics

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	12/18/97	Th	Day	915	1040	579.00	0.00	579.00	85.0	408.71	Tripped out 8-5/8-in. casing advance system from 579 ft to surface to unplug
	12/18/97	Th	Day	1230	1330	0.00	579.00	579.00	60.0	579.00	Tripped in 8-5/8-in. casing advance system from surface to 579 ft
	12/18/97	Th	Day	1345							**Encountered water at 579 ft and observed water in cyclone discharge**
	12/18/97	Th	Day	1400	1410	579.00	580.00	1.00	10.0	6.00	Drilled 8-5/8-in. casing from 579 to 580 ft; tuffaceous Puye Fm clastics
	12/18/97	Th	Day	1455	1600	579.00	0.00	579.00	65.0	534.46	Tripped out 8-5/8-in. casing advance system from 579 ft
	12/18/97	Th	Day	1608							Measured DTW inside the 8-5/8-in. casing at 574.03 ft bgz
	12/18/97	Th	Day	1625		574.03	573.33	0.70	17.0	2.47	Measured DTW inside the 8-5/8-in. casing at 573.33 ft bgz
	12/18/97	Th	Day	1640		573.33	572.63	0.70	15.0	2.80	Measured DTW inside the 8-5/8-in. casing at 572.63 ft bgz
	12/18/97	Th	Day	1655		572.63	571.78	0.85	15.0	3.40	Measured DTW inside the 8-5/8-in. casing at 571.78 ft bgz
	12/18/97	Th	Day	1725		571.78	570.63	1.15	30.0	2.30	Measured DTW inside the 8-5/8-in. casing at 570.63 ft bgz
93.0	12/18/97	Th	Evening	1820		570.63	568.13	2.50	55.0	2.73	Measured DTW inside the 8-5/8-in. casing at 568.13 ft bgz
	12/18/97	Th	Evening	1850							Collected ~4.5 gal. of water at ~568 ft using 3-in. stainless steel bailer for preliminary characterization water sample
	12/18/97	Th	Evening	1905		568.13	568.34	0.21	45.0	0.2800	Measured DTW inside the 8-5/8-in. casing at 568.34 ft bgz
				1945							Installed 30 ft of 4-in. slotted polyvinyl chloride (PVC) well screen with bottom cap at 580.5 ft
	12/18/97	Th	Evening	1950	2000	580.00	557.00	23.00	10.0	138.00	Pulled back 8-5/8-in. casing from 580 to 557 ft
	12/18/97	Th	Evening	2035		568.34	565.36	2.98	40.0	4.47	Measured DTW at 565.36 ft bgz
				2050							Bottled 6 L of water collected with cuttings drilled from 579 to 580.5 ft
	12/18/97	Th	Evening	2125		565.36	563.95	1.41	50.0	1.69	Measured DTW at 563.95 ft bgz
	12/19/97	Fri	Day	835		563.95	537.85	26.10	670.0	2.34	Measured DTW at 537.85 ft bgz
	12/19/97	Fri	Day	1140		537.85	530.71	7.14	185.0	2.32	Measured DTW at 530.71 ft bgz
	12/19/97	Fri	Day	1415							Collected contaminant characterization cuttings samples of precurated cuttings from 568 to 569.7 ft and 570 to 571.5 ft to comply with the SAP, which indicated that a contaminant characterization sample be collected from 10 ft above saturation
	12/19/97	Fri	Day	1535		530.71	524.05	6.66	235.0	1.70	Measured DTW at 524.05 ft bgz
	12/20/97	Sat	Day	925		524.05	497.98	26.07	1070.0	1.46	Measured DTW at 497.98 ft bgz

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	12/20/97	Sat	Day	1130	1430						Collected ~26 gal. of water at ~498 ft using 3-in. stainless steel bailer for contaminant characterization water sample. NMED collected 1 gal. and 1 L as split water sample
	12/20/97	Sat	Day	1500		497.98	502.79	4.81	335.0	0.8615	Measured DTW at 502.79 ft bgz
	12/21/97	Sun	Day	1232		502.79	527.51	24.72	1292.0	1.15	Measured DTW at 527.51 ft bgz
	12/21/97	Sun	Day	1700		527.51	527.25	0.26	268.0	0.0582	Measured DTW at 527.25 ft bgz
	12/22/97	Mon	Day	732		527.25	526.95	0.30	872.0	0.0206	Measured DTW at 526.95 ft bgz
	12/22/97	Mon	Day	1600		526.95	526.62	0.33	508.0	0.0390	Measured DTW at 526.62 ft bgz
	12/23/97	Tue	Day	1200		526.62	525.72	0.90	1200.0	0.0450	Measured DTW at 525.72 ft bgz
	12/23/97	Tue	Day	1215							Installed transducer in water to monitor water level equilibrium with Hermit 3000 data collection system
	12/29/97	Mon	Day	1030		525.72	523.62	2.10	1350.0	0.0933	Measured DTW at 523.62 ft bgz
94.0	1/5/98	Mon	Day	710		523.62	523.06	0.56	9880.0	0.0034	Measured DTW at 523.06 ft bgz
	1/5/98	Mon	Day	720	735						Collected ~5 gal. of water at ~523 ft using 3-in. stainless steel bailer for preliminary contaminant characterization water sample
	1/5/98	Mon	Day	845							Measured DTBot inside temporary PVC screen at ~579.2 ft bgs
	1/5/98	Mon	Day	955							Recovered temporary PVC screen using wireline
	1/5/98	Mon	Day	1010		523.06	525.82	2.76	180.0	0.9200	Measured DTW in open hole at 525.82 ft bgz
	1/5/98	Mon	Day	1011							Measured DTBot in open hole at 576.72 ft bgz
	1/5/98	Mon	Day	1030	1045	557.00	578.90	21.90	15.0	87.60	Tripped in 8-5/8-in. casing from 557 to 578.5 ft
	1/5/98	Mon	Day	1310	1410	0.00	570.00	570.00	60.0	570.00	Tripped in drive sampling tool on core rods from surface to 570 ft
	1/5/98	Mon	Day	1430	1500	580.00	583.00	3.00	30.0	6.00	Drilled drive sampling tool from 580 to 583 ft; tuffaceous clay-rich Puye Fm clastics
	1/5/98	Mon	Day	1532	1630	583.00	0.00	583.00	58.0	603.10	Tripped out drive sampling tool from 583 ft to surface
95.0	1/6/98	Tue	Day	655	815	0.00	580.00	580.00	80.0	435.00	Tripped in Stratex 8-5/8-in. casing advance system from surface to 580 ft
	1/6/98	Tue	Day	850	1000						Purged and stored ~200 gal. of borehole water using air circulation system
	1/6/98	Tue	Day	1015	1115	580.00	581.50	1.50	60.0	1.50	Drilled 8-5/8-in. casing from 580 to 581.5 ft; cuttings plugged bit; tuffaceous clay-rich Puye Fm clastics
	1/6/98	Tue	Day	1230	1335	581.50	0.00	581.50	65.0	536.77	Tripped out 8-5/8-in. casing advance system from 581.5 ft to surface
	1/6/98	Tue	Day	1340							Measured DTW at 579.31 ft bgz
	1/6/98	Tue	Day	1345	1415	581.50	578.50	3.00	30.0	6.00	Pulled back 8-5/8-in. from 581.5 to 578.5 ft

