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THIS FORM IS SUBJECT TO CHANGE. CONTACT THE RPF FOR LATEST VERSION. (JUNE 1997)

52

Los Alamos National Laboratory

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Date: September 16, 1998
Refer to: EM/ER:98-352

Mr. Ted Taylor
US Department of Energy
Los Alamos Area Office, MS A316
Los Alamos, NM 87545

SUBJECT: INTERIM WELL COMPLETION REPORT FOR REGIONAL WELL R-12 TO FULFILL PM FOR FUNCTIONAL AREA A.4

Dear Ted:

Enclosed are two copies of the Interim Well Completion Report for Regional Well R-12. The interim report is complete and submitted to Department of Energy Los Alamos Area Office (DOE-LAAO) in satisfaction of Appendix F Performance Measures approved by DOE-LAAO on April 3, 1998, and revised May 14, 1998.

This report partially fulfills requirements for Functional Area A.4, Canyons Work Performed in FY98 (Enclosure 1), which requires submittal of the document to DOE-LAAO for review and acceptance. This document contributes towards meeting the "outstanding" level of performance for FY98.

Please note that credit for completion of the deep wells will be given when the wells are completed and a well completion report (or interim well completion report) has been submitted to and accepted by DOE-LAAO. Approval to submit an interim well completion report was obtained verbally during a Groundwater Integration Team meeting with DOE personnel. This Environmental Restoration (ER) Project Well Completion Report is in accordance with all ER procedures and report outline guidance (EM/ER:98-269).

Received by ER-RPF
SEP 17 1998

Please document DOE's approval of the interim well completion report approach along with your acceptance and approval of the deliverable within ten working days of receipt of document, as required by the performance measures. If you have any questions or comments, please contact Allyn Pratt 667-4308.

Sincerely,

Julie A. Canepa

Julie A. Canepa, Program Manager
Environmental Restoration Project

JC/DB/se
Enclosure(s): (1) A.4 Canyons Work Performed in FY98
(2) Two copies of the Interim Well Completion Report for Regional Well R-12

Cy: (w/enc.):
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A. Pratt, EES-13, MS M992
RPF, MS M707, Record Package 306

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LA-UR-98-3976
September 1998

Interim Completion Report for Characterization Well R-12

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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Functional Area A.4. Canyons work performed in FY98. Weight 15%

Unsatisfactory Perform less than the requirements identified to achieve a rating of "marginal."

Marginal Conduct sampling in 7 reaches of canyons, complete installation of 3 alluvial aquifer wells, complete drilling on deep well R-9, and start drilling of deep well R-12 in FY98.

Good Conduct sampling and submit a Reaches report to DOE-LAAO on 9 reaches of canyons by September 30, 1998, complete installation of 5 alluvial aquifer wells, submit the Pajarito Canyon work plan to DOE-LAAO by September 16, 1998, and complete the drilling of deep wells R-9 and R-12 in FY98.

Excellent Conduct sampling and submit a report to DOE-LAAO on 9 reaches of canyons, begin the first phase of sampling on 3 additional reaches, complete the installation of 8 alluvial aquifer wells, submit the Pajarito Canyon work plan to DOE-LAAO by August 17, 1998, and complete the drilling deep wells R-9 and R-12 in FY98.

Outstanding Conduct sampling and submit a report to DOE-LAAO on 9 reaches of canyons, begin the first phase of sampling on 5 additional reaches, complete the installation of 10 alluvial aquifer wells, submit the Pajarito Canyon work plan to DOE-LAAO by July 17, 1998, complete the drilling of deep wells R-9 and R-12, and start (as defined by breaking ground) drilling deep well R-7 or another well as recommended by the Groundwater Integration Team and approved by UC and LAAO in FY98.

Assumptions

1. The format for the reports submitted in FY98 for will follow the RFI Report Framework or other guidance as mutually agreed upon and documented by UC and DOE-LAAO.

2. Credit for completion of the canyons sampling will be obtained when the final Reaches report(s) is (are) submitted to and accepted by DOE-LAAO. Credit for the first phase of sampling will be considered when the sampling is started and a memo documenting the start date is transmitted to DOE-LAAO. Credit for installation of the alluvial aquifer wells will be considered when the wells are completed and a well completion report has been submitted to and accepted by DOE-LAAO. Credit for completion of the Pajarito Canyon work plan will be upon submittal of the work plan to DOE-LAAO. Credit for completion of the deep wells will be when the wells are completed and a well completion report (or interim well completion report if the well is not to be completed, upon approval by DOE) has been submitted to and accepted by (following General Assumption 5) DOE-LAAO.

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ABSTRACT

Characterization well R-12, located in Sandia Canyon near the eastern boundary of Los Alamos National Laboratory ("the Laboratory"), is the second of approximately 32 wells being installed in the regional aquifer as part of the Laboratory's *Hydrogeologic Workplan* (LANL 1996, 55430). R-12 was funded 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. R-12 is downgradient of multiple contaminant source areas that potentially include release sites in the upper Sandia Canyon, Los Alamos Canyon, and Mortandad Canyon watersheds. R-12 is also sited to provide early warning for contaminants approaching water supply well PM-1 and to provide hydrologic and geologic data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory.

R-12 was drilled to a total depth of 847 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-12 included alluvium, tephras and volcaniclastic sediments of the Cerro Toledo interval, Otowi Member of the Bandelier Tuff, basaltic rocks of the Cerros del Rio volcanic field, old alluvium, Puye Formation, and basaltic rocks of the Santa Fe Group.

A perched groundwater system was encountered from depths of 443 to 519 ft in the lower part of the Cerros del Rio basalt and in underlying old alluvium. Groundwater in this zone was confined and the water level stabilized at a depth of 424 ft after the top of the zone was penetrated. The confining layer at the top of this zone apparently is massive basalt, and the lower perching layer is a clay-rich lacustrine deposit. The saturated thickness of this groundwater body is approximately 75 ft, making it one of the thickest intermediate-depth perched groundwater bodies identified yet on the Pajarito Plateau.

The regional water table was encountered at a depth of 805 ft in fractured basalt of the Santa Fe Group. The water is unconfined and occurs at the same elevation as at R-9, located approximately 1 km to the north. The elevation of the water table in R-12 is approximately 62 ft lower than the static water level in nearby supply well PM-1 under nonpumping conditions.

Groundwater samples were collected from the perched zone at depths of 443, 464, and 495 ft. These samples were chemically characterized with respect to major ions, trace elements, dissolved organic carbon (DOC), 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 compositions are similar for the samples collected at depths of 443 and 495 ft, but the groundwater sampled at 464 ft has a distinctive chemistry.

Groundwater from the perched zone is dominantly a calcium-sodium-bicarbonate-chloride type as represented by the samples collected at depths of 443 and 495 ft. There is also a sodium-calcium-chloride-sulfate-bicarbonate groundwater at a depth of 464 ft. Groundwater from the depths of 443 and 495 ft was found to contain 249.3 to 254.7 pCi/L tritium (analysis by low-level electrolytic enrichment), 31.5 to 33.4 parts per million (ppm) chloride, <0.02 to 0.26 ppm ammonium, 4.9 to 5.5 ppm nitrate, and 2.46 to 2.51 parts per billion (ppb) uranium. Groundwater from the depth of 464 ft was found to contain 208.1 pCi/L tritium, 200 ppm chloride, 13.5 ppm ammonium, 0.21 ppm nitrate, and 2.04 ppb uranium.

Groundwater at the top of the regional saturated zone is a calcium-sodium-bicarbonate type with a total dissolved solids (TDS) content of 386 ppm. The major cation and anion chemistry of this water is similar to groundwater in supply wells PM-1 and PM-3. Measurable tritium activity in the regional saturated zone (46.9 pCi/L) suggests that a component of the groundwater is less than 50 years old.

1.0 INTRODUCTION

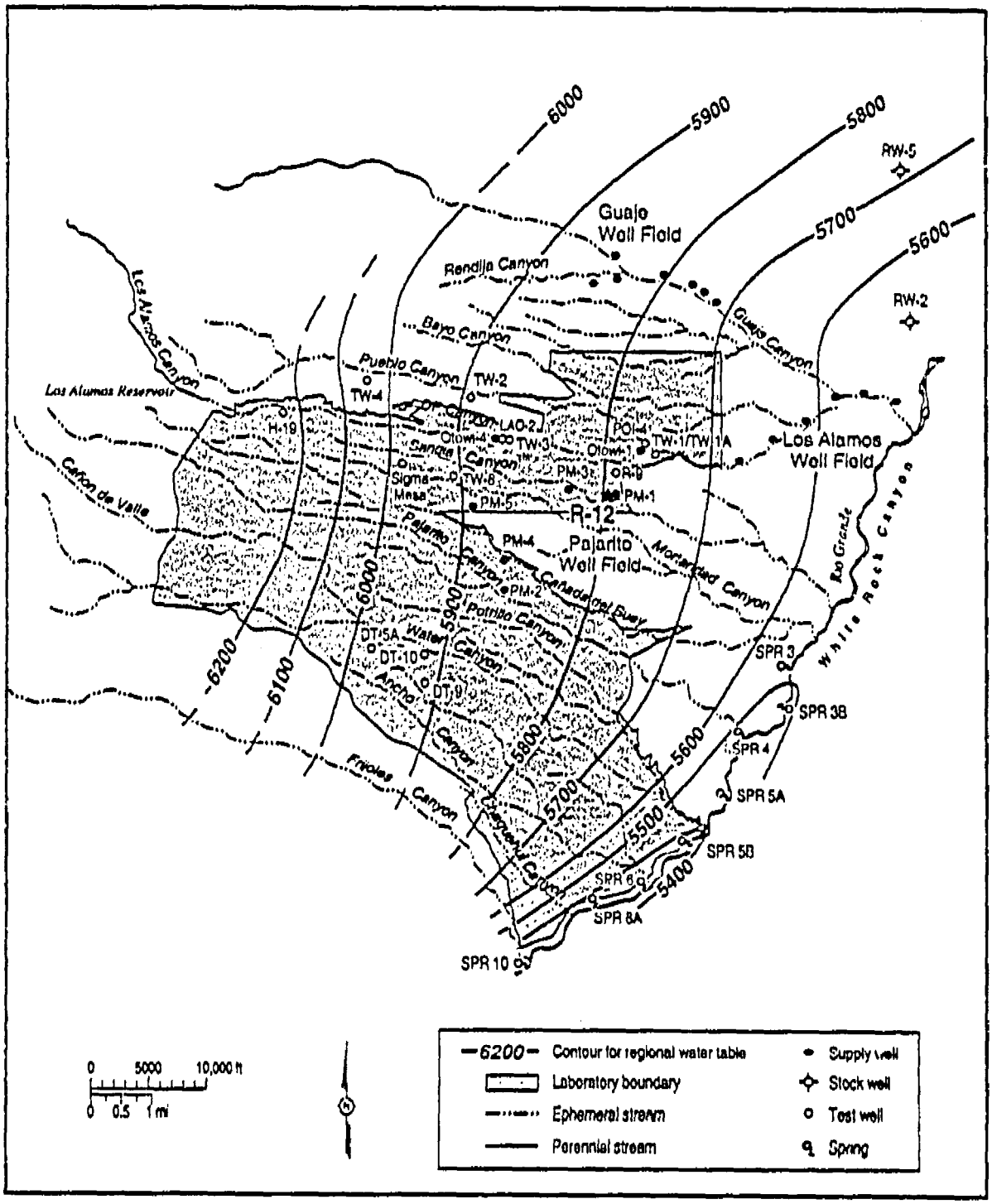
This interim report describes the drilling, construction, temporary completion, and testing activities for characterization well R-12. R-12 is located in Sandia Canyon at the eastern Laboratory boundary (Figure 1-1) west of state road NM 4 and north of East Jemez Road. This well was installed by personnel from the Canyons Focus Area of the ER Project. It is the second 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).

R-12 is primarily designed to provide water quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of contaminant release sites in the upper Sandia Canyon, Los Alamos Canyon, and Mortandad Canyon watersheds. R-12 is also sited to provide early warning of contaminants approaching supply well PM-1 (Figure 1-1) and to provide hydrologic and geologic data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory. Data collected from R-12 will be used in conjunction with data from other planned characterization boreholes as well as from other data sources to evaluate and update the site-wide hydrologic conceptual model.

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* wells. A future report will provide an integrated human health and ecological risk assessment and will include groundwater data from other nearby ER Project wells. 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-12 is located 14.9 ft west of drill hole SCOI-3. SCOI-3 was completed to a depth of 132.5 ft before operations were temporarily suspended because of a lack of funds to complete the hole. SCOI-3 was specified in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* ("the work plan"; LANL 1995, 50290) as an intermediate-depth well, and its original intent was to sample perched groundwater identified at a depth of 450 ft during installation of water supply well PM-1 in 1964 (Cooper et al. 1965, 8582). The purpose of SCOI-3 was reevaluated during development of the Laboratory's *Hydrogeologic Workplan* (LANL 1996, 55430), and it was decided that a single well designed to characterize perched zones and the regional aquifer was needed at this location. This new well was named R-12 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). Instead of deepening SCOI-3, R-12 was started as a new well so that larger casing sizes could be used to ensure that a well of adequate diameter could be installed in the regional aquifer.

Although R-12 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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R1-1 / R-12 WELL COMPLETION RPT / 090698

Figure 1-1. Location of R-12, existing water supply wells and test wells, and generalized water-level contours for the regional water table.

2.0 SUMMARY OF DRILLING ACTIVITIES

R-12 drilling was halted at a depth of 847 ft, and a temporary characterization well was installed. Completion of a permanent well will take place when ongoing evaluations of combined data for R-9 and R-12 are completed by the Canyons Focus Area technical team and the Groundwater Integration Team and after a final completion strategy is approved by the regulators. Therefore, this section summarizes drilling activities that have occurred to date, and it will be revised when the permanent well is installed.

2.1 Equipment

R-12 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 134-mm core system and 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, Hermit data logger, depth-to-water meter, water sampling bailers, pressure transducers, 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 Geology and Geochemistry group (EES-1) and the FSF provided core logging microscopes.

2.2 Schedule

The T-4 drill rig was mobilized to R-12 on March 10, 1998, and it was demobilized on June 8, 1998. Drilling operations required 63 drilling shifts. The following table compares the actual number of shifts with the number of shifts projected for R-12 in planning documents.

	Conceptual Design Report	Field Implementation Plan	Actual
Number of shifts	40	79	63

Drilling shifts averaged 12 hours each, depending on production needs. Chronological operations for R-12 are summarized in Appendix A.

2.3 Production

Drilling techniques used in R-12 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 847 ft, the total footage drilled by the different drilling techniques and casing sizes was 1050.6 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 17,535.5 ft, and the total trip-out footage was 15,366 ft.

TABLE 2.3-1

PRELIMINARY PERFORMANCE STATISTICS[a]
CHARACTERIZATION WELL R-12

Drilling Types	Open Hole	Core	8-5/8-in. Casing[b]	10-3/4-in. Casing[c]	12-3/4-in. Casing[c]	14-in. Casing[d]	16-in. Casing	Casing Advance System (4-1/2-in. rods)[b]	Casing Advance System (7-in. rods)[c,d]	Total (ft)[e]
Total footage drilled (ft)	142	91.6	319	22.5	38	430	20	0	0	1,050.6
Total footage rate (ft/hr)[f]	9.9	3.9	9.9	12.3	1.9	3.5	NA			
Basalt[g] footage (ft)	122	21.3	48	0	38	319	0	0	0	527
Basalt[g] rate (ft/hr)[f]	16.3	1.5	8.3	0	1.9	3.0	0			0
Puye[h] clastics footage (ft)	0	69.8	271	22.5	0	0	0	0	0	293.5
Puye[h] clastics rate (ft/hr)[f]	0	7.3	10.2	12.3	0	0	0			0
Otowi Member[i] footage (ft)	0	0	0	0	0	111	20			131
Otowi Member[i] rate (ft/hr)[f]	0	0	0	0	0	6.8				
Trip-in footage (ft)	0	5665.5	300	480	448	20	0	6259	4143	17,535.5
Trip-in rate (ft/hr)[f]	0	356	138.5	71.1	45.9		0	286.7	269.6	0
Trip-out footage (ft)	0	5470	50	0	464	0	0	5222	4160	15,366
Trip-out rate (ft/hr)[f]	0	318	22.2	0	309.3	0		569.7	272.8	0
Pull back footage (ft)	0	0	126.5	0	0	0	0	0	0	126.5
Pull back rate (ft/hr)[f]			17.7		0	0	0	0	0	0
Temporary seal (#)										
Mill shoe[j] (number)						2				
Mill shoe (total hrs)						15.7				
Life-of-hole casing TD (ft)			790	520.5	0	449	20			

a. Most performance statistics are complete as of the date of this report. However, R-12 may be deepened and trip out footage and rates do not include withdrawal of casings in ground.
b. Stratex 6-5/8-in. and 8-5/8-in. casing advance systems use 4-1/2-in. reverse circulation (RC) rods.
c. Stratex 10-3/4-in. and 12-33/4-in. casing advance systems use 7-in. RC rods.
d. Hole 14-in casing advance system used 7-in. RC rods.
e. Total depth (TD) of borehole is 847 ft. Total cored footage (91.6 ft) is 10.8% of total borehole footage (847 ft).
f. Rates are weighted averages over footages drilled or tripped, including breaks but excluding repairs and change out of tools.
g. Basalt footage and rates include Cerros del Rio basalt and Santa Fe Group basalt.
h. Puye footage and rates include old alluvium.
i. Otowi Member footage and rates include Cerro Toledo.
j. Milling bits for 14-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).

2.3.1 Open Borehole Drilling

Open borehole drilling was 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 16.3 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.

2.3.2 Core Drilling

Core was collected in R-12 to provide undisturbed samples for geological, contaminant, and hydrological characterization. In addition, core was used to identify perching layers beneath perched groundwater and to provide information for placing casing seals. Core was not collected from the land surface to a depth of 132.5 ft because this interval was continuously cored during drilling of SCOI-3. The SCOI-3 core is archived at the FSF. In R-12, Tonto cored a total of 91.6 ft, or 10.8% of the 847 ft depth. The following table compares the actual core production at this location (includes SCOI-3 core) with the projected core production in planning documents.

	Conceptual Design Report	Hydrogeologic Workplan	Field Implementation Plan	Actual
% Core	100%	100%	50%	26.5%*
*Includes core collected in SCOI-3				

In R-12, average core recovery was 72.6% from all cored intervals. Of the 91.6 ft cored, 21.3 ft were produced from basaltic rocks at an average rate of 1.5 ft per hour and average recovery of 72%; 69.8 ft were produced from sedimentary rocks at an average rate of 7.3 ft per hour and average recovery of 82%.

Coring operations in R-12 were performed with a Longyear 134-mm coring system. A 101-mm coring system was used during drilling of R-9 but was found to lack the strength and stability for coring through large-diameter casing sizes. Unfortunately, the new 134-mm system used in R-12 provided poor performance because of repeated failure in the latching system. The poor performance of this coring system reduced the amount of core collected in R-12. The coring system was returned to the manufacturer for modifications to the latching system, and performance of this system should improve in future boreholes.

2.3.3 Casing Advancement

After the 16-in.-diameter surface casing was installed, multiple telescoped casing strings were installed to advance the borehole and 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 casing), 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.

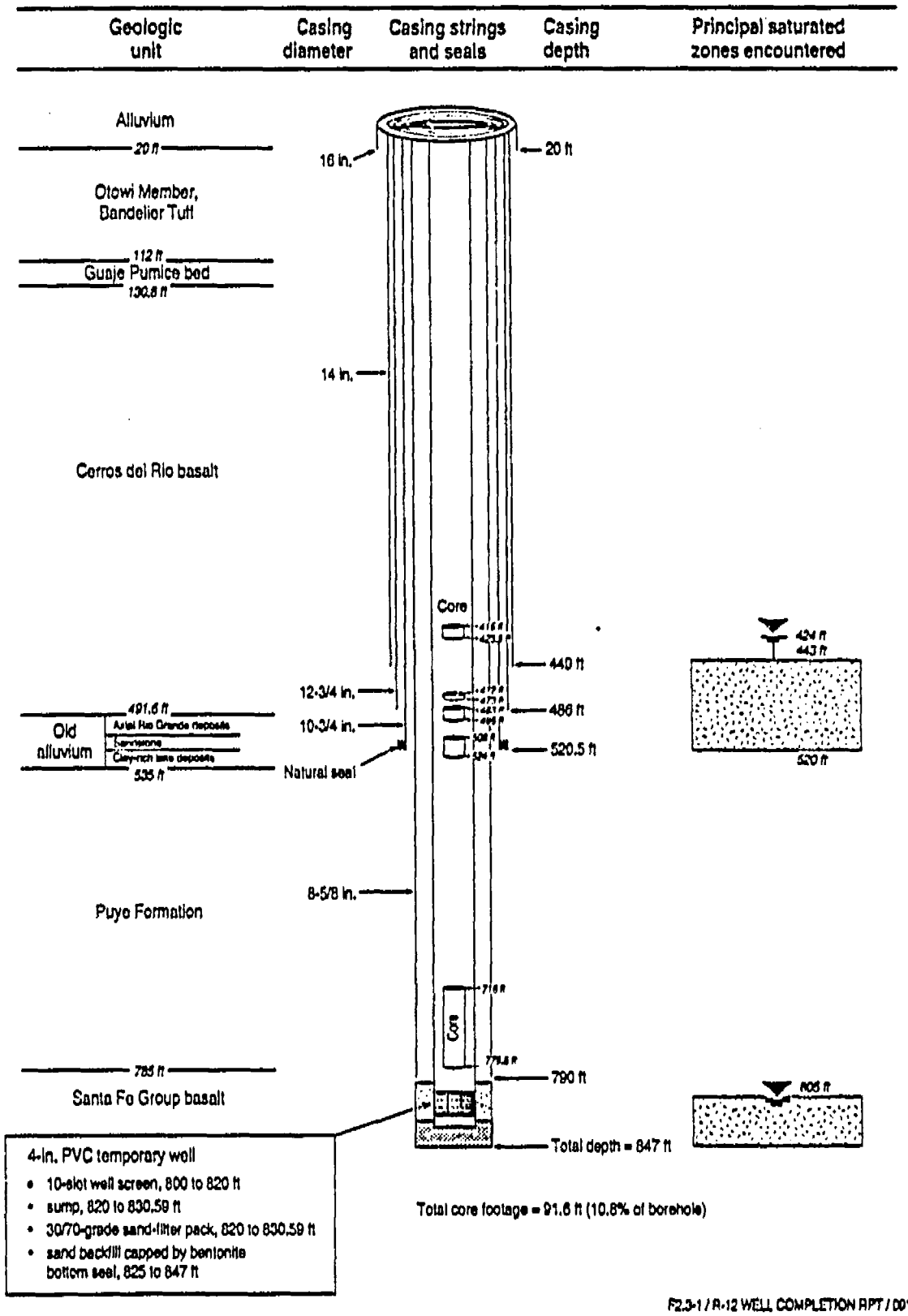

Figure 2.3-1. Configuration of R-12 as of June 10, 1998.

2.3.4 Other Drilling Activities

Other drilling activities included milling the casing shoes and reaming the borehole. These activities also included operations to clean clay cake from drill bits, casing, and air-circulation equipment during drilling of clay-rich rock units.

3.0 STRATIGRAPHY/LITHOLOGY

Geologic units encountered in R-12 consisted of, in descending order, alluvium, tephras and volcaniclastic sediments of the Cerro Toledo interval, Otowi Member of the Bandelier Tuff, late Pliocene soil, basaltic rocks of the Cerros del Rio volcanic field, old alluvium, the Puye Formation, and basaltic rocks of the Santa Fe Group. A brief summary of unit characteristics is given in the following sections, and a lithologic log is provided in Appendix B. An interpretive north-south cross section based on R-9 and R-12 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 a depth of approximately 12.5 ft (Appendix B). The alluvium is pumiceous, and contains abundant 1- to 2-mm crystals of quartz and chatoyant sanidine derived from exposures of the Bandelier Tuff up-canyon.

3.2 Tephras and Volcaniclastic Sediments of the Cerro Toledo Interval

Reworked tuff of the Pleistocene Cerro Toledo interval was encountered from depths of 12.5 to 31.3 ft (Appendix B). This unit is massive and brown, and it contains small, white, vitric pumicec. A basal 2-ft zone contains abundant clasts of dark, intermediate-composition lava, which were probably derived from the Tschicoma Formation. A 1-ft-thick, pumice-rich zone overlies this clast-rich zone.