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	1/6/98	Tue	Day	1425							Measured DTW at 572.76 ft bgz
	1/6/98	Tue	Day	1530							Measured DTW at 571.34 ft bgz
	1/6/98	Tue	Day	1600	1630						Collected ~10 gal. of water at ~571 ft using 3-in. stainless steel bailer for preliminary contaminant characterization water sample
	1/6/98	Tue	Day	1710							Added granular bentonite (four bags) through 8-5/8-in. casing
	1/6/98	Tue	Day	1745	1830	0.00	570.00	570.00	45.0	760.00	Tripped in plunger on 3-7/8-in. RC rods from surface to refusal at 570 ft
	1/6/98	Tue	Day	1840	1910	570.00	581.50	11.50	30.0	23.00	Pushed bentonite inside 8-5/8-in. casing from 570 to 578.5 ft and 8-5/8-in. casing from 578.5 to 581.5 ft
96.0	1/7/98	Wed	Day	650	744	0.00	570.00	570.00	54.0	633.33	Tripped out plunger on 3-7/8-in. RC rods from 570 ft to surface
	1/7/98	Wed	Day	745							Measured DTW as nondetect (dry)
	1/7/98	Wed	Day	746							Measured DTBot at 569.22 ft bgz
	1/7/98	Wed	Day	800							Modified auger tool to remove bentonite from 8-5/8-in. casing
	1/7/98	Wed	Day	1010							Measured DTW as nondetect (dry)
	1/7/98	Wed	Day	1011							Measured DTBot at 569.22 ft bgz
	1/7/98	Wed	Day	1050	1145	0.00	574.00	574.00	55.0	626.18	Tripped in bentonite auger from surface to 574 ft
	1/7/98	Wed	Day	1145	1210	574.00	580.50	6.50	25.0	15.60	Drilled auger in bentonite from 574 to 580.5 ft
	1/7/98	Wed	Day	1240	1330	580.50	0.00	580.50	50.0	696.60	Tripped out bentonite auger from 580.5 ft to surface
	1/7/98	Wed	Day	1340							Measured DTBot at unsuccessful because of bentonite on interior of 8-5/8-in. casing
	1/7/98	Wed	Day	1500	1715	0.00	580.50	580.50	135.0	258.00	Tripped in core system from surface to 580.5 ft
97.0	1/8/98	Th	Day	645	1135	581.00	601.00	20.00	290.0	4.14	Cored 4-1/2-in. hole from 581 to 601 ft; recovery = 95.5% in tuffaceous Puye Fm clastics
	1/8/98	Th	Day	1205							Measured DTW as nondetect (dry)
	1/8/98	Th	Day	1206							Measured DTBot at 600.06 ft bgz
	1/8/98	Th	Day	1230							Measured DTW as nondetect (dry)
	1/8/98	Th	Day	1231							Measured DTBot at 600.06 ft bgz
	1/8/98	Th	Day	1300							Measured DTW at 599.79 ft bgz; 0.27 ft of standing water in corehole
	1/8/98	Th	Day	1315							Measured DTW at 599.19 ft bgz; 0.87 ft of standing water in corehole
	1/8/98	Th	Day	1325	1615	601.00	615.00	14.00	170.0	4.94	Cored 4-1/2-in. hole from 601 to 615 ft; recovery = 67.1% in tuffaceous Puye Fm clastics

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	1/8/98	Th	Day	1625	1800	615.00	230.00	385.00	95.0	243.16	Tripped out core system from 615 to 230 ft
	1/8/98	Th	Day	1802							Measuring DTW unsuccessful because of bentonite inside 8-5/8-in. casing
98.0	1/9/98	Fri	Day	745	820	230.00	0.00	230.00	35.0	394.29	Tripped out core system from 230 ft to surface
	1/9/98	Fri	Day	1445	1745	0.00	579.00	579.00	180.0	193.00	Tripped in 6-5/8-in. casing from surface to 579 ft
	1/9/98	Fri	Day	1745							Measured DTW as nondetect (dry)
	1/9/98	Fri	Day	1746							Measured DTBot at 560.55 ft bgz
99.0	1/12/98	Mon	Day	615							Measured DTW at 524.70 inside 6-5/8-in. casing
	1/12/98	Mon	Day	621							Measured DTBot at 560.70 ft bgz
	1/12/98	Mon	Day	820	925	0.00	581.00	581.00	65.0	536.31	Tripped in bentonite auger from surface to 581 ft inside 6-5/8-in. casing
	1/12/98	Mon	Day	925	1030	550.00	581.00	31.00	65.0	28.62	Drilled auger in bentonite from 550 to 581 ft
	1/12/98	Mon	Day	1030	1140	581.00	0.00	581.00	70.0	498.00	Tripped out bentonite auger from 581 ft to surface
	1/12/98	Mon	Day	1145							Measured DTW at 548.45 inside 6-5/8-in. casing
	1/12/98	Mon	Day	1220							Measured DTW at 548.00 inside 6-5/8-in. casing
	1/12/98	Mon	Day	1221							Measured DTBot at 576.25ft bgz; 28.25 ft of standing water inside 6-5/8-in. casing
	1/12/98	Mon	Day	1310							Collected ~9 gal. of water at ~548 ft using 3-in. stainless steel bailer for preliminary contaminant water sample; sample very turbid
	1/12/98	Mon	Day	1400	1600	0.00	581.00	581.00	120.0	290.50	Tripped in 6-5/8-in. casing advance system from surface to 581 ft
	1/12/98	Mon	Day	1730	1800	581.00	589.00	8.00	30.0	16.00	Drilled 6-5/8-in. casing from 581 to 589 ft; tuffaceous Puye Fm clastics
100.0	1/13/98	Tue	Day	720	945	589.00	605.00	145.00	30.0	290.00	Drilled 6-5/8-in. casing from 589 to 605 ft; plugged bit; tuffaceous clay-rich Puye Fm clastics
	1/13/98	Tue	Day	1015	1125	605.00	0.00	605.00	70.0	518.57	Tripped out 6-5/8-in. casing advance system from 605 ft to surface
	1/13/98	Tue	Day	1135							Measured DTW as nondetect (dry)
	1/13/98	Tue	Day	1136							Measured DTBot at 600.51 ft bgz
	1/13/98	Tue	Day	1242							Measured DTW as nondetect (dry)
	1/13/98	Tue	Day	1242							Measured DTBot at 600.70 ft bgz
	1/13/98	Tue	Day	1245	1315	0.00	605.00	605.00	30.0	1210.0	Tripped in 6-5/8-in. casing advance system from surface to 605 ft
	1/13/98	Tue	Day	1335	1530	605.00	609.00	4.00	115.0	2.09	Drilled 6-5/8-in. casing from 605 to 609 ft; plugged bit; tuffaceous clay-rich Puye Fm clastics
	1/13/98	Tue	Day	1600	1725	609.00	0.00	609.00	85.0	429.88	Tripped out 6-5/8-in. casing advance system from 609 ft to surface

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	1/13/98	Tue	Day	1735							Measured DTW as nondetect (dry)
	1/13/98	Tue	Day	1735							Measured DTBot at 606.45 ft bgz
101.0	1/14/98	Wed	Day	630							Measured DTW at 582.35 ft bgz
	1/14/98	Wed	Day	631							Measured DTBot at 606.25 ft bgz; 23.90 ft of standing water inside 6-5/8-in. casing
	1/14/98	Wed	Day	730							Collected ~5 gal. of water at ~582 ft using 3-in. stainless steel bailer for preliminary contaminant water sample
	1/14/98	Wed	Day	820	920	0.00	609.00	609.00	60.0	609.00	Tripped in 6-5/8-in. casing advance system from surface to 609 ft
	1/14/98	Wed	Day	940	1230	609.00	619.00	10.00	170.0	3.53	Drilled 6-5/8-in. casing from 609 to 619 ft; tuffaceous Puye Fm clastics
	1/14/98	Wed	Day	1315							**Encountered water at 615 ft**
	1/14/98	Wed	Day	1330	1515	619.00	0.00	619.00	105.0	353.71	Tripped out 6-5/8-in. casing advance system from 619 ft to surface
	1/14/98	Wed	Day	1525							Measured DTW as nondetect (dry)
	1/14/98	Wed	Day	1525							Measured DTBot at 618.50 ft bgz
	1/14/98	Wed	Day	1625	1745	0.00	619.00	619.00	80.0	464.25	Tripped in core system from surface to 619 ft
	1/14/98	Wed	Day	1752							Measured DTW as nondetect (dry)
	1/14/98	Wed	Day	1752							Measured DTBot at 617.01 ft bgz
102.0	1/15/98	Th	Day	550							Measured DTW at 617.56 ft bgz
	1/15/98	Th	Day	550							Measured DTBot at 617.01 ft bgz; 0.55 ft of standing water in core system
	1/15/98	Th	Day	715	1030	619.00	626.00	7.00	195.0	2.15	Cored 4-1/2-in. hole from 619 to 626 ft; recovery = 71.4% in tuffaceous Puye Fm clastics
	1/15/98	Th	Day	1040		617.56	562.50	55.06	290.0	11.39	Measured DTW at 562.50 ft bgz inside core system
	1/15/98	Th	Day	1052		562.50	551.40	11.10	12.0	55.50	Measured DTW at 551.40 ft bgz inside core system
	1/15/98	Th	Day	1102		551.40	543.65	7.75	10.0	46.50	Measured DTW at 543.65 ft bgz inside core system
	1/15/98	Th	Day	1112		543.65	540.40	3.25	10.0	19.50	Measured DTW at 540.40 ft bgz inside core system
	1/15/98	Th	Day	1125		540.40	536.90	3.50	13.0	16.15	Measured DTW at 536.90 ft bgz inside core system
	1/15/98	Th	Day	1135		536.90	534.70	2.20	10.0	13.20	Measured DTW at 534.70 ft bgz inside core system
	1/15/98	Th	Day	1145		534.70	533.72	0.98	10.0	5.88	Measured DTW at 533.72 ft bgz inside core system
	1/15/98	Th	Day	1155		533.72	532.80	0.92	10.0	5.52	Measured DTW at 532.80 ft bgz inside core system
	1/15/98	Th	Day	1205		532.80	532.00	0.80	10.0	4.80	Measured DTW at 532 ft bgz inside core system
	1/15/98	Th	Day	1235		532.00	530.60	1.40	30.0	2.80	Measured DTW at 530.6 ft bgz inside core system