3.3 Otowi Member of the Bandelier Tuff

Tuffs of the Pleistocene Otowi Member, including the basal Guaje Pumice Bed, were encountered between the depths of 31.3 and 131 ft. The main body of the Otowi Member consists of poorly consolidated, vitric, nonwelded ash-flow tuff. The ash-flow tuff is massive but probably includes multiple ash-flow deposits based on recognizable depositional breaks within this unit in nearby surface exposures. The Guaje Pumice Bed occurs from 112 to 131 ft and includes a vitric, fines-depleted pumice fall from 112 to 117 ft.

3.4 Late Pliocene Soil

Thin Late Pliocene soil overlies basaltic rocks of the Cerros del Rio volcanic field from a depth of 131 to 132.5 ft. The soil consists of oxidized, fine-grained sand that contains rock fragments derived from the underlying Cerros del Rio basalt (Appendix B). This soil is probably correlative with the thin soil that overlies the Cerros del Rio basalt in the road cut along state road NM 502, near the junction of Los Alamos Canyon and Pueblo Canyon, 1.8 km northeast of R-12.

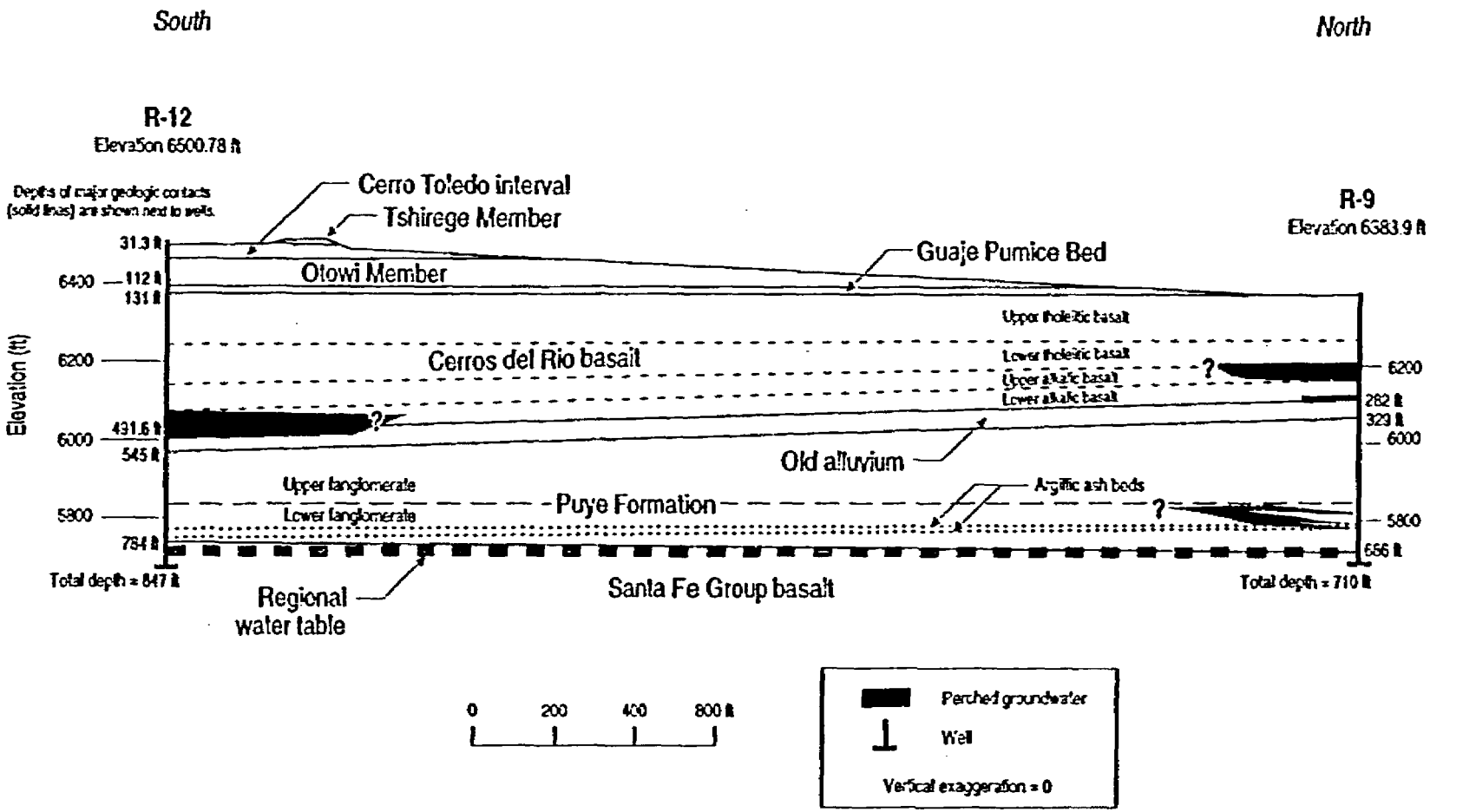

Figure 3-1. North-south cross section showing correlation of geologic units and occurrences of groundwater in R-9 and R-12.

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3.5 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 132.5 to 491.6 ft (Appendix B). These rocks consist of vesicular to massive basalt flows, thin zones of basaltic breccia, paleosols, and a thin basal layer of basaltic tephra. Four flow units are distinguished by their textural characteristics or by the recognition of vesicular zones that overlie or underlie massive flow interiors. These flow units are tentatively correlated with four flow units in R-9 and consist of, in descending order, an upper tholeiitic flow, a lower tholeiitic flow, an upper alkalic flow, and a lower alkalic flow (Table 3.5-1; Figure 3-1). In R-12, the upper tholeiitic flow unit consists of two texturally distinct flows. Additional work is underway to confirm these correlations by characterizing the petrography and chemistry of the R-12 basalts.

TABLE 3.5-1

PRELIMINARY CORRELATION OF BASALT FLOW UNITS BETWEEN R-12 AND R-9*

Flow Unit	R-12					R-9				
	Depth		Elevation		Thickness	Depth		Elevation		Thickness
	Top	Base	Top	Base		Top	Base	Top	Base	
Upper tholeiite flow	132.5	260.5	6368	6240	128	10	118.5	6374	6266	108.5
Lower tholeiite flow	260.5	342.3	6240	6158	81.8	118.5	180	6266	6204	61.5
Upper alkalic flow	342.3	425	6158	6076	82.7	180	206	6204	6178	26
Lower alkalic flow	425	488.9	6076	6012	63.9	206	282	6178	6102	76
Lower alkalic tephra	488.9	491.6	6012	6009	2.7	282	289.8	6102	6094	7.75
Miocene flow	784	>847	5717		>63	686.4	>710	5697		>23.6

*All data are expressed in feet.

In R-12, flow unit boundaries are characterized by the presence of abundant clay. These clays, which give rise to sharply higher moisture contents (see Section 5.3), occupy vesicles and fractures at the tops and bottoms of basalt units. The upper alkalic flow and the lower alkalic flow in R-12 are separated by a paleosol that occurs between the depths of 411 and 419.2 ft. In contrast, flow unit boundaries in R-9 were generally difficult to recognize because clay or other secondary minerals were not associated with some of the contacts.

The age of the Cerros del Rio basalts in R-12 has not been determined. However, in R-9 the upper tholeiitic flow unit has an age of 2.15 Ma, and the lower alkalic flow has an age of 2.45 Ma (see Table 3.2-1 in Broxton et al. 1998, 59158).

Basaltic tephra occurs between the depths of 488.9 and 491.6 ft (Appendix B). The tephra is a hydrovolcanic unit characterized by well stratified fine-grained to coarse-grained deposits made up of basaltic glass. These tephras were considered part of the old alluvium by Griggs (1964, 8795) but are included with basalt of the Cerros del Rio volcanic field in this report. A tephra at the same stratigraphic position in R-9 is chemically related to the overlying lower alkalic flow unit. The tephras in R-9 and R-12 are probably correlative, although the tephra in R-9 is nearly three times thicker (7.5 ft) than that encountered in R-12 (2.7 ft).

3.6 Old Alluvium

Pliocene old alluvium occurs from depths of 491.6 to 545 ft (Appendix B). 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 during the Late Pliocene before emplacement of the Bandelier Tuff. Old alluvium at R-12 is subdivided into three distinct subunits: an upper conglomerate, a middle claystone, and a basal sandstone.

The conglomerate subunit occurs between the depths of 491.6 and 519.1 ft. This unit is dominated by a distinctive conglomerate deposit between the depths of 495 to 509 ft that is sandwiched between unconsolidated silt and sand at the top (491.6 to 495 ft) and at the base (509 to 519.1 ft). The conglomerate contains rounded gravel up to 37 mm diameter in a sandy matrix. Cobbles in the upper part of the conglomerate are mostly of volcanic origin, but in its lower part the cobbles are dominated by gneiss and quartzite. The presence of large rounded clasts of nonvolcanic origin establishes that the conglomerate subunit is an axial deposit of the late Pliocene Rio Grande. These ancestral Rio Grande deposits are much younger than those usually assigned to the Totavi lentil of the Puye Formation but are similar in origin.

The middle claystone subunit occurs between the depths of 519.1 and 535.5 ft and consists of massive yellow brown claystone, with fine sandy to silty claystone in its upper part. These deposits are interpreted as lake beds and serve as the perching layer for perched groundwater in the Cerros del Rio basalt and the conglomerate subunit of the old alluvium (see Section 4.1).

The lower sandstone subunit occurs between the depths of 535.5 and 545 ft and consists of gravelly sandstone. It is lithologically similar to the underlying fanglomerate facies of the Puye Formation except that basalt clasts are prominent within the lower sandstone subunit. Basalt clasts are virtually absent within the fanglomerate facies of the Puye Formation, particularly within the upper part. Old alluvium deposits at R-9 are similar to the lower sandstone unit of R-12.

3.7 Puye Formation (Fanglomerate Facies)

The Pliocene fanglomerate facies of the Puye Formation extends from the depths of 545 to 784 ft (Appendix B) and consists of coarse, pumiceous, volcaniclastic sediments as described by Waresback (1986, 58715). Pumice clasts in the upper half of the unit are vitric (glassy), whereas pumices in the lower half are generally altered to clay (argillized). This is similar to the alteration pattern for the Puye Formation in R-9 (Figure 3-1).

From depths of 545 to 666 ft, the Puye Formation consists of poorly-consolidated sand, pebbly sand, and gravel (Appendix B) derived from volcanic rocks of the Tschicoma Formation. Many volcanic clasts within this interval are vitric. Most of the clasts in this upper part of the fanglomerate were derived from a distinctive rhyodacite within the Tschicoma Formation exposed in the upper part of Rendija Canyon.

From depths of 666 to 784 ft, the Puye Formation consists of consolidated sandstone, pebbly sandstone, and conglomerate characterized by abundant pumice clasts. Pumice clasts in this interval are generally altered to clay (Appendix B), although vitric pumices are occasionally present. Clasts of devitrified dacitic rocks within these lower fanglomerate deposits were derived from Tschicoma sources other than upper Rendija Canyon. Two beds of argillic volcanic ash occur at depths of 726.2 and 746.1 ft. Similar argillic ash beds were encountered in the lower part of the Puye Formation in R-9 (Table 3.7-1; Figure 3-1).

The upper part of the Puye Formation (above 666 ft) generally contains thicker and coarser gravel deposits than those of the lower part of the formation. The upper Puye Formation is also much less pumiceous and is generally unconsolidated because of its lack of argillic alteration.

TABLE 3.7-1

CORRELATION OF CONTACTS WITHIN THE PUYE FORMATION FOR R-12 AND R-9*

	R-12					R-9				
	Depth		Elevation			Depth		Elevation		
Puye Formation	Top	Base	Top	Base	Thickness	Top	Base	Top	Base	Thickness
Upper fanglomerate	545	666	5956	5835	121	329	539	6055	5845	210
Lower fanglomerate	666	784	5835	5717	118	539	686.4	5845	5697	147.4
Upper tephra	726.2	726.4	5774.6	5774.4	0.2	595.1	595.25	5788.9	5789	0.15
Lower tephra	746.1	746.4	5754.7	5754.4	0.3	606.2	607.2	5778	5779	1.0

*All data are expressed in feet.

The Puye Formation is significantly thinner in R-12 (239 ft thick) than in R-9 (357 ft thick). Contacts within the Puye Formation differ in elevation by 10 to 23 ft between the two wells (Table 3.7-1), and the apparent southerly dip of these contacts is less than 0.5° (Figure 3-1). The correlations established between the upper and lower Puye Formation in both wells demonstrates that these subunits can probably be mapped regionally.

3.8 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.

3.9 Santa Fe Group Basalt

Miocene Santa Fe Group basalt occurs from depths of 784 ft to greater than 847 ft (total depth). This basalt is slightly vesicular, with clay filling some vesicles below 830 ft. This basalt correlates with a tholeiitic basalt at the same stratigraphic position in R-9 (Table 3.5-1) that has a minimum eruption age of 8.45 to 8.63 Ma (see Table 3.2-1 in Broxton et al. 1998, 59158). This basalt is the same as that encountered at a depth of 836 ft in water supply well PM-1 (Cooper et al. 1965, 8582).

4.0 OCCURRENCES OF GROUNDWATER

Two saturated zones were encountered during R-12 drilling operations. The tops of these two well-defined saturated zones occurred at depths of 443 and 805 ft. The upper of these two zones is a perched groundwater zone, and the lower is associated with the regional aquifer. Figure 2.3-1 summarizes the occurrences of these saturated zones.

4.1 Perched Zone(s)

A thick perched zone was encountered from a depth of 443 to 519 ft in the lower part of the basaltic rocks of the Cerros del Rio volcanic field and in the underlying old alluvium (Figure 4.1-1). This perched zone was first recognized in 1964 during the installation of water supply well PM-1 (Cooper et al. 1965, 8582), although its vertical extent was not specified. Based on this investigation, the saturated thickness of this groundwater body is approximately 75 ft, making it one of the thickest intermediate-depth perched groundwater bodies identified yet on the Pajarito Plateau. Water was first encountered at a depth of 443 ft, and the water level quickly rose to 424 ft after the top of the water-bearing zone was penetrated. These conditions indicate that the perched zone is relatively permeable and confined. The confining layer at the top of the perched zone is probably massive basalt with few fractures. The claystone subunit of the old alluvium forms the perching layer.

The basalt flows making up the upper part (443 to 488.9 ft) of the perched zone are typically fractured and yielded water rapidly to the borehole. Interspersed within the saturated zone, thin zones of massive unfractured basalt typically yielded dry core or cuttings, but the borehole always produced significant water when deeper, fractured basalts were penetrated. Bentonite seals were placed several times in dry, unfractured, massive basalts in the belief that the bottom of the perched zone had been reached. However, water quickly filled the borehole to a static water level of 424 ft each time new fractured basalts were encountered. These relations suggest that all the groundwater in these basalts is part of a single perched zone in which the water-producing materials are connected by fractures (Figure 4.1-1). The dry, unfractured, massive basalts within the water-producing zones probably represent regions of low permeability that are crossed by fractures outside the volume of the borehole. The basaltic tephra (488.9 to 491.6 ft), which acts as a perching layer for groundwater in R-9, is saturated in R-12.

The lower part of the perched zone (491.6 to 519 ft) occurs within the sand and silt deposits and the axial Rio Grande gravels of the upper subunit of the old alluvium. Perched water in these sedimentary deposits have a static water level of 424 ft, indicating that they are hydraulically connected with groundwater in the overlying basalts.

A seal to isolate the perched zone from the rest of the borehole was created by driving the 10-3/4-in.-diameter casing into the top of the lacustrine deposits at a depth of 519 ft. This natural clay seal prevented downward migration of water to potential deeper perched water zones and the regional aquifer and allowed representative water samples to be collected from deeper zones.

Core with a high moisture content was encountered in clay-rich, tuffaceous, sedimentary rocks in the lower part of the Puye Formation. The moist core was returned from depths of 736 to 741 ft, but at the end of the drilling day no measurable water was present at a depth of 741 ft. However, a downhole moisture probe indicated the presence of moisture at a depth of 733.80 ft after the borehole rested overnight. Collection of a water sample was not attempted in the belief that the regional aquifer had been reached based on projections from supply well PM-1 (projected depth to the regional water table was 740 ft) and that further opportunities for sampling would be available as the borehole was deepened to accommodate a bailer. However, the borehole failed to yield water as drilling progressed, and no water sample was obtained. Based on information currently available, it cannot be determined whether saturated conditions are present in the clay-rich materials in the lower Puye Formation or if an erroneous indication of saturation occurred when the tip of the moisture probe became embedded in formational units and indicated the presence of moist clays. Furthermore, absence of saturation at a depth of 741 ft is suggested by the lack of water circulating out of the hole when the air circulation system was started and as drilling operations proceeded beyond 741 ft.

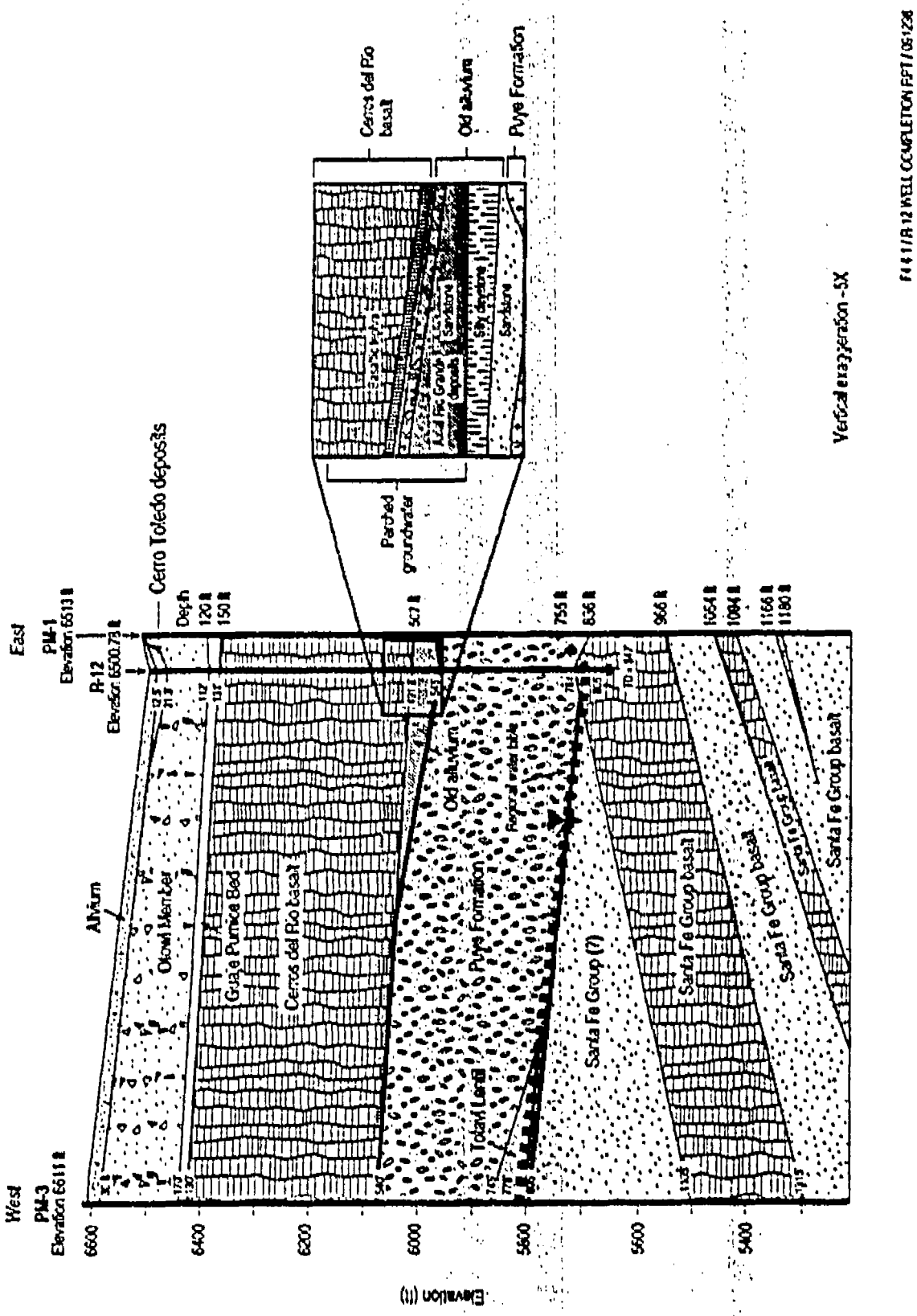


Figure 4.1-1. East-west cross section showing geologic relationships and groundwater occurrences in lower Sandia Canyon.

4.2 Regional Aquifer

The regional water table was encountered at a depth of 805 ft (elevation 5696 ft) in fractured basalt of the Santa Fe Group. Groundwater at the top of the regional saturated zone is unconfined, and the static water level occurs at the same elevation as that encountered in well R-9 (elevation 5696 ft). This saturated zone is believed to represent the regional aquifer because its water quality is similar to that found in nearby supply wells PM-1 and PM-3, and in test well TW-3. In addition, the elevation at the top of this zone is lower than static water levels (under nonpumping conditions) in wells PM-1 (5758 ft) and Otowi-1 (5724 ft), and it is lower than the elevation predicted based on the regional water table map (5795 ft) (Figure 1-1).

The higher static water levels in nearby water supply wells are probably due to their long screen lengths, allowing multiple zones to contribute to a composite hydraulic head. For example, PM-1 is screened over a 1554-ft interval (Cooper et al. 1965, 8582) that starts at a elevation 86 ft below the total depth of R-12. The higher static water levels for the supply wells suggest that higher head zones occur in the regional aquifer at depths greater than those penetrated by R-12 and R-9. The regional aquifer may have upward hydraulic gradients in this part of the Pajarito Plateau.

The potential for upward hydraulic gradients in the regional aquifer is an important issue for the final design and completion of R-12 and R-9. Both characterization wells were designed to determine the impact of Laboratory operations on the quality of regional groundwater downgradient from multiple potential release sites. Because these wells are located at the eastern Laboratory boundary, they should be completed in a manner that would allow their use as components of a potential monitoring system designed to determine the quality of regional groundwater leaving the Laboratory. In addition, one of the goals of R-12 was to provide early warning of contaminants approaching water supply well PM-1.

In the case of R-9, the goal of monitoring groundwater leaving the Laboratory could be satisfied by a well with a single screen located in the uppermost part of the regional saturated zone where contaminants are probably most concentrated. For R-12, the possible completion design is more complex because of the objectives of monitoring contaminants leaving the Laboratory and providing early warning for PM-1. To provide early warning, well screen(s) should be placed within one or more transmissive zones contributing to water production. However, in an area of upward gradients, screen intervals below the water table may not detect contaminants impacting the top of the regional saturated zone. Discussions are currently underway among the Canyons Focus Area technical team, the Groundwater Integration Team, and regulators to reassess the completion details for R-12 and R-9 based on new findings from this investigation.

5.0 SAMPLING AND ANALYSIS

Discharges within Sandia Canyon and Mortandad Canyon may have impacted water quality at R-12. Contaminants of concern in Sandia Canyon include tritium and nitrate (Environmental Surveillance and Compliance Programs 1997, 56684). For several decades treated sewage has been discharged from the Technical Area (TA) -3 sanitary system into upper Sandia Canyon. Surface water samples collected in upper Sandia Canyon suggest that this discharge may have contained tritium until the early 1980s (Rogers 1998, 59169). Tritium activities up to 18,000 pCi/L have been observed at surface water sampling station SCS-2 (Rogers 1998, 59169).

Known groundwater contaminants within Mortandad Canyon west of R-12 include americium-241; cesium-137; plutonium-138; plutonium-239,240; strontium-90; tritium; uranium-235; uranium-238; and other inorganic solutes (Environmental Surveillance and Compliance Programs 1997, 56684; Rogers 1998, 59169; LANL 1997, 56684). Tritium activities up to 1,000,000 pCi/L have been observed in alluvial groundwater within Mortandad Canyon in the past.

Known groundwater contaminants 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 Contaminant Characterization of Core and Cuttings

Samples of core and cuttings were collected from R-12 and analyzed for metals and radionuclides as required by the Resource Conservation and Recovery Act (RCRA). Results of chemical and radiochemical analyses are used to determine both naturally-occurring elements and contaminant distributions within R-12. Organic compounds were not identified as contaminants of concern at R-12, based on sediment and water sampling conducted by the Laboratory in upper Sandia Canyon (Environmental Surveillance and Compliance Programs 1997, 56684).

5.1.1 Methods

Fourteen samples of core and cuttings were collected for geochemical and contaminant characterization. Ten samples of cuttings were collected from nine depth intervals: 25 to 25.5 ft, 31.5 to 32.5 ft, 122 to 125 ft, 135 to 136 ft, 455 to 456.5 ft, 555 to 559 ft, 791 to 792.5 ft, 800 to 805 ft, 812 to 814.6 ft, and 812 to 814.6 ft (duplicate). Four samples of core were collected from four intervals: 431 to 438 ft, 520 to 521.9 ft, 555 to 559 ft (duplicate), and 567 to 569 ft. Approximately 500 to 1,000 g of core or cuttings samples were placed in appropriate sample jars in protective plastic bags before they were shipped to analytical laboratories.