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	1/15/98	Th	Day	1305		530.60	529.45	1.15	30.0	2.30	Measured DTW at 529.45 ft bgz inside core system
	1/15/98	Th	Day	1315	1545						Collected ~15 gal. of water at ~529 ft using 1.5-in. stainless steel bailer for preliminary contaminant water sample
	1/15/98	Th	Day	1615	1750	626.00	631.00	5.00	95.0	3.16	Cored 4-1/2-in. hole from 626 to 631 ft; recovery = 55% in tuffaceous Puye Fm clastics
	1/15/98	Th	Day	1755		529.45	554.30	24.85	290.0	5.14	Measured DTW at 554.3 ft bgz inside core system
103.0	1/16/98	Fri	Day	650		554.30	528.48	25.82	775.0	2.00	Measured DTW at 528.48 ft bgz inside core system
	1/16/98	Fri	Day	730	1145	631.00	645.50	14.50	255.0	3.41	Cored 4-1/2-in. hole from 631 to 645.5 ft; recovery = 98.6% in tuffaceous Puye Fm clastics; lost circulation
	1/16/98	Fri	Day	1200	1410	645.50	0.00	645.50	130.0	297.92	Tripped out core system from 645.5 ft to surface
	1/16/98	Fri	Day	1445		528.48	537.52	9.04	475.0	1.14	Measured DTW in water at 537.52 ft bgz inside 6/58-in. casing
	1/16/98	Fri	Day	1450	1700	0.00	604.00	604.00	130.0	278.77	Tripped in 6-5/8-in. casing advance system from surface to 604 ft
	1/16/98	Fri	Day	1705							Measured DTW at 480.70 ft bgz inside 6-5/8-in. casing advance system
104.0	1/19/98	Mon	Day	625		537.52	524.53	12.99	3820.0	0.2040	Measured DTW in water at 524.53 ft bgz
	1/19/98	Mon	Day	1030	1045	604.00	619.00	15.00	15.0	60.00	Tripped in 6-5/8-in. casing advance system from 604 to 619 ft
	1/19/98	Mon	Day	1045	1510	619.00	649.00	30.00	25.0	72.00	Drilled 6-5/8-in. casing from 619 to 649 ft; tuffaceous Puye Fm clastics
	1/19/98	Mon	Day	1520	1635	649.00	600.00	49.00	75.0	39.20	Tripped out 6-5/8-in. casing advance system from 649 to 600 ft
	1/19/98	Mon	Day	1645	1802	0.00	600.00	600.00	77.0	467.53	Tripped in core system from surface to 600 ft
105.0	1/20/98	Tue	Day	650	725	600.00	649.00	49.00	35.0	84.00	Tripped in core system from 600 to 649 ft
	1/20/98	Tue	Day	743	1200	649.00	681.00	32.00	257.0	7.47	Cored 4-1/2-in. hole from 649 to 681 ft; recovery = 88.1% in tuffaceous Puye Fm clastics; lost circulation
	1/20/98	Tue	Day	1202							**Encountered water at 624 ft**
	1/20/98	Tue	Day	1205							Measured DTW as nondetect (dry)
	1/20/98	Tue	Day	1205							Measured DTBot at 680.25 ft bgz
	1/20/98	Tue	Day	1250							Measured DTW as nondetect (dry)
	1/20/98	Tue	Day	1305	1527	681.00	696.00	15.00	142.0	6.34	Cored 4-1/2-in. hole from 681 to 696 ft; recovery = 90.7% in mafic-rich tuffaceous sandstone to 686.4 ft; wet Santa Fe Group basalt to 696 ft
	1/20/98	Tue	Day	1535							Measured DTW at 687.90 ft bgz
	1/20/98	Tue	Day	1608	1635	696.00	700.00	4.00	27.0	8.89	Cored 4-1/2-in. hole from 696 to 700 ft; recovery = 100% in wet Santo Fe Group basalt to 700 ft

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	1/20/98	Tue	Day	1638							**Encountered water at 679 ft**
	1/20/98	Tue	Day	1640		687.90	687.96	0.06	65.0	0.06	Measured DTW at 687.96 ft bgz
	1/20/98	Tue	Day	1701		687.96	687.93	0.03	21.0	0.09	Measured DTW at 687.93 ft bgz
	1/20/98	Tue	Day	1715	1845						Collected ~5 gal. of water at ~688 ft using 1.5-in. stainless steel bailer for preliminary contaminant water sample
106.0	1/21/98	Wed	Day	730		687.93	687.96	0.03	869.0	0.0021	Measured DTW at 687.96 ft bgz
	1/21/98	Wed	Day	712	847	700.00	703.00	3.00	95.0	1.89	Cored 4-1/2-in. hole from 700 to 703 ft; recovery = 50% in wet Santa Fe Group basalt to 703 ft
	1/21/98	Wed	Day	915	1110	703.00	0.00	703.00	115.0	366.78	Tripped out core system from 703 ft to surface
	1/21/98	Wed	Day	1230	1350	703.00	651.00	52.00	20.0	156.00	Backfilled corehole from 703 to 651 ft with 14 bags of 8/12 silica sand
	1/21/98	Wed	Day	1350	1355	651.00	645.00	6.00	5.0	72.00	Added bentonite seal through core tools from 651 to 645 ft; bentonite bridged off in corehole
	1/21/98	Wed	Day	1430	1520	0.00	645.00	645.00	50.0	774.00	Tripped in core rods to clean out bridged bentonite and tremie in more bentonite
	1/21/98	Wed	Day	1530	1600	645.00	651.00	6.00	30.0	12.00	Drilled out bentonite in corehole from 645 to 651 ft
	1/21/98	Wed	Day	1600							Measured DTBot at 651 ft bgz
	1/21/98	Wed	Day	1600							Added bentonite seal through core tools from 651 to 649 ft; bentonite bridged off in corehole
	1/21/98	Wed	Day	1625	1730	651.00	0.00	651.00	65.0	600.92	Tripped out core rods from 651 ft to surface
107.0	1/22/98	Th	Day	700	1330	649.00	0.00	649.00	390.0	99.85	Tripped out 6-5/8-in. casing from 649 ft to surface
	1/22/98	Th	Day	1430	1600	0.00	581.00	581.00	90.0	387.33	Tripped in 8-5/8-in. casing advance system from surface to 581 ft
108.0	1/23/98	Fri	Day	820	1530	581.50	649.00	67.50	430.0	9.42	Drilled 8-5/8-in. casing from 581.5 to 649 ft; tuffaceous Puye Fm clastics
109.0	1/26/98	Mon	Day	755	1145	649.00	679.00	30.00	230.0	7.83	Drilled 8-5/8-in. casing from 649 to 679 ft; tuffaceous Puye Fm clastic.
	1/26/98	Mon	Day	1305	1415	679.00	0.00	679.00	70.0	582.00	Tripped out 8-5/8-in. casing advance system from 679 ft to surface
	1/26/98	Mon	Day	1445	1615	0.00	659.00	659.00	90.0	439.33	Tripped in core rods from surface to 659 ft to tremie bentonite in for 8-5/8-in. casing seal at 679 ft
	1/26/98	Mon	Day	1620							Measured DTW as nondetect (dry)
	1/26/98	Mon	Day	1625							Measured DTBot at 679.16 ft bgz
	1/26/98	Mon	Day	1630							Added bentonite seal (two bags) through core tools from 674 to 679 ft; bentonite bridged off in corehole
	1/26/98	Mon	Day	1630							Added DI water (10 gal.) to hydrate bentonite tremied down hole