Samples of core and cuttings were analyzed using analytical methods specified by EPA (1987, 57589). 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 of aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc were determined by inductively coupled plasma emission spectroscopy (ICPES). Concentrations of uranium in core samples were determined by using laser-induced kinetic phosphorimetric analysis (LIKPA). Mercury was analyzed by cold vapor atomic absorption (CVAA). Core samples were washed with deionized water for 16 hours before anion analyses. Bromide, chloride, fluoride, nitrate, and sulfate contents were determined by ion chromatography (IC). Total cyanide content was determined by colorimetry. The precision limits for major anions and trace elements were generally ± 10%.

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 gamma-emitting isotopes); and gas proportional counting (strontium-90) at Paragon Analytics, Inc. Sample duplicates were collected and analyzed in accordance with EPA procedures.

Field screening for volatile organic compounds was conducted using a photoionization detector (PID) instrument. No volatile organic compounds were detected with the field instrument.

5.1.2 Results

Table 5.1-1 provides radionuclide activities in core and cuttings from R-12. Isotopes of uranium (uranium-234, uranium-235, and uranium-238); gross alpha; gross beta; and gross gamma generally are detected at activities greater than their minimum detectable activities (MDAs) in most core samples. Activities of gross alpha, gross beta, and gross gamma in samples of core and cuttings are greater than 1 pCi/g, where measurable, and vary with depth (Table 5.1-1).

Activities of isotopic uranium are greatest in samples collected from the Bandelier Tuff, reflecting the high total uranium in this unit (Ryti et al. 1998, 58093). Lower activities of uranium-234, uranium-235, and uranium-238 were found in samples collected from Cerros del Rio basalt, Puye Formation, and Santa Fe Group basalt. This suggests that little if any Laboratory contaminants are present in these samples.

Activities of americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 generally are less than detection in the samples of core and cuttings, indicating that no Laboratory-derived contamination from these isotopes is detectable in most of these core samples. Possible exceptions include detectable plutonium-239,240 within cuttings collected in the 31.5- to 32.5-ft interval and in the 431- to 438-ft interval (Table 5.1-1). The 31.5- to 32.5-ft interval is within the uppermost part of the Otowi Member. The 431- to 438-ft interval is just above the saturated zone encountered at a depth of 443 ft. Further comparisons with background data will be made when ongoing background studies for basalts are completed.

Samples of core and cuttings were analyzed for metals including aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, uranium, vanadium, and zinc; however, they are not contaminants of concern in Sandia Canyon. Transition metals, including cobalt, copper, manganese, nickel, and iron, 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.

5.2 Water Quality Determinations

Four groundwater samples were collected from two saturated zones encountered in R-12. Three of these samples were collected from the perched zone within the Cerros del Rio basalt (at 443 and 464 ft) and old alluvium (at 495 ft), and one sample was collected from the regional aquifer in Santa Fe Group basalt (at 805 ft). Samples were analyzed for inorganic and organic chemicals and radionuclides to determine natural solute and contaminant distributions within the different saturated zones.

5.2.1 Methods

Groundwater samples for inorganic and organic chemicals and radionuclides were collected using a stainless-steel bailer. Temperature, dissolved oxygen (DO), 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 DOC; stable isotopes of hydrogen, oxygen, and nitrogen; major cations and anions; metals; organic compounds; and radionuclides. Aliquots of the samples were pressure-filtered (nitrogen gas) through a 0.45-µm Gelman filter and acidified with analytical-grade HNO_3 to a pH of 2.0 or less for metal and radionuclide analyses. DOC samples were filtered with a special 0.45-µm silver filter to eliminate biodegradation of organic solutes, which may bias analytical results. 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 BOREHOLE R-12[a,b]

Part I							
Depth (ft)	25–25.5	31.5–32.5	122–125	135–136	431–438	455–456.5	520–521.9
Geologic Unit	Bandelier Tuff	Bandelier Tuff	Bandelier Tuff	CR basalt[c]	CR basalt	CR basalt	Old alluvium
Strontium-90[d]	0.01 ± 0.44	-0.22 ± 0.46	-0.20 ± 0.46	0.06 ± 0.44	-0.12 ± 0.49	0.05 ± 0.11	0.08 ± 0.11
Cesium-137	-0.053 ± 0.057	0.043± 0.067	0.006± 0.079	-0.013± 0.037	-0.014 ± 0.042	0.001± 0.035	-0.034 ± 0.077
Plutonium-238	0.0146 ± 0.0080	0.0000 ± 0.0064	-0.0086± 0.0050	0.0104 ± 0.0068	0.0092 ± 0.0138	-0.024± 0.020	0.021± 0.028
MDA[e]	0.026	0.036	0.034	0.025	0.028	0.088	0.056
Plutonium-239,240	0.0167 ± 0.0079	0.092 ± 0.018	0.0131 ± 0.0072	0.0214 ± 0.0089	0.108 ± 0.034	0.004 ± 0.020	0.0113 ± 0.0194
MDA	0.020	0.0099	0.024	0.022	0.022	0.058	0.032
Americium-241	0.0026 ± 0.0050	0.036 ± 0.013	0.0159 ± 0.0080	0.018 ± 0.011	0.062 ± 0.046	0.0063 ± 0.0194	0.024 ± 0.030
MDA	0.025	0.025	0.026	0.042	0.049	0.048	0.057
Uranium-234	1.63 ± 0.24	1.69 ± 0.24	3.97 ± 0.50	0.397 ± 0.080	0.462 ± 0.086	0.498 ± 0.108	1.069 ± 0.190
MDA	0.018	0.023	0.026	0.025	0.021	0.026	0.041
Uranium-235	0.083 ± 0.032	0.060 ± 0.026	0.163 ± 0.340	0.0276 ± 0.0192	0.0241 ± 0.0162	0.0209 ± 0.0192	0.081 ± 0.040
MDA	0.015	0.019	0.018	0.020	0.0170	0.022	0.031
Uranium-238	1.73 ± 0.24	1.80 ± 0.24	4.19 ± 0.54	0.415 ± 0.082	0.547 ± 0.098	0.446 ± 0.100	1.082 ± 0.183
MDA	0.021	0.025	0.02	0.027	0.024	0.026	0.038
Uranium (LIKPA[f]) (mg/kg)	1.35 ± 0.19	3.09 ± 0.42	0.86 ± 0.12	5.45 ± 0.75	1.33 ± 0.18	1.03 ± 0.14	2.08± 0.29
MDC[g]	0.05	0.49	0.48	0.49	0.48	0.47	0.05
Gross Alpha	2.51 ± 0.68	1.73 ± 0.57	1.44 ± 0.55	3.0 ± 1.7	7.6 ± 3.2	6.5 ± 3.0	10.2 ± 3.2
Gross Beta	1.90 ± 0.58	1.60 ± 0.57	1.73 ± 0.57	1.7 ± 1.8	4.4 ± 2.1	<3.2 (MDA)	8.0 ± 2.5
Gross Gamma	14.46 ± 1.09	13.72 ± 1.01	24.76 ± 1.74	3.01 ± 0.36	4.02 ± 0.35	3.87 ± 0.36	3.86 ± 0.33
MDA	0.69	0.58	0.82	0.44	0.34	0.38	0.30
Strontium-90[d]	0.12 ± 0.49	-0.13 ± 0.43	-0.13 ± 0.49	0.06 ± 0.37	0.30 ± 0.59	-0.06 ± 0.35	0.03± 0.36
Cesium-137	-0.023 ± 0.029	0.007± 0.065	0.023± 0.061	0.061± 0.043	-0.002 ± 0.038	0.000 ± 0.049	0.029 ± 0.038

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
f. LIKPA = laser-induced kinetic phosphorimetric analysis
g. MDC = minimal detectable concentration

TABLE 5.1-1 (continued)

RADIONUCLIDE ACTIVITIES IN SAMPLES OF CORE AND CUTTINGS FROM BOREHOLE R-12[a,b]

Part 2							
Depth (ft)	555–559	555–559 (dup[c])	567–569	791–792.5	800–801.5	812–814.6	812–814.6 (dup)
Geologic Unit	Puye Formation[d]	Puye Formation	Puye Formation	SFG basalt[e]	SFG basalt	SFG basalt	SFG basalt
Plutonium-238	0.017 ± 0.026	0.007 ± 0.022	0.0084 ± 0.0194	0.0147 ± 0.0184	0.0017 ± 0.0110	0.0132 ± 0.0146	0.0036 ± 0.0156
MDA[g]	0.050	0.056	0.040	0.035	0.030	0.024	0.040
Plutonium-239,240	0.0037 ± 0.0190	-0.0024 ± 0.0194	0.0018 ± 0.0200	-0.0036 ± 0.0106	0.0034 ± 0.0122	0.027 ± 0.020	-0.0007 ± 0.0112
MDA	0.037	0.051	0.0180	0.039	0.019	0.028	0.029
Americium-241	0.084 ± 0.050	0.112 ± 0.066	0.027 ± 0.026	-0.0031 ± 0.0088	0.067 ± 0.040	0.037 ± 0.032	0.097 ± 0.048
MDA	0.053	0.060	0.033	0.027	0.034	0.045	0.041
Uranium-234	0.746 ± 0.140	0.905 ± 0.160	1.162 ± 0.190	0.348 ± 0.090	0.252 ± 0.072	0.232 ± 0.068	0.173 ± 0.058
MDA	0.025	0.035	0.032	0.039	0.029	0.023	0.013
Uranium-235	0.048 ± 0.028	0.054 ± 0.032	0.061 ± 0.032	0.037 ± 0.026	0.038 ± 0.028	0.0188 ± 0.0190	0.047 ± 0.028
MDA	0.025	0.032	0.026	0.014	0.035	0.028	0.013
Uranium-238	0.742 ± 0.140	0.906 ± 0.160	1.155 ± 0.188	0.283 ± 0.078	0.322 ± 0.082	0.269 ± 0.074	0.190 ± 0.060
MDA	0.033	0.021	0.030	0.027	0.029	0.013	0.013
Uranium (LIKPA[h]) (mg/kg)	1.50 ± 0.20	2.26 ± 0.31	2.26 ± 0.31	0.85[i]	0.97[i]	0.81[i]	0.57[i]
MDC[j]	0.05	0.50	0.05				
Gross Alpha	1.44 ± 0.61	2.04 ± 0.68	1.58 ± 0.59	1.4 ± 1.2	2.2 ± 1.1	1.57 ± 0.32	1.61 ± 0.32
Gross Beta	1.20 ± 0.54	1.29 ± 0.53	0.93 ± 0.51	0.38 ± 0.96	1.00 ± 0.74	DNR[k]	DNR
Gross Gamma	6.75 ± 1.12	8.89 ± 1.50	7.99 ± 1.35	2.17 ± 0.41	2.15 ± 0.41	DNR	DNR
MDA	0.20	0.35	0.36	0.29	0.29		

a. pCi/g
b. Error of two standard deviations is reported.
c. dup = duplicate sample
d. Puye Formation = fanglomerate facies of the Puye Formation
e. SFG basalt = Santa Fe Group basalt
f. Radionuclides and parameters analyzed by Paragon Analytics, Inc.
g. MDA = minimum detectable activity
h. LIKPA = laser-induced kinetic phosphorimetric analysis
i. Calculated from uranium-238 activity
j. MDC = minimum detectable concentration
k. DNR = data not received yet

Groundwater samples were analyzed using techniques specified in EPA SW-846 (EPA 1987, 57589) including IC for bromide, chloride, fluoride, nitrate, nitrite, phosphate, and sulfate; graphite furnace atomic absorption (GFAA) for trace elements (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, cesium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, rubidium, selenium, silicon, silver, sodium, strontium, thallium, tin, titanium, vanadium, and zinc); colorimetry for total cyanide; CVAA for mercury; and ICPES for aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, sodium, thallium, vanadium, and zinc. This work was performed by a contract laboratory, Paragon Analytics, Inc., and EES-1.

Radionuclide activity in groundwater was determined by liquid scintillation counting (LSC) for tritium; electrolytic enrichment for low-level tritium; LIKPA for 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 including Paragon Analytics, Inc., Teledyne, and the University of Miami.