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	1/26/98	Mon	Day	1645	1758	659.00	0.00	659.00	73.0	541.64	Tripped out core rods from 659 ft to surface
110.0	1/27/98	Tue	Day	700	815	0.00	669.00	669.00	75.0	535.20	Tripped in plunger on core rods from surface to 669 ft
	1/27/98	Tue	Day	815	901	669.00	679.00	10.00	16.0	37.50	Pushed plunger inside 8-5/8-in. casing from 669 to 679 ft
	1/27/98	Tue	Day	910	1000	679.00	0.00	679.00	50.0	814.80	Tripped out plunger on core rods from 679 ft to surface
	1/27/98	Tue	Day	1130	1410	0.00	699.00	699.00	280.0	149.79	Tripped in RC-44 4-7/8-in. percussion hammer and RC rods from surface to 699 ft
	1/27/98	Tue	Day	1410	1610	699.00	710.00	11.00	120.0	5.50	Drilled open borehole from 699 to 710 ft using RC-44 4-7/8-in. percussion hammer and RC rods; Cerros del Rio Basalt
	1/27/98	Tue	Day	1615	1630	710.00	679.00	31.00	15.0	124.00	Pulled back RC-44 4-7/8-in. percussion hammer and RC rods from 710 to 679 ft
	1/27/98	Tue	Day	1630	1735	679.00	0.00	679.00	65.0	626.77	Tripped out RC-44 4-7/8-in. percussion hammer and RC rods from 679 ft to surface
	1/27/98	Tue	Day	1755		687.96	688.60	0.64	9265.0	0.0041	Measured DTW at 688.60 ft bgz
111.0	1/28/98	Wed	Day	550		688.60	688.50	0.10	715.0	0.0084	Measured DTW at 688.50 ft bgz
	1/28/98	Wed	Day	710	830	0.00	679.00	679.00	80.0	509.25	Tripped in tricone bit on RC rods from surface to 679 ft
	1/28/98	Wed	Day	830	1000	679.00	710.00	31.00	90.0	20.67	Cleaned out borehole from 679 to 710 ft with tricone bit
	1/28/98	Wed	Day	1130	1245	710.00	0.00	710.00	75.0	568.00	Tripped out tricone bit on RC rods from 710 ft to surface
	1/28/98	Wed	Day	1540	1645	0.00	708.00	708.00	65.0	653.54	Tripped in 1.5-in. OD tremie pipe from surface to 708 ft
	1/28/98	Wed	Day	1645	1800						Assembled 5-in. OD PVC casing in 30-ft sections
112.0	1/29/98	Th	Day	715		688.50	688.29	0.21	750.0	0.0168	Measured DTW at 688.29 ft bgz
	1/29/98	Th	Day	716							Measured DTBot at 704.85 ft bgz
	1/29/98	Th	Day	730	842						Assembled 5-in. OD PVC casing in 30-ft sections
	1/29/98	Th	Day	930	1430	0.00	706.95	706.95	300.0	141.39	Tripped in 5-in. OD PCV casing, 20 ft of 0.010 in screen, and 2.85 in of bottom sump from surface to 706.95
	1/29/98	Th	Day	1500							Backfilled sand from 706.95 to 678.5 ft with withdrawing tremie pipe
	1/29/98	Th	Day	1615	1720	678.50	0.00	678.50	65.0	626.31	Tripped out tremie pipe from 678.5 ft to surface
113.0	1/30/98	Fri	Day	800							Demobilize equipment and supplies from R-9 site
	1/30/98	Fri	Day	1100		688.29	688.05	0.24	1665.0	0.0086	Measured DTW at 688.05 ft bgz
	1/30/98	Fri	Day	1155							Removed cuttings to roll-offs
114.0	2/2/98	Mon	Day	915		688.05	688.61	0.56	4215.0	0.0080	Measured DTW at 688.61 ft bgz
	2/2/98	Mon	Day	930							Collected ~5 gal. of water at ~688 ft through PVC casing to test PVC effect on turbidity

Drilling Shifts (Cumulative Total)	Date	Day	Shift	From (time)	To (time)	Production From (ft)	Production To (ft)	Production (ft)	Time (min)	Rate (ft/hr)	Field Activity
	2/2/98	Mon	Day	1200							Purged ~40 gal. of water; water turbidity remained high
	2/2/98	Mon	Day	1700							Removed hydraulic casing jacks from cellar
115.0	2/3/98	Tue	Day	1300							Demobilized T-4 drill rig from R-9 site to the Field Support Facility (FSF)
	2/3/98	Tue	Day	1430							Demobilized 6-5/8-in. casing from R-9 site to FSF (start)
116.0	2/4/98	Wed	Day	1000							Demobilized 6-5/8-in. casing from R-9 site to FSF (complete)
	2/10/98	Tue	Day	1100		688.61	688.41	0.20	11625.0	0.0010	Measured DTW at 688.41 ft bgz; PVC casing is 3.35 ft above ground zero
	2/10/98	Tue	Day	1100							Installed transducer in water at ~697 ft to monitor water level with Hermit data collection system; transducer reads ~8.6 ft head
	2/26/98	Th	Day	1000		688.41	688.10	0.56	22980.0	0.0015	Measured DTW at 688.1 ft bgz
	2/26/98	Th	Day	1100							Removed transducer from water at ~697 ft
	3/2/98	Mon	Day								Developed temporary PVC well by bailing ~20 gal. of turbid water
	3/2/98	Mon	Day	1500		688.10	688.40	0.56	6060.0	0.0055	Measured DTW at 688.4 ft bgz
	3/2/98	Mon	Day								Installed transducer in water at ~688 ft to monitor water level with Hermit data collection system

Appendix B

Lithologic Log

APPENDIX B LITHOLOGIC LOG

This appendix contains the lithologic log prepared for characterization well R-9. With minor variations and additions, the log follows the format specified in the Laboratory Environmental Restoration Project standard operating procedure LANL-ER-SOP-12.01, R2, "Field Logging, Handling, and Documentation of Borehole Samples," Attachment E, "Core Sample Log." The log depicts cored intervals and recovery; noncored intervals of cuttings production; locations and identity numbers of contract laboratory samples; locations, identity numbers, and type of samples for hydrologic testing; curation of borehole materials; lithologic interpretations; and interim well construction. All borehole materials (i.e., core, cuttings, and chips), except samples removed for analysis, are stored at the Laboratory's Field Support Facility (FSF) in accordance with LANL-ER-SOP-12.01, R2.

This log is preliminary and subject to revision for use in subsequent hydrogeologic investigation reports. The stratigraphic nomenclature used in the log to identify pre-Bandelier lithologic units follows the *Core Document for Canyons Investigations* (LANL 1997, 55622) and Griggs (1964, 8795). The stratigraphic nomenclature used to identify Bandelier Tuff units follows Broxton and Reneau (1995, 49726).

Footages on the logs are distances down borehole in feet (') below the ground surface.

Contacts between stratigraphic units are indicated on the logs by solid or dashed lines within the lithology, graphic log, and lithologic unit columns. Informal (unpublished) subunits based on differing lithologic characteristics and preliminary stratigraphic interpretation are indicated by dotted lines within the lithology and graphic log columns.

The column for field analytical sample number shows the intervals of the borehole material sampled for contract laboratory analysis and the associated sample identity number. The column for hydraulic property samples indicates samples collected for moisture and matric potential analysis and/or samples that were protected from moisture loss for subsequent hydraulic property and isotope analysis.

The legend on the following page shows abbreviations and symbols that were used in the log.

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Lithologic Log Legend

Abbreviations and explanations

Bearing = direction of angled borehole

crse. = course

Orientation = borehole angle from horizontal

devit. = devitrified

dk. = dark

dkr. = darker

FeOx = iron oxidation

Fm = formation

lt. = light

mass. = massive

med. = medium

Mn02 = manganese oxide

mod. = moderate

modly. = moderately

ol. = olivine

plag. = plagioclase

PWZ = perched water zone

SAA = same as above

sat. = saturated

sltly. = slightly

strgly. = strongly

TD = total depth

w/ = with

wk. = weak

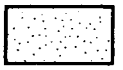
wkly. = weakly

Lithologic Symbols

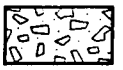
alluvium

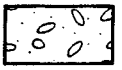
basalt

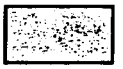
basaltic tephra


sandstone, siltstone, and gravel

siltstone and sandstone


gravel


conglomerate and gravel


ash bed

LOS ALAMOS NATIONAL LABORATORY
REGIONAL HYDROGEOLOGIC CHARACTERIZATION PROJECT
ENVIRONMENTAL RESTORATION, CANYONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: R-9 | TA/OU: LA Canyon | Aggregate: 1 | Page: 1 of: 6

Drilling Co.: Tonto Environmental Drilling Inc. | Core Box #(s) 29 Core 24 Cuttings | Start Date: 9/25/97 Time: 0906 | End Date: temporary Time: suspension

Drilling Equip./Method: Ingersoll-Rand T-4/ODEX casing/air core with total dust suppression | Sampling Method: Wireline core barrel sampling

Driller: Larry Thoren | Geologist: Jon Marin, Rick Warren | Orientation: Vertical | Bearing: NA | TD: 710.0 ft

Location: x=1,648,239.91' y=1,770,845.91' Ground Elevation: 6383.93' NAD83, NM State Plane Coordinate System

Depth (feet)	Core Run C-# Core Recovery %	Field Analytical Sample Number	Hydrologic Property Samples	Core Box # From - To (feet)	Depth	Lithology	Graphic Log	Lithologic Unit	Well Construction	Notes
0					0-10.0'	ALLUVIUM, coarse basalt fragments, dry.				Borehole R-9 is a redrill of well LAOI-7 and is located in Los Alamos Canyon inside the eastern Laboratory boundary ~ 200 yards northwest of State Route 4
10	Recovery Not Attempted				10.0'-40.0'	BASALT, upper tholeiite, moderately vesicular, dry, with vesicles to 1 mm, near base to 9 mm; orange brown clay thinly coats some surfaces throughout, but vesicles are completely free of clay.		10'		
20										
30	1/30%		R-9-1, R-9-2							
	2/24%			C-1/ 33.0'-184.5'	40.0'-118.5'	BASALT, upper tholeiite, mass., dry, with scattered round to elongate vesicles, mostly 2 to 4 mm; near base, basalt is moderately vesicular, with round vesicles mostly 1 to 6 mm in diameter; no clay is evident within this interval.				
40		CC/97-350	R-9-3							R-9 contained multiple casing strings to seal off perched water zones (PWZs) from communicating downhole as drilling proceeded.
50		CC/97-352	R-9-4							
60	Air Rotary Cuttings			Cuttings in boxes 1 to 3	118.5'-180.0'	BASALT, lower tholeiite, mass., med. grained upper part, crs. grained lower part, dry; modly. vesicular with scarce to common vesicles from round to 1 mm, to very elongate to 6 by 1 mm; clay is absent.		Cerros del Rio Basalt, upper tholeiite flow	Temporary 4-in PVC	
70			R-9-5							
80			R-9-6							
90			R-9-7		180.0'-196.8'	BASALT, upper alkalic flow, vesicular, sat., common sltly. ovoid vesicles to 10 by 5 mm; some vesicles are thickly coated w/ exogenetic clay, fractures thinly coated with clay; unaltered ol. indicates a complete lack of secondary alteration.				
100			R-9-8							
110			R-9-9					118.5'		@ 108.0'-112.0', caved in, repeatedly redrilled.
120										

LOS ALAMOS NATIONAL LABORATORY
REGIONAL HYDROGEOLOGIC CHARACTERIZATION PROJECT
ENVIRONMENTAL RESTORATION, CANYONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: R-9 | TA/OU: L.A. Canyon | Aggregate: 1 | Page: 2 of: 6

Drilling Co.: Tonto Environmental Drilling Inc. | Core Box #(s) 29 Core 24 Cuttings | Start Date: 9/25/97 Time: 0906 | End Date: temporary Time: suspension

Drilling Equip./Method: Ingersoll-Rand T-4/ODEX casing/air core with total dust suppression | Sampling Method: Wireline core barrel sampling

Driller: Larry Thoren | Geologist: Jon Marin, Rick Warren | Orientation: Vertical | Bearing: NA | TD: 710.0 ft

Depth (feet)	Core Run C-# Core Recovery %	Field Analytical Sample Number	Hydrologic Property Samples	Core Box # From - To (feet)	Depth	Lithology	Graphic Log	Lithologic Unit	Well Construction	Notes
120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240	Air Rotary Cuttings; 3/94%, 4/100%, 5/72%, 6/50%, 7/100%, 8/100%, 9/30%, 10-12, 80%, 13/48%, 14/100%, 15/100%, 16/97%, 17/100%, 18/50%, 19/100%, 20/100%, 21/100%, 22/80%, 23/53%, 24/100%, 25/100%, 26/100%, 27/100%, 28/84%, 29/100%, 30/100%	CC/97-354, CC/97-356, CC/97-358, CC/97-360, CC/97-362, CC/97-364, CC/97-366	R-9-10, R-9-11, R-9-12, R-9-13, R-9-14, R-9-15, R-9-16, R-9-17, R-9-18, R-9-20, R-9-21, R-9-22, R-9-23, R-9-24, R-9-25, R-9-26	Cuttings in boxes 3 to 5; C-1/cont.; C-2/164.5'-196.3'; C-3/196.3'-203.8'; C-3/203.8'-212.5'; C-5/212.5'-220.0'; C-6/220.0'-226.5'; C-7/226.5'-235.4'; C-8/235.4'-245.0'	196.8'-206.0'	BASALT, upper alkalic flow, mass., moist, scattered aligned ovoid vesicles to 4 by 1 mm; ol. is locally strgly. altered to iddingsite; fractures thickly coated w/ mod. orange pink exogenetic clay.		Cerros del Rio Basalt, upper tholeiite flow	Temporary 4-in PVC	@ 137.7'= static water level for depth of saturated zone @ 180.0'.
					206.0'-212.5'	BASALT, lower alkalic flow, modly to highly vesicular at 212.5' sat., grading to mass. at 212.5', moist; ovoid vesicles to 30 by 20 mm; mod. yellowish brown clay fills vesicles above 209.4'.		180.0'		@ 180.0'; enountered 1st saturated zone, high clay content
					212.5'-225.5'	BASALT, lower alkalic flow, modly. to highly vesicular, highly fractured at 212.5' sat. grading to unfractured at 225.5' dry; ovoid to round vesicles to 20 by10 mm, pervasive pinkish gray to mod. reddish brown, locally laminated clay in fractures; clay is absent from unfractured core; local MnO2 black dendrites on clay.		Cerros del Rio Basalt, upper alkalic flow; 206.0'		@ 211.0'-212.5' fracture coated with 1 mm thick mod. yellowish brown clay.
					225.5'-278.9'	BASALT, lower alkalic flow, mass., dry; unusually large irregular vesicles to 40 mm to 226.7';				@ 225.5', massive basalt perches saturated zone @ 180.0'

LOS ALAMOS NATIONAL LABORATORY
REGIONAL HYDROGEOLOGIC CHARACTERIZATION PROJECT
ENVIRONMENTAL RESTORATION, CANYONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: R-9 | TA/OU: L.A. Canyon | Aggregate: 1 | Page: 3 of: 6

Drilling Co.: Tonto Environmental Drilling Inc. | Core Box #(s) 29 Core 24 Cuttings | Start Date: 9/25/97 Time: 0906 | End Date: temporary Time: suspension

Drilling Equip./Method: Ingersoll-Rand T-4/ODEX casing/air core with total dust suppression | Sampling Method: Wireline core barrel sampling

Driller: Larry Thoren | Geologist: Jon Marin, Rick Warren | Orientation: Vertical | Bearing: NA | TD: 710.0 ft

Depth (feet)	Core Run C-# Core Recovery %	Field Analytical Sample Number	Hydrologic Property Samples	Core Box # From - To (feet)	Depth	Lithology	Graphic Log	Lithologic Unit	Well Construction	Notes
240–360	31/100%; 32/100%; 33/100%; 34/50%; 35/100%; 36/100%; 37/100%; 38/90%; 39-40/80%; 41/100%; 42/100%; 43/100%; 44/100%; 45/100%; 46/78%; 47/100%; 48-49/65%; 50-52/88%; 53/69%; 54-55/80%; 56/100%; 57/45%; 58/27%; 59/25%; 60/0%; 61/0%; 62/0%; 63/0%; Air Rotary Cuttings	CC/97-368; CC/97-370; CC/97-372; Hydrologic	R9-27; R9-28; R9-29; R9-30; R9-31; R9-32; R9-33; R9-34; R9-35; R9-36; R9-37; R9-38; R9-39; R9-40; R9-41; R9-42; R9-43; R9-44; R9-45; R9-46; R9-47	C-8/cont.; C-9/245.0'-253.0'; C10/253.0'-261.1'; C11/261.1'-268.5'; C12/268.5'-277.8'; C13/277.8'-284.4'; C14/284.4'-299.2'; C15/299.2'-587.2'; Cuttings in boxes 5 to 7	225.5'-278.9' continued	BASALT, lower alkalic flow, mass., continued, some vesicles from 227.7' to 228.0' are filled with mod. orange pink to reddish brown locally laminated clay w/ local Mn02 dendrites; modly vesicular from 278.6' - 278.9'; thin clay to 12 mm in vesicles.		Cerros del Rio Basalt, lower alkalic flow	Temporary 4-in PVC	@ 243.8', 14-in casing sealed w/ bentonite below 1st PWZ. @ 264.2'= static water level for saturated zone at depth of 275.0' @ 258.3', fracture coating is lt yellow dry clay different from clay in 1st PWZ. @ 275.5', encountered 2nd PWZ in borehole. @ 278.0', clay filled fracture perpendicular to core axis. @281.5'-281.8', fracture filled with brecciated basalt and clay. @ 282.0', BASALTIC TEPHRA perches saturated zone at 275.0' @ 292.5', 12 3/4-in casing sealed w/ bentonite saturated zone at 275.0'
					278.9'-282.0'	BASALT, scoriaceous, moist; scattered very elongate vesicles to 40 mm, lightly to heavily coated with mod. orange pink clay to 2 mm.		282.0' Basalt Tephra		
					282.0'-285.8'	BASALTIC TEPHRA, dry, well sorted to 283.7' consisits mostly of hydroclastic shards of basalt w/ rare lithics and plag. to 0.5 mm; poorly sorted to 285.8' is ash w/ some vesicular basaltic clasts; vesicles filled w/ very pale orange clay at 282.0' to less clay at 282.6'; local white calcite at 285.8'.		289.8' Old Alluvium		
					285.8'-289.8'	BASALTIC TEPHRA, mass., dry, rare lithics to 1.5 mm, rare felsics to 2 mm; 1mm white calcite masses in vugs.		329.0'		
					289.8'-329.0'	SANDSTONE and BOULDERS, dry, sandstone is yellowish brown, med. grained; boulders are modly. mostly angular basalt fragments w/ 5 to10% grayish red vitric lava.		Puye Fm, fan-glomerate facies		