Stable isotopes of oxygen (oxygen-18 and oxygen-16), hydrogen (hydrogen and deuterium), and nitrogen (nitrogen-15 and nitrogen-14) were analyzed by Geochron Laboratories (Cambridge, Massachusetts) and Coastal Science Laboratories, Inc. (Austin, Texas), respectively, using isotope ratio mass spectrometry (IRMS).

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 collected at 443 ft within the uppermost portion of the perched zone in the basalt, and at 805 ft within the regional aquifer, were analyzed for semivolatile organic compounds (polychlorinated biphenyls [PCBs] and pesticides) using gas chromatography-mass spectrometry by RECRA Weston. Semivolatile organic compounds were not detected in the groundwater samples from either of these zones. Groundwater samples collected from the two other perched zones were not analyzed for organic compounds.

The following sections focus primarily on the distributions of inorganic chemicals (major cations and anions, nitrate, and ammonium) and radionuclides in groundwater encountered in R-12.

5.2.2 Results

5.2.2.1 Quality of Groundwater within Cerros del Rio Basalt and Santa Fe Group Basalt

Field-measured parameters for the borehole groundwater samples, including pH, temperature, specific conductance, and turbidity, are provided in Table 5.2-1. These parameters were measured at the time of sample collection when groundwater was in contact with the atmosphere. 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.

TABLE 5.2-1

FIELD-MEASURED PARAMETERS FOR GROUNDWATER SAMPLES COLLECTED AT R-12

Geologic Unit	Cerros del Rio Basalt		Old Alluvium	Santa Fe Group Basalt
Depth (ft)	443	464	495	805
Date sampled	04/13/98	04/29/98	04/30/98	06/08/98
pH (standard units)	7.65	7.65	8.25	7.64
Temperature (°C)	14.2	15.5	16.0	18.9
Specific conductance (µS/cm)	376	1381	365	279
Turbidity (NTU[a])	clear	os[b]	os	6

a. NTU = nephelometric turbidity unit

b. os = off the scale because of very high turbidity values for open borehole groundwater samples. The sample collected from the 443-ft zone was clear; however, the turbidity meter was not operating.

Table 5.2-2 provides analytical results for major ions and trace elements in filtered and nonfiltered samples collected from the two saturated zones in R-12. Bar plots for dissolved major ions and silica for the perched groundwater at R-12, R-9, POI-4, and Spring 9B are shown in Figure 5.2-1.

The uppermost sample collected from the perched zone, in Cerros del Rio basalt at a depth of 443 ft, is characterized by a mixed calcium-sodium-bicarbonate-chloride ionic composition with a field pH value of 7.65 and a TDS of 511 ppm (filtered) (Figure 5.2-1; Tables 5.2-1 and 5.2-2). A groundwater sample collected from a depth of 464 ft in Cerros del Rio basalt is characterized by a sodium-calcium-chloride-sulfate-bicarbonate ionic composition with a field pH value of 7.65 and a TDS of 959 ppm (filtered) (Figure 5.2-1; Tables 5.2-1 and 5.2-2). Dissolved sodium, sulfate, and chloride concentrations in this sample are 186, 191, 197 ppm, respectively. The groundwater sample collected in the old alluvium at a depth of 495 ft is characterized by a calcium-sodium-bicarbonate-chloride ionic composition with a field pH value of 8.25 (Figure 5.2-1; Tables 5.2-1 and 5.2-2) and a TDS of 476 ppm (filtered). The chemistry of this water sample is similar to that of the sample collected at a depth of 443 ft.

The static water is the same for all parts of the perched zone in R-12, suggesting that all saturated parts of this zone are hydraulically connected (see Section 4.1). However, water chemistries of samples collected at depths of 443 and 495 ft are distinct from those of the sample collected at 464 ft. These observations are difficult to reconcile for a hydraulically connected perched water zone. The sample at a depth of 464 ft may represent groundwater with a relatively long residence time compared with that of samples collected at depths of 443 and 495 ft. Though hydraulically connected, these groundwaters may acquire different chemical characteristics as they pass through the perched zone at different rates.

Stable isotope data for hydrogen and oxygen were collected to evaluate the sources(s) of water encountered in R-12. The isotopic values for deuterium/hydrogen and oxygen-18/oxygen-16 in R-12 groundwater samples collected from depths of 443, 495, and 805 ft are -76 and -10.6 per mil, -77 and -11.0 per mil, and -72 and -10.8 per mil, respectively. These values plot close to the Jemez Mountain meteoric and global meteoric water lines provided by Blake et al. (1995, 49931), suggesting that these groundwaters were derived from a meteoric or atmospheric source, and that evaporation has not affected their isotopic composition.

TABLE 5.2-2

WATER QUALITY OF GROUNDWATER SAMPLES COLLECTED AT BOREHOLE R-12, SANDIA CANYON[a]

Depth (ft)[b]	443	443	464	495	495	810	805	805
Geologic Unit	CR basalt	CR basalt	CR basalt	Old alluvium	Old alluvium	SFG basalt[c]	SFG basalt	SFG basalt
Sample Treatment	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered
Date Sampled	04/13/98	04/13/98	04/29/98	04/30/98	04/30/98	06/02/98	06/08/98	06/08/98
Temp °C	14.2	14.2	15.5	16	16	18.9	18.9	18.9
Ag (ppm)	<0.001	<0.001	<0.001	<0.001	0.042	<0.001	<0.001	<0.001
Std. Dev. (+/-)					0.002			
Al (ppm)	<0.02	6.90	0.10	0.11	59.0	0.21	0.10	1.29
Std. Dev. (+/-)		0.01	0.01	0.01	0.7	0.01	0.01	0.03
Alk (Lab) (ppm CaCO3)	118	119	142	107	121	116	119	121
As (ppm)	0.0013	0.0021	0.0005	0.0005	0.015	0.0008	0.0019	0.0020
B (ppm)	0.069	0.079	0.16	0.088	0.19	0.04	0.06	0.06
Std. Dev. (+/-)	0.001	0.002	0.01	0.003	0.01	0.01	0.01	0.01
Ba (ppm)	0.015	0.057	0.036	0.014	0.58	0.079	0.085	0.094
Std. Dev. (+/-)	0.001	0.001	0.001	0.001	0.01	0.002	0.001	0.002
Be (ppm)	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002
Std. Dev. (+/-)					0.001			
Br (ppm)	0.18	0.23	0.23	0.17	0.19	0.05	0.08	0.08
Ca (ppm)	45.1	48.6	23.5	36.9	68.4	27.9	28.2	28.3
Std. Dev. (+/-)	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.1
Cd (ppm)	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Std. Dev. (+/-)					0.001			
Cl (ppm)	31.5	32.0	197	33.4	35.7	9.52	10.1	9.93
ClO_3 (ppm)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Co (ppm)	<0.002	0.006	<0.002	<0.002	0.031	<0.002	<0.002	<0.002
Std. Dev. (+/-)		0.002			0.004			

a. The data in this table should be used *only* for screening purposes.

b. Sample collected at 810 ft is from undeveloped well; sample collected from 805 ft is from developed well

c. SFG basalt = Santa Fe Group basalt

TABLE 5.2-2 (continued)

WATER QUALITY OF GROUNDWATER SAMPLES COLLECTED AT BOREHOLE R-12, SANDIA CANYON[a]

Depth (ft)[b]	443	443	464	495	495	810	805	805
Geologic Unit	CR Basalt	CR Basalt	CR basalt	Old alluvium	Old alluvium	SFG basalt[c]	SFG basalt	SFG basalt
Sample Treatment	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered
Date Sampled	04/13/98	04/13/98	04/29/98	04/30/98	04/30/98	06/02/98	06/08/98	06/08/98
CO_3 (ppm)	0	0	0	0	0	0	0	0
Cond. (Lab) (µS/cm)	429	433	1381	434	443	277	282	284
Cr (ppm)	<0.002	0.017	<0.002	<0.002	0.061	<0.002	0.006	0.008
Std. Dev. (+/-)		0.001			0.004		0.002	0.002
Cs (ppm)	<0.002	<0.002	<0.002	<0.002	0.008	<0.002	<0.002	<0.002
Std. Dev. (+/-)					0.002			
Cu (ppm)	0.007	0.040	0.007	0.003	0.22	0.004	0.006	0.007
Std. Dev. (+/-)	0.002	0.004	0.002	0.002	0.01	0.001	0.002	0.002
F (ppm)	0.52	0.53	0.85	0.28	0.29	0.47	0.43	0.43
Fe (ppm)	0.03	9.34	<0.01	0.12	95.8	0.12	<0.01	1.05
Std. Dev. (+/-)	0.01	0.01		0.01	0.7	0.01		0.01
Hardness (CaCO3 ppm)	164	195	86.4	135	317	96.1	94.1	94.5
HCO_3 (ppm)	144	145	173	131	148	142	145	148
Hg (ppm)	<0.00005	<0.00005	0.00008	<0.00005	<0.00005	0.00014	<0.00005	0.00009
I (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K (ppm)	3.12	3.71	65.7	5.54	13.4	3.93	4.33	4.36
Std. Dev. (+/-)	0.01	0.01	0.3	0.01	0.01	0.01	0.02	0.02
Li (ppm)	0.09	0.09	0.08	0.05	0.09	0.04	0.04	0.04
Std. Dev. (+/-)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg (ppm)	12.4	17.9	6.72	10.4	35.5	6.42	5.76	5.80
Std. Dev. (+/-)	0.2	0.1	0.02	0.1	0.5	0.02	0.01	0.02

a. The data in this table should be used only for screening purposes.

b. Sample collected at 810 ft is from undeveloped well; sample collected from 805 ft is from developed well

c. SFG basalt = Santa Fe Group basalt

TABLE 5.2-2 (continued)

WATER QUALITY OF GROUNDWATER SAMPLES COLLECTED AT BOREHOLE R-12, SANDIA CANYON[a]

Depth (ft)[b]	443	443	464	495	495	810	805	805
Geologic Unit	CR basalt	CR basalt	CR basalt	Old alluvium	Old alluvium	SFG basalt[c]	SFG basalt	SFG basalt
Sample Treatment	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered
Date Sampled	04/13/98	04/13/98	04/29/98	04/30/98	04/30/98	06/02/98	06/08/98	06/08/98
Mn (ppm)	0.026	0.18	0.12	0.083	2.01	0.065	0.029	0.042
Std. Dev. (+/-)	0.001	0.01	0.01	0.001	0.01	0.001	0.001	0.001
Mo (ppm)	0.005	0.013	0.066	0.007	0.007	0.022	0.003	0.003
Std. Dev. (+/-)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Na (ppm)	20.2	20.8	186	30.7	33.6	19.4	21.3	21.4
Std. Dev. (+/-)	0.2	0.1	2	0.1	0.1	0.1	0.1	0.1
NH_4 (ppm)	<0.02	<0.02	17.3	0.34	0.43	<0.02	0.02	0.02
Ni (ppm)	0.004	0.023	0.008	0.005	0.08	<0.002	0.002	0.004
Std. Dev. (+/-)	0.002	0.002	0.002	0.002	0.01		0.002	0.002
NO_2 (ppm)	0.43	1.00	2.14	0.23	4.07	<0.02	0.18	<0.02
NO_3 (ppm)	21.7	21.2	1.04	24.2	13.0	4.48	2.03	2.12
Oxalate (ppm)	<0.02	<0.02	<0.02	0.39	<0.02	<0.02	<0.02	<0.02
Pb (ppm)	<0.002	0.004	<0.002	<0.002	0.06	<0.002	<0.002	0.002
Std. Dev. (+/-)		0.002			0.01			0.002
pH (Lab)	7.95	7.50	7.65	7.92	7.29	7.94	7.88	7.80
PO_4 (ppm)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Rb (ppm)	0.006	0.012	0.025	0.009	0.071	0.007	0.007	0.010
Std. Dev. (+/-)	0.002	0.002	0.002	0.002	0.005	0.002	0.002	0.002
Sb (ppm)	0.0005	0.0009	0.0010	0.0003	0.0011	0.0002	0.0002	0.0002
Se (ppm)	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001
Si (ppm)	20.0	30.6	3.45	17.2	79.5	28.4	29.8	31.8
Std. Dev. (+/-)	0.1	0.2	0.01	0.1	0.9	0.1	0.1	0.1

a. The data in this table should be used only for screening purposes.

b. Sample collected at 810 ft is from undeveloped well, sample collected from 805 ft is from developed well

c. SFG basalt = Santa Fe Group basalt

TABLE 5.2-2 (continued)

WATER QUALITY OF GROUNDWATER SAMPLES COLLECTED AT BOREHOLE R-12, SANDIA CANYON[a]