LOS ALAMOS NATIONAL LABORATORY
REGIONAL HYDROGEOLOGIC CHARACTERIZATION PROJECT
ENVIRONMENTAL RESTORATION, CANYONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: R-9 | TA/OU: L.A. Canyon | Aggregate: 1 | Page: 4 of: 6

Drilling Co.: Tonto Environmental Drilling Inc. | Core Box #(s) 29 Core 24 Cuttings | Start Date: 9/25/97 Time: 0906 | End Date: temporary Time: suspension

Drilling Equip./Method: Ingersoll-Rand T-4/ODEX casing/ air core with total dust suppression | Sampling Method: Wireline core barrel sampling

Driller: Larry Thoren | Geologist: Jon Marin, Rick Warren | Orientation: Vertical | Bearing: NA | TD: 710.0 ft

Depth (feet)	Core Run C-# Core Recovery %	Field Analytical Sample Number	Hydrologic Property Samples	Core Box # From - To (feet)	Depth	Lithology	Graphic Log	Lithologic Unit	Well Construction	Notes
360, 370, 380, 390, 400, 410, 420, 430, 440, 450, 460, 470, 480	Air Rotary Cuttings		R-9-48, R-9-49, R-9-50, R-9-51, R-9-52, R-9-53, R-9-54, R-9-55, R-9-56, R-9-57, R-9-58, R-9-59, R-9-60, R-9-61, R-9-62, R-9-63, R-9-64, R-9-65, R-9-66, R-9-67, R-9-68, R-9-69, R-9-70, R-9-71	Cuttings in boxes 7 to 11	329.0'-349.0'	SAND, vitric, pebbly, dry.		Puye Fm, fanglomerate facies	Temporary 4-in PVC	Air rotary cuttings collected while advancing the 10 3/4-in and 8 5/8-in casings.
					349.0'-365.0'	SAND, vitric, dry, fine grained at 349', pebbly at 365';				
					365.0'-379.0'	SAND, vitric, fine grained at 365'; med. grained to pebbly at 379'.				
					379.0'-399.0'	SAND, vitric, pumiceous, med. grained; pumice to 1 mm, few to 6 mm, pumice abundant from 384' to 394'.				@ 356.5'-359.0' and 409'-414' pebbles are mostly subangular devit. dacitic lava similar to Rendija Canyon rhyodacite.
					399.0'-401.5'	SAND, vitric, fine grained, w/ some pebbles to 7 mm.				
					401.5'-407.7'	GRAVEL, vitric, w/ pebbles from 5 to 10 mm.				
					407.7'-436.5'	SAND, fine to coarse grained, sltly pebbly, vitric, pumiceous some vitric lava pebbles.				
					436.5'-469.0'	GRAVEL, some sand, vitric, pumiceous, pebbles 5 to 10 mm; coarsest gravel occurs between 442' to 443', sand occurs from 455' to 458'.				@ 420.0', advancement of 10 3/4-in casing halted; no bentonite seal installed.
					469.0'-482.7'	SAND and GRAVEL, med. grained, sand at 469' grades to gravel at 482.7'; vitric, pumiceous.				
					482.7'-496.5'	SAND and GRAVEL, med. grained sand at 482.7' grades to gravel at 496.5'; vitric, pumiceous.				@496.5'- 539'; pebbles are subangular lithics of devit. to vitric phenocryst-poor Rendija Canyon rhyodacite.
					496.5'-539.0'	GRAVEL, dry, vitric, pumiceous; 2 to 5 mm pebbles.				
					539.0'-544.4'	SANDSTONE, dry, argillic, pumiceous, fine grained, w/ pebbles to 6 mm.				

LOS ALAMOS NATIONAL LABORATORY
REGIONAL HYDROGEOLOGIC CHARACTERIZATION PROJECT
ENVIRONMENTAL RESTORATION, CANYONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: R-9 | TA/OU: L.A. Canyon | Aggregate: 1 | Page: 5 of: 6

Drilling Co.: Tonto Environmental Drilling Inc. | Core Box #(s) 29 Core 24 Cuttings | Start Date: 9/25/97 Time: 0906 | End Date: temporary suspension Time:

Drilling Equip./Method: Ingersoll-Rand T-4/ODEX casing/ air core with total dust suppression | Sampling Method: Wireline core barrel sampling

Driller: Larry Thoren | Geologist: Jon Marin, Rick Warren | Orientation: Vertical | Bearing: NA | TD: 710.0 ft

Depth (feet)	Core Run C-# Core Recovery %	Field Analytical Sample Number	Hydrologic Property Samples	Core Box # From - To (feet)	Depth	Lithology	Graphic Log	Lithologic Unit	Well Construction	Notes
480–600	Air Rotary Cuttings; C-64/100%, C-65/80%, C-66/100%, C-67/100%, C-68/100%	CG-97-374, CG-97-376, CG-97-378	R-9-72, R-9-73, R-9-74, R-9-75, R-9-76, R-9-77, R-9-78, R-9-79, R-9-80, R-9-81, R-9-82, R-9-83, R-9-84, R-9-85, R-9-86, R-9-87,88, R-9-89, R-9-90, R-9-91, R-9-92, R-9-93, R-9-94, R-9-95, R-9-96, R-9-97, R-9-98, R-9-99, R-9-100, R-9-101, R-9-102, GT/97-307, R-9-103, GT/97-308, R-9-104	Cuttings in boxes 11 to 22; C-15/cont., C-16/587.2'-595.1', C-17/595.1'-603.3'	544.4'-554.0'	SANDSTONE, dry, partly vitric partly argillic, fine to coarse grained, pumiceous.		Puye Fm, fanglomerate facies	Temporary 4-in PVC	@496.5'- 539'; pebbles are subangular lithics of devitrified to vitric phenocryst-poor Rendija Canyon rhyodacite.
					554.0'-559.0'	CONGLOMERATE, dry, argillic; pumice to 2 mm; devit. lava clasts 5 to 9 mm, 1 to 3 mm near 554', some to 17 mm near 559'.				
					559.0'-565.8'	SANDSTONE, dry, argillic; conglomeratic from 563.9' to 564.0'; clasts are mostly devit. dacitic lavas; 7% argillic lava, 1% siltstone clasts.				@ 524.5'= static water level for saturated zones at depths of 579.0', 615.0', and 624.0'
					565.8'-570.6'	CONGLOMERATE, dry, argillic, clasts 2 to 4 mm.				
					570.6'-580.5'	SANDSTONE, dry, argillic; some vitric pumices to 2 mm.				
					580.5'-584.0'	CONGLOMERATE, dry, argillic; pumice to 9 mm, devitrified lava pebbles to 10 mm.		539.0'		
					584.0'-587.0'	SANDSTONE, dry, fine grained, argillic; pumice to 11 by 3 mm at 584', at 587' med. grained sandstone w/ pumice to 25 mm.		Puye Fm, pumiceous fanglomerate facies		@ 539.0', 1st appearance of dull greenish white clay-rich (argillic) massive pumice fragments.
					587.0'-595.1'	SANDSTONE, argillic, dry; pumice to 25 by 12 mm; devit. lava pebbles to 11 mm; local thin sat. sand lenses.				@ 595.1'-596.2' and 606.2'-607.2', lt yellow green TUFFs are marker horizons of highly argillic altered pumice w/ mafic accessory minerals.
					595.1'-596.2'	TUFF, argillic, moist, hematitic, nonwelded.				
					596.2'-602.1'	SANDSTONE, argillic, fine grained, pumice to 18 mm.				
					602.1'-606.2'	SANDSTONE, conglomeratic, argillic to vitric; pumice to 17 mm;				

LOS ALAMOS NATIONAL LABORATORY
REGIONAL HYDROGEOLOGIC CHARACTERIZATION PROJECT
ENVIRONMENTAL RESTORATION, CANYONS FOCUS AREA
BOREHOLE LOG

BOREHOLE ID: R-9 | TA/OU: L.A. Canyon | Aggregate: 1 | Page: 6 of: 6

Drilling Co.: Tonto Environmental Drilling Inc. | Core Box #(s) 29 Core 24 Cuttings | Start Date: 9/25/97 Time: 0906 | End Date: temporary Time: suspension

Drilling Equip./Method: Ingersoll-Rand T-4/ODEX casing/air core with total dust suppression | Sampling Method: Wireline core barrel sampling

Driller: Larry Thoren | Geologist: Jon Marin, Rick Warren | Orientation: Vertical | Bearing: NA | TD: 710.0 ft

Depth (feet)	Core Run C-# Core Recovery %	Field Analytical Sample Number	Hydrologic Property Samples	Core Box # From - To (feet)	Depth	Lithology	Graphic Log	Lithologic Unit	Well Construction	Notes
600	C-68/cont. C-69/70% C-70/50% C-71/85% C-72/100% C-73/50% C-74/50% C-75/33% C-76/50% C-77/100% C-78/100% C-79/100% C-80/90% C-81/90% C-82/140% C-83/100% C-84/100% C-85/100% C-86/94% C-87/90% C-88/80% C-89/60% C-90/100% C-91/100% C-92/80% C-93/73% C-94/100% C-95/53% C-96/50% C-97/40%		GT/97-310 GT/97-311 GT/97-312 GT/98-005 R-9-108 GT/98-006 GT/98-007 GT/98-008 GT/98-009 GT/98-010 GT/98-011 R-9-109 GT/98-012 GT/98-013 R-9-110 GT/98-016 R-9-111 GT/98-017 R-9-112 GT/98-018 R-9-113 GT/98-019 R-9-114 R-9-115 GT/98-020 R-9-116 R-9-117 GT/98-021 GT/98-022 R-9-118 R-9-119 GT/98-023 R-9-120 GT/98-024 GT/98-025 R-9-121	C-17/cont. C-18/603.3'-613.8' C-19/613.8'-626.8' C-20/626.8'-634.5' C-21/634.5'-642.0' C-22/642.0'-653.1' C-23/653.1'-661.5' C-24/661.5'-668.8' C-25/668.8'-676.3' C-26/676.3'-684.5' C-27/684.5'-691.7' C-28/691.7'-699.1' C-29/699.1'-703.0'	602.1'-606.2'	(continued) devit. lava pebbles to 7 mm.		Puye Fm, pumiceous fanglomerate facies		@ 606.2'-607.2', TUFF, marker horizon.
610					606.2'-607.2'	TUFF, argillic, non welded; pumice to 10 by 1 mm.				
					607.2'-613.0'	SILTSTONE and SANDSTONE, argillic, fine grained w/ pumice at 611'.				@ 607.2'-612.0', siltstone is paleosol.
620					613.0'-626.8'	CONGLOMERATE, argillic, clasts 1 to 8 mm, friable, sltly calcareous, zeolitic; abundant pumice near 626.8'.				
630					626.8'-640.8'	SANDSTONE, pebbly, white pumice to 13 mm; largest argillic, smaller vitric.				@ 679.0', 8 5/8-in casing sealed w/ bentonite below 3rd PWZ.
640					640.8'-652.2'	SANDSTONE, argillic, sltly calcareous, zeolitic, fine grained.				R-9 contains a temporary 4-in schedule 40 PVC monitoring well with 30' of 0.01-in machine slotted screen from 683.2' to 703.2'; sand in annular space from 678.5' to 706.8'.
650					652.2'-676.3'	SANDSTONE, argillic, very friable, sltly zeolitic, 5 by 1 pumice to 9 mm.				
660					676.3'-686.4'	SANDSTONE, pumiceous, crse grained, modly well sorted, w/ abundant lithics to 2 mm; thin sat. sandstone lenses.				
670					686.4'					
680					686.4'-689.0'	BASALT, weathered, argillic, calcareous; mass. exogenetic clay and sand in fractures to 12 mm wide.		Santa Fe Group Basalt		688.0'= static water level for saturated zone at 688'; probably regional aquifer water table.
690					689.0'-710.0'	BASALT, mass., platy, fine-grained, Miocene age, locally highly fractured, some hairline calcite veins.				
700										
710					TD = 710.0'	Temporary TD.				
720										

Appendix C

Samples for Hydraulic Property Characterization

APPENDIX C SAMPLES FOR HYDRAULIC PROPERTY CHARACTERIZATION

TABLE C-1

MOISTURE SAMPLES AND RESULTS

Sample ID*	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)	Moisture in Cuttings (dry wt. %)	Moisture in Core (dry wt. %)
R9-1	26.5	27	26.75	1.34	
R9-2	32	33	32.50	0.82	
R9-3	41	50.5	45.75	3.59	
R9-4	50.5	58	54.25	1.94	
R9-5	70	72	71.00	1.17	
R9-6	80	82	81.00	1.65	
R9-7	90	92	91.00	1.54	
R9-8	100	102	101.00	1.41	
R9-10	121	122	121.50	1.32	
R9-11	130	132	131.00	0.73	
R9-12	140	142	141.00	0.73	
R9-13	149	152	150.50	0.56	
R9-14	160	162	161.00	1.46	
R9-15	170	172	171.00	0.49	
R9-25	227.7	228	227.85		3.63
R9-26	234.3	234.5	234.40		3.13
R9-27	243.85	244.1	243.98		2.31
R9-28	252.4	252.6	252.50		2.14
R9-29	255	255.5	255.25		1.83
R9-30	266.35	266.6	266.48		1.59
R9-31	273.3	273.7	273.50		2.07
R9-35	285.3	285.5	285.40		15.28
R9-36	290.5	290.7	290.60		25.58
R9-37	306	309	307.50	7.35	
R9-38	311.5	314	312.75	7.81	
R9-39	316.5	319	317.75	8.14	
R9-40	321.5	324	322.75	7.93	
R9-41	326.5	329	327.75	8.13	
R9-42	331.5	334	332.75	7.35	
R9-43	336.5	339	337.75	5.68	
R9-44	341.5	344	342.75	5.71	
R9-45	346.5	349	347.75	4.46	
R9-46	351.5	354	352.75	6.23	
R9-47	356.5	359	357.75	5.13	
R9-48	361.5	364	362.75	4.48	

*See Appendix B

TABLE C-1 (continued)

MOISTURE SAMPLES AND RESULTS

Sample ID*	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)	Moisture in Cuttings (dry wt. %)	Moisture in Core (dry wt. %)
R9-49	366.5	369	367.75	4.95	
R9-50	371.5	374	372.75	3.22	
R9-51	376.5	379	377.75	4.01	
R9-52	381.5	384	382.75	4.74	
R9-53	386.5	389	387.75	5.75	
R9-54	391.5	394	392.75	6.42	
R9-55	396.5	399	397.75	5.57	
R9-56	401.5	404	402.75	7.54	
R9-57	406.5	409	407.75	4.98	
R9-58	411.5	414	412.75	4.10	
R9-59	416.5	419	417.75	5.00	
R9-60	421.5	424	422.75	3.57	
R9-61	426.5	429	427.75	3.66	
R9-62	431.5	434	432.75	5.20	
R9-63	436.5	439	437.75	7.38	
R9-64	443	444	443.50	4.79	
R9-65	448	449	448.50	4.99	
R9-66	453	454	453.50	5.60	
R9-67	458	459	458.50	6.19	
R9-68	463	464	463.50	5.01	
R9-69	468	469	468.50	4.67	
R9-70	471.5	474	472.75	5.06	
R9-71	476.5	479	477.75	4.88	
R9-72	481.5	484	482.75	6.64	
R9-73	486.5	489	487.75	6.93	
R9-74	491.5	494	492.75	6.35	
R9-75	496.5	499	497.75	5.98	
R9-76	501.5	504	502.75	6.88	
R9-77	506.5	509	507.75	5.49	
R9-78	511.5	514	512.75	5.93	
R9-79	516.5	519	517.75	12.47	
R9-80	521.5	524	522.75	5.42	
R9-81	526.5	529	527.75	4.02	
R9-82	531.5	534	532.75	2.85	
R9-83	536.5	539	537.75	3.65	
R9-84	541.5	542	541.75		11.44
R9-85	543.5	544	543.75		12.17
R9-86	544.8	545	544.90		11.28

*See Appendix B

TABLE C-1 (continued)