Depth (ft)[b]	443	443	464	495	495	810	805	805
Geologic Unit	CR basalt	CR basalt	CR basalt	Old alluvium	Old alluvium	SFG basalt[c]	SFG basalt	SFG basalt
Sample Treatment	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered	Filtered	Filtered	Nonfiltered
Date Sampled	04/13/98	04/13/98	04/29/98	04/30/98	04/30/98	06/02/98	06/08/98	06/08/98
SiO_2 (ppm calc)	42.8	65.5	7.38	36.8	170	60.8	63.8	68.1
SO_4 (ppm)	24.7	25.5	191	30.0	28.3	8.01	10.1	9.93
S_2O_3 (ppm)	<0.05	<0.05	<0.01	<0.05	<0.05	<0.01	<0.01	<0.01
Sn (ppm)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sr (ppm)	0.18	0.24	0.44	0.19	0.55	0.15	0.16	0.17
Std. Dev. (+/-)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ti (ppm)	<0.002	0.53	<0.002	<0.002	1.67	0.005	<0.002	0.015
Std. Dev. (+/-)		0.01			0.01	0.002		0.001
Tl (ppm)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
V (ppm)	0.003	0.013	<0.002	<0.002	0.095	0.005	0.012	0.012
Std. Dev. (+/-)	0.001	0.001			0.001	0.001	0.001	0.002
Zn (ppm)	0.06	0.60	<0.01	<0.01	0.65	<0.01	0.01	0.02
Std. Dev. (+/-)	0.01	0.01			0.01		0.01	0.01
TDS (ppm)	510.8	595.2	959.3	476.0	1029.2	379.8	386.0	395.8
Cation Sum	4.249	6.208	12.486	4.225	19.976	2.907	2.942	3.145
Anion Sum	4.154	4.206	12.472	4.129	4.343	2.662	2.935	2.973
Balance (%)	2.2700	NA[d]	0.1100	2.3100	NA	1.5400	0.2400	NA

a. The data in this table should be used only for screening purposes.

b. Sample collected at 810 ft is from undeveloped well. Sample collected from 805 ft is from developed well.

c. SFG basalt = Santa Fe Group basalt

d. NA = not applicable

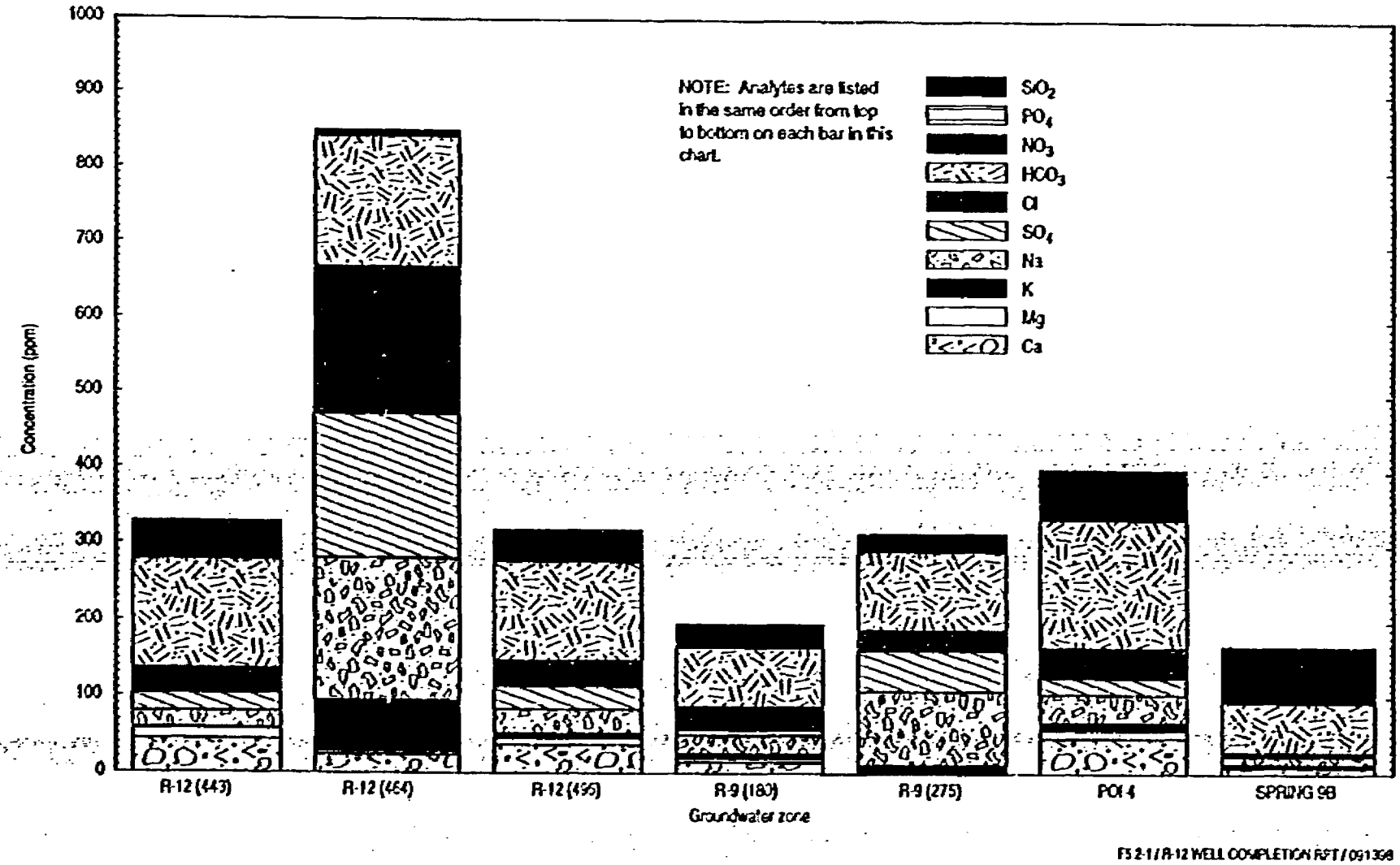


Figure 5.2-1. Comparison of major ion and nutrient chemistry of groundwater in R-12 with intermediate-depth perched groundwater in basalt (R-9, POI-4, and Spring 98). Values in parentheses are sample depths in feet.

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 groundwater in R-12. Spring 9B, which has a calcium-sodium-bicarbonate ionic composition, is the only known spring on the Pajarito Plateau discharging from basalt that does not contain elevated concentrations or activities of anthropogenic chemicals including chloride, nitrate, sulfate, tritium, and uranium. Perched groundwater in R-12 and Spring 9B do not have similar major ion compositions (Figure 5.2-1). In addition, concentrations of chloride, nitrate, and sulfate are higher in the R-12 perched groundwater in comparison with Spring 9B. Concentration of nitrate (as nitrogen) is typically 0.5 ppm in Spring 9B, whereas concentrations of this solute in the upper, middle, and lower portion of the perched zone in R-12 are 4.9, 0.21, 5.5 ppm, respectively (Table 5.2-2).

The major ion chemistries of the three samples collected from the perched zone in R-12 differ significantly from the chemistries of the two perched zones encountered in the Cerros del Rio basalt in R-9 (Figure 5.2-1). This suggests that groundwater within the basalt beneath Los Alamos Canyon at R-9 is not the same as that at R-12. This assumes that mineral precipitation/dissolution is not taking place along this inferred flow path, which could affect the major ion chemistry. Additional data interpretation, including geochemical modeling, will be performed in the future to assess water/rock interactions along groundwater flow paths within Sandia Canyon and possibly Mortandad Canyon.

The perched groundwater zone within the Cerros del Rio basalt and old alluvium at R-12 may contain a component of surface water and alluvial groundwater derived from upper Sandia Canyon to the west. Historic information suggests that discharge of treated sewage effluent from TA-3 in upper Sandia Canyon contained tritium (Rogers 1998, 59169). Current releases of treated effluent contain detectable concentrations of ammonium, nitrate, and organic nitrogen (Environmental Protection Group unpublished data). Surface water samples collected east of the TA-3 outfall show that this treated effluent is characterized by a sodium-bicarbonate-chloride ionic composition with an alkaline pH (Environmental Surveillance and Compliance Programs 1997, 56684). However, the major ion chemistry of treated effluent from TA-3 (sodium-bicarbonate-chloride) differs from that of the perched zone (calcium-sodium-bicarbonate) at R-12, based on recent analytical data (Environmental Surveillance and Compliance Programs 1997, 56684). Thus, the relationship between TA-3 effluent and perched water at R-12, if any, is poorly understood.

Another potential source of groundwater contributing to the chemical composition of perched groundwater observed at R-12 may be Mortandad Canyon. Alluvial groundwater in Mortandad Canyon contains activities of tritium, fission products, and actinides and concentrations of nitrate, sodium, calcium, bicarbonate, and other major ions above background values (LANL 1997, 56835). If perched groundwater originating in Mortandad Canyon flows eastward toward Sandia Canyon, it is possible that this groundwater mixes with perched groundwater beneath Sandia Canyon. This mixed groundwater could influence the water chemistry observed at R-12.

The perched groundwater in the Cerros del Rio basalt and old alluvium encountered in R-12 are chemically similar to those found in a similar geologic setting in well POI-4 located approximately 1.2 km to the north in lower Pueblo Canyon (Figure 5.2-1). This suggests that the occurrence of perched groundwater in basalts found in Pueblo Canyon and Sandia Canyon may have been affected by similar contaminant source chemistries of recharge water (treated sewage effluent from the TA-3 in Sandia Canyon and the sewage treatment plants in Pueblo Canyon). However, these two canyons are probably not hydraulically connected between POI-4 and R-12. Perched intermediate groundwater beneath Pueblo Canyon probably flows to the east-southeast and partially discharges at Basalt Spring, whereas perched

groundwater beneath Sandia Canyon probably flows to the east-southeast, possibly discharging at Sandia Spring west of the Rio Grande.

5.2.2.2 Quality of Groundwater within the Santa Fe Group Basalt

The regional saturated zone at R-12 occurs in Santa Fe Group basalt at a depth of 805 ft and is characterized by a calcium-sodium-bicarbonate ionic composition with a TDS content of 386 ppm (Figure 5.2-2; Table 5.2-2). The major cation and anion chemistry of this water is similar to that of regional aquifer water in R-9 and in supply wells PM-1 and PM-3 (Figure 5.2.2). Also the major cation and anion chemistry of the regional aquifer in R-12 is similar to that of the upper and lower portions of the perched zone (443 and 495 ft), but lower concentrations of calcium, chloride, and sulfate are present in the regional aquifer. Concentrations of chloride and sulfate at the top of the regional aquifer in R-12 are 10.1 ppm and 10.1 ppm, respectively. Concentrations of those two solutes are slightly greater than those found in PM-1 (chloride = 6.6 mg/L, sulfate = 6.1 mg/L) and PM-3 (chloride = 7 mg/L, sulfate = 6.3 mg/L) (Environmental Surveillance and Compliance Programs 1997, 56684). Concentrations of nitrate (as nitrogen) less than 1 ppm or mg/L are similar in R-12, PM-1, and PM-3.

5.2.2.3 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-12 are summarized in Tables 5.2-3 and 5.2-4, respectively. Activities of gross alpha, gross beta, and gross gamma are greater than 1 pCi/L for both filtered and nonfiltered samples. Activities of most radionuclides (excluding plutonium-239,240; tritium; and uranium) are less than detectable levels in both saturated zones.

The activities of tritium for the groundwater samples collected at depths of 443, 464, and 495 ft in R-12 are 254.7 ± 16.6 (two standard deviations), 208.1 ± 7.0, and 249.3 ± 8.3 pCi/L, respectively (Table 5.2-3). The tritium activity for the regional aquifer at R-12 is 46.9 ± 1.6 pCi/L. Groundwater in both saturated zones contains a component of surface water and/or alluvial water that is less than 50 years old (Blake et al. 1995, 49931; Adams et al. 1995, 47192) based on these elevated tritium activities.

The combined isotopes plutonium-239,240 are detected (0.048 ± 0.028 pCi/g, MDA = 0.024 pCi/g) in a mixture of water and sediment separated from the sample with a high suspended solids content collected from a depth of 464 ft (Table 5.2-3). Plutonium-239,240 was not detected in a filtered split of the same water sample. Plutonium-239,240 was detected (0.082 ± 0.016 pCi/L, MDA = 0.029 pCi/L) in a filtered groundwater sample collected from 805 ft (Table 5.2-4). However, plutonium-230,240 was not detected in a nonfiltered split of the same sample (Table 5.2-3). Resampling plutonium-239,240 and other radionuclides is recommended after the characterization well at R-12 has been installed and developed.