MOISTURE SAMPLES AND RESULTS

Sample ID*	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)	Moisture in Cuttings (dry wt. %)	Moisture in Core (dry wt. %)
R9-87	546.6	547	546.80		12.78
R9-88	547.8	548	547.90		9.63
R9-89	549.4	549.8	549.60		12.88
R9-90	551.8	552	551.90		8.51
R9-91	553.9	554	553.95		8.17
R9-92	556.9	557	556.95		9.88
R9-93	558.9	559	558.95		11.31
R9-94	561.9	562	561.95		8.43
R9-95	563.9	564	563.95		7.55
R9-96	565.9	566	565.95		7.31
R9-97	569.7	570	569.85		4.47
R9-98	572.9	573	572.95		3.53
R9-99	574.8	575	574.90		3.58
R9-100	576.9	577	576.95		4.56
R9-101	578.9	579	578.95		4.19
R9-102	584	584.3	584.15	17.83	
R9-103	586.4	586.7	586.55	21.12	
R9-104	595.2	595.8	595.50	20.88	
R9-106	615.5	616.5	616.00	7.22	
R9-107	616.5	617.5	617.00	11.74	
R9-108	621	621.3	621.15	17.40	
R9-109	639.6	639.8	639.70	23.82	
R9-110	645.25	645.35	645.30	44.78	
R9-111	651.5	651.7	651.60	27.51	
R9-112	655.1	655.3	655.20	27.08	
R9-113	660.8	661	660.90	27.31	
R9-114	665.5	665.7	665.60	18.74	
R9-115	669.8	669.9	669.10	25.30	
R9-116	669	669.2	669.85	25.56	
R9-117	672.9	673.1	673.00	22.09	
R9-118	678.8	679	678.90	15.31	
R9-119	684.9	685.1	685.00	15.10	

*See Appendix B

TABLE C-2

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R9-1	Cuttings	26.5	27	26.75
R9-2	Cuttings	32	33	32.50
R9-3	Cuttings	41	50.5	45.75
R9-4	Cuttings	50.5	58	54.25
R9-5	Cuttings	70	72	71.00
R9-6	Cuttings	80	82	81.00
R9-7	Cuttings	90	92	91.00
R9-8	Cuttings	100	102	101.00
R9-9	Cuttings	110	112	111.00
R9-10	Cuttings	121	122	121.50
R9-11	Cuttings	130	132	131.00
R9-12	Cuttings	140	142	141.00
R9-13	Cuttings	149	152	150.50
R9-14	Cuttings	160	162	161.00
R9-15	Cuttings	170	172	171.00
R9-25	Core	227.7	228	227.85
R9-26	Core	234.3	234.5	234.40
R9-27	Core	243.85	244.1	243.98
R9-28	Core	252.4	252.6	252.50
R9-30	Core	266.35	266.6	266.48
R9-31	Core	273.3	273.7	273.50
R9-36	Core	290.5	290.7	290.60
R9-37	Cuttings	306	309	307.50
R9-38	Cuttings	311.5	314	312.75
R9-39	Cuttings	316.5	319	317.75
R9-40	Cuttings	321.5	324	322.75
R9-41	Cuttings	326.5	329	327.75
R9-42	Cuttings	331.5	334	332.75
R9-43	Cuttings	336.5	339	337.75
R9-44	Cuttings	341.5	344	342.75
R9-45	Cuttings	346.5	349	347.75
R9-46	Cuttings	351.5	354	352.75
R9-47	Cuttings	356.5	359	357.75
R9-48	Cuttings	361.5	364	362.75
R9-49	Cuttings	366.5	369	367.75
R9-50	Cuttings	371.5	374	372.75
R9-51	Cuttings	376.5	379	377.75
R9-52	Cuttings	381.5	384	382.75
R9-53	Cuttings	386.5	389	387.75

*See Appendix B

TABLE C-2 (continued)

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R9-54	Cuttings	391.5	394	392.75
R9-55	Cuttings	396.5	399	397.75
R9-56	Cuttings	401.5	404	402.75
R9-57	Cuttings	406.5	409	407.75
R9-58	Cuttings	411.5	414	412.75
R9-59	Cuttings	416.5	419	417.75
R9-60	Cuttings	421.5	424	422.75
R9-61	Cuttings	426.5	429	427.75
R9-62	Cuttings	431.5	434	432.75
R9-63	Cuttings	436.5	439	437.75
R9-64	Cuttings	443	444	443.50
R9-65	Cuttings	448	449	448.50
R9-66	Cuttings	453	454	453.50
R9-67	Cuttings	458	459	458.50
R9-68	Cuttings	463	464	463.50
R9-69	Cuttings	468	469	468.50
R9-70	Cuttings	471.5	474	472.75
R9-71	Cuttings	476.5	479	477.75
R9-72	Cuttings	481.5	484	482.75
R9-73	Cuttings	486.5	489	487.75
R9-74	Cuttings	491.5	494	492.75
R9-75	Cuttings	496.5	499	497.75
R9-76	Cuttings	501.5	504	502.75
R9-77	Cuttings	506.5	509	507.75
R9-78	Cuttings	511.5	514	512.75
R9-79	Cuttings	516.5	519	517.75
R9-80	Cuttings	521.5	524	522.75
R9-81	Cuttings	526.5	529	527.75
R9-82	Cuttings	531.5	534	532.75
R9-83	Cuttings	536.5	539	537.75
R9-84	Cuttings	541.5	542	541.75
R9-85	Cuttings	543.5	544	543.75
R9-86	Cuttings	544.8	545	544.90
R9-87	Cuttings	546.6	547	546.80
R9-88	Cuttings	547.8	548	547.90
R9-89	Cuttings	549.4	549.8	549.60
R9-90	Cuttings	551.8	552	551.90
R9-91	Cuttings	553.9	554	553.95
R9-92	Cuttings	556.9	557	556.95

*See Appendix B

TABLE C-2 (continued)

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R9-93	Cuttings	558.9	559	558.95
R9-94	Cuttings	561.5	562	561.75
R9-95	Cuttings	563.9	564	563.95
R9-96	Cuttings	565.9	566	565.95
R9-97	Cuttings	569.7	570	569.85
R9-98	Cuttings	572.9	573	572.95
R9-99	Cuttings	574.8	575	574.90
R9-100	Cuttings	576.9	577	576.95
R9-101	Cuttings	578.9	579	578.95
R9-102	Core	584	584.3	584.15
R9-103	Core	586.4	586.7	586.55
R9-104	Core	595.2	595.8	595.50
R9-106	Core	615.5	616.5	616.00
R9-107	Core	616.5	617.5	617.00
R9-108	Core	621	621.3	621.15
R9-109	Core	639.6	639.8	639.70
R9-110	Core	645.25	645.35	645.30
R9-111	Core	651.5	651.7	651.60
R9-112	Core	655.1	655.3	655.20
R9-113	Core	660.8	661	660.90
R9-114	Core	665.5	665.7	665.60
R9-116	Core	669	669.2	669.10
R9-115	Core	669.8	669.9	669.85
R9-117	Core	672.9	673.1	673.00
R9-118	Core	678.8	679	678.90
R9-119	Core	684.9	685.1	685.00

*See Appendix B

TABLE C-3

SAMPLES PRESERVED FOR POTENTIAL HYDRAULIC PROPERTY TESTING

Start Depth (ft)	End Depth (ft)	ID (04LA-97-)	Average Depth (ft)	Matrix Type
181.5	181.8	292	181.65	Core
183	183.7	294	183.35	Core
184.8	185.3	293	185.05	Core
198.7	199.3	295	199	Core
199.5	200.2	296	199.85	Core
203.5	203.8	297	203.65	Core
206	206.5	298	206.25	Core
228.8	229.2	299	229	Core
229.2	229.6	300	229.4	Core
235	235.4	301	235.2	Core
243.25	243.85	302	243.55	Core
252.6	253	303	252.8	Core
258.3	258.85	304	258.58	Core
282.6	283.1	305	282.85	Core
290.7	291.2	306	290.95	Core
584.6	585.1	307	584.85	Core
590.4	590.8	308	590.6	Core
603.8	604.3	310	604.05	Core
607.5	607.8	311	607.65	Core
607.8	608.3	312	608.05	Core
613.8	614.1	98-05	613.95	Core
621.3	621.8	98-06	621.55	Core
626.5	626.8	98-07	626.65	Core
630.5	631	98-08	630.75	Core
631	631.5	98-09	631.25	Core
635	635.5	98-10	635.25	Core
636.2	636.7	98-11	636.45	Core
640.5	641	98-12	640.75	Core
644.2	644.6	98-13	644.4	Core
650	650.5	98-16	650.25	Core
654.5	654.9	98-17	654.7	Core
660.1	660.6	98-18	660.35	Core
664.8	665.3	98-19	665.05	Core
669.9	670.4	98-20	670.15	Core
673.1	673.6	98-21	673.35	Core
678.4	678.8	98-22	678.6	Core
685.1	685.6	98-23	685.35	Core
688.6	689	98-24	688.8	Core
691.7	692.2	98-25	691.95	Core

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