Dissolved uranium concentrations in groundwater samples collected at 443, 464, and 495 ft are 2.51, 2.04, and 2.46 µg/L, respectively. The dissolved uranium concentration in the sample collected at 805 ft is 4.08 µg/L. Concentrations of dissolved uranium in perched groundwater and the regional aquifer at R-12 are below the proposed EPA maximum concentration level (MCL) of 20 µg/L and the New Mexico Water Quality Control Commission standard of 5 mg/L. However, background concentrations of dissolved uranium in the upper portion of the regional saturated zone, west of the Rio Grande, typically are less than 2 µg/L (see Table 5.2-5 in Broxton et al. 1998, 59158; Environmental Surveillance and Compliance Programs 1997, 56684). Further work is needed to determine if uranium concentration and their isotopic ratios in groundwater of the regional aquifer are within the range of natural background values.

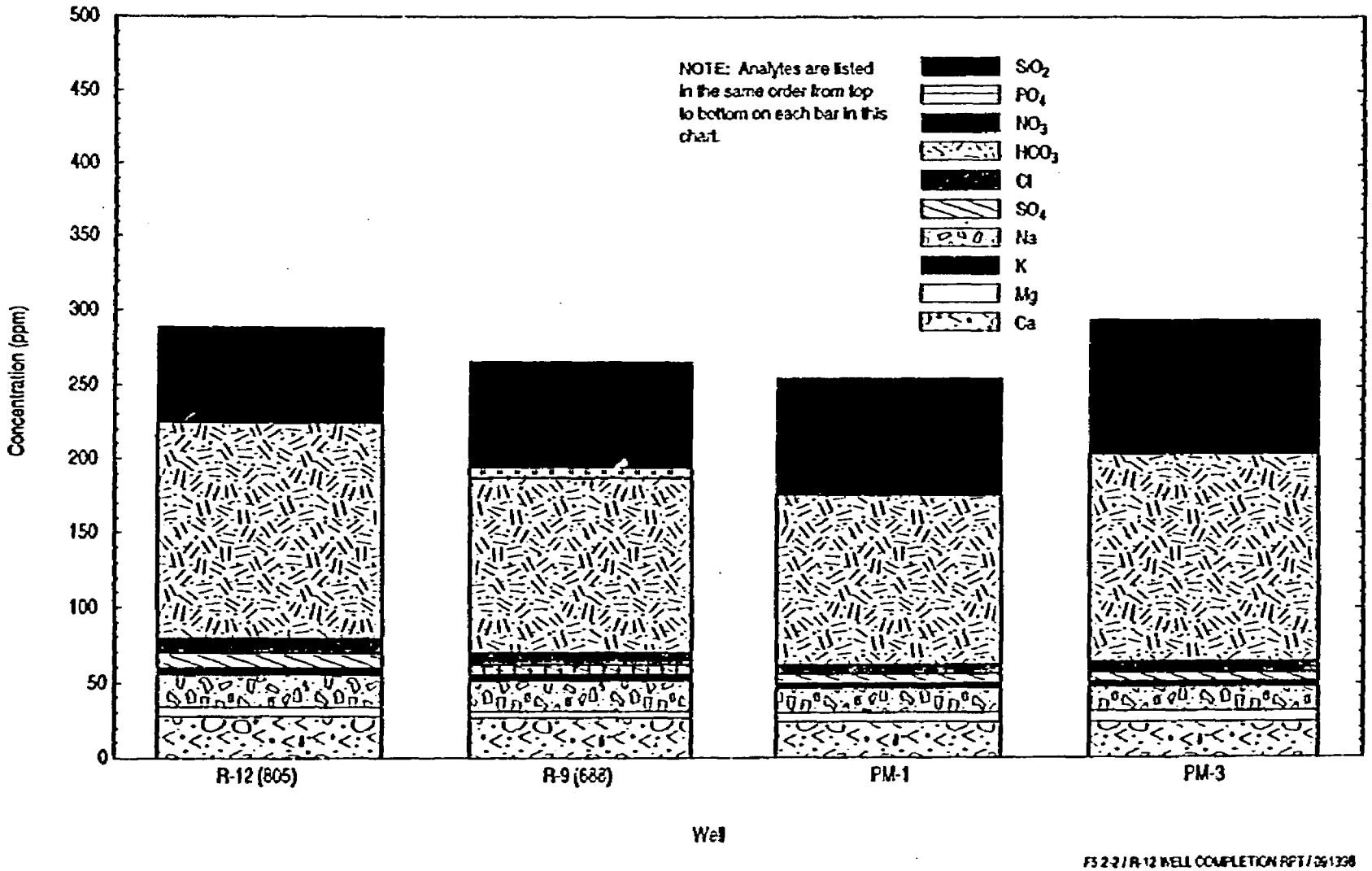


Figure 5.2-2. Comparison of major ion and nutrient chemistry of Santa Fe Group groundwater in R-12 with regional aquifer groundwater in nearby supply wells PM-1 and PM-3. Values in parentheses are sample depths in feet.

TABLE 5.2-3

RADIONUCLIDE ACTIVITIES IN SAMPLES OF NONFILTERED GROUNDWATER FROM BOREHOLE R-12[a]

Depth (ft)	443	464	495	805
Geologic Unit	CR basalt[b]	CR basalt[b]	CR basalt	SFG basalt[d]
Tritium	254.7 ± 16.6	208.1 ± 7.0	249.3 ± 8.3	46.9 ± 1.6
Strontium-90	0.47 ± 0.75	-0.20 ± 0.32	-0.04 ± 0.71	0.16 ± 0.66
Cesium-137	-0.793 ± 1.95	0.040 ± 0.074	-0.3 ± 2.0	-1.3 ± 1.9
Plutonium-238	-0.0145 ± 0.0170	0.0111 ± 0.0156	-0.011 ± 0.010	-0.0024 ± 0.0174
MDA[e]	0.063	0.27	0.068	0.047
Plutonium-239, 240	0.023 ± 0.026	0.048 ± 0.028	0.0066 ± 0.0089	0.0015 ± 0.0174
MDA	0.047	0.024	0.032	0.0138
Americium-241	0.0168 ± 0.0192	0.014 ± 0.022	0 .0152 ± 0.0194	0.0127 ± 0.0170
MDA	0.017	0.021	0.034	0.029
Uranium-234	1.74 ± 0.26	2.13 ± 0.32	2.56 ± 0.38	2.39 ± 0.36
MDA	0.03	0.036	0.038	0.038
Uranium-235	0.061 ± 0.034	0.146 ± 0.052	0.085 ± 0.048	0.070 ± 0.042
MDA	0.027	0.036	0.057	0.043
Uranium-238	0.926 ± 0.176	2.46 ± 0.34	1.15 ± 0.20	1.32 ± 0.22
MDA	0.027	0.032	0.032	0.047
Uranium (LIKPA[f]) (µg/L)	2.56 ± 0.35	7.5 ± 1.0	10.2 ± 1.4	4.26 ± 0.58
MDC[g]	0.10	0.49	1.00	0.10
Gross Alpha	2.2 ± 1.3	23.6 ± 9.4	24.4 ± 4.1	5.52 ± 0.92
Gross Beta	4.9 ± 1.5	15.2 ± 5.6	27.2 ± 4.0	6.0 ± 1.0
Gross Gamma	111 ± 13	11.09 ± 1.88	226 ± 18	213 ± 17
MDA	17	0.55	18	18

a. pCi/L
b. CR basalt = Cerros del Rio basalt
c. Sediment with water from sample with high suspended solids content, pCi/g, excluding tritium and uranium
d. SFG basalt = Santa Fe Group basalt
e. MDA = minimum detectable activity
f. LIKPA = laser-induced kinetic phosphorimetric analysis
g. MDC = minimal detectable concentration

TABLE 5.2-4

RADIONUCLIDE ACTIVITIES IN SAMPLES OF FILTERED GROUNDWATER FROM BOREHOLE R-12[a,b]

Depth (ft)[c]	443	464	495	805
Geologic Unit	CR basalt[d]	CR basalt	CR basalt	SFG basalt[e]
Tritium[f]	(see non filtered data for results of tritium analyses for the four saturated zones)			
Strontium-90	-0.52 ± 0.82	-0.20 ± 0.70	0.04 ± 0.71	-0.31 ± 0.60
Cesium-137	-0.516 ± 2.14	0.1 ± 2.0	0.2 ± 2.0	0.4 ± 2.1
Plutonium-238	-0.007 ± 0.030	0.010 ± 0.030	0.001 ± 0.011	0.0006 ± 0.0196
MDA[g]	0.079	0.075	0.059	0.054
Plutonium-239, 240	0.011 ± 0.026	0.016 ± 0.030	-0.0004 ± 0.0086	0.082 ± 0.016
MDA	0.059	0.058	0.032	0.029
Americium-241	-0.52 ± 0.82	0.032 ± 0.034	0.008 ± 0.022	0.034 ± 0.036
MDA	0.053	0.060	0.050	0.062
Uranium-234	1.53 ± 0.24	2.93 ± 0.42	2.17 ± 0.34	2.08 ± 0.32
MDA	0.046	0.053	0.055	0.044
Uranium-235	0.052 ± 0.032	0.134 ± 0.058	0.039 ± 0.032	0.143 ± 0.058
MDA	0.036	0.049	0.044	0.044
Uranium-238	0.962 ± 0.172	0.703 ± 0.158	0.948 ± 0.182	1.42 ± 0.24
MDA	0.061	0.033	0.048	0.030
Uranium (LIKPA[h]) (µg/L)	2.51 ± 0.34	2.04 ± 0.28	2.46 ± 0.34	4.08 ± 0.56
MDC[i]	0.10	0.10	0.10	0.10
Gross Alpha	2.0 ± 1.1	insufficient sample	2.75 ± 0.63	2.55 ± 0.74
Gross Beta	4.0 ± 1.4	insufficient sample	4.40 ± 0.89	4.50 ± 0.94
Gross Gamma	135 ± 14	232 ± 18	225 ± 18	210 ± 17
MDA	19	18	17	18

a. pCi/L
b. Error of 2 standard deviations is reported.
c. Zones 443 ft, 464 ft, 495 ft, and 805 ft were sampled on 04/13/98, 04/29/98, 04/30/98, and 06/08/98, respectively.
d. CR basalt = Cerros del Rio basalt
e. SFG 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 (pCi/L)
h. LIKPA = laser-induced kinetic phosphorimetric analysis
i. MDC = minimal detectable concentration (µg/L)

Under oxidizing conditions, uranium is predicted to occur as $UO_2(CO_3)_2^{2-}$ and $UO_2(CO_3)_3^{4-}$ within the upper and lower portion of the perched zone based on model simulations using the computer code MINTEQA2 (Allison et al. 1991, 49930). These uranyl carbonate complexes do not completely adsorb onto ferric oxyhydroxide surfaces at pH values greater than 7.5 in the presence of carbon dioxide gas at 10^{-2} atmosphere (Langmuir 1997, 56037). This desorption process probably accounts for elevated concentrations of uranium in the perched zone.

Total (dissolved and suspended) uranium concentrations in the upper, middle, and lower portions of the perched zone are 2.56, 7.5, and 10.2 µg/L, respectively. Turbidity values for the middle and lower portion

of the perched zone exceeded the maximum readable value for the instrument, suggesting that high particulate contents account for a significant portion of the uranium in the nonfiltered samples.

5.2.2.4 Nitrogen Isotopes in Groundwater

The main sources of nitrate found in groundwater and surface water at the Laboratory include (1) natural organic nitrogen in soils, (2) dissolved nitric acid discharges, (3) fertilizers, and (4) treated septic/effluent discharges. Of these possible sources, aqueous discharges of both dissociated nitric acid and treated septic/effluent probably exceed naturally- and fertilizer-derived nitrate.

Water samples were collected from R-12 and from several other wells, springs, and treated outfalls within Los Alamos Canyon, Pueblo Canyon, and Sandia Canyon and at TA-50 and were analyzed for ammonium, nitrate, and nitrogen-15/nitrogen-14. Analytical results of nitrogen species and isotopes are presented in Table 5.2-5.

TABLE 5.2-5

SUMMARY OF NITROGEN CHEMISTRY AND NITROGEN ISOTOPES FOR SEVERAL WATERS IN SANDIA PUEBLO, LOS ALAMOS CANYON, AND TA-50[a,b]

Location	NO_3-N	NH_4-N	Del $^{15/14}$N-NO_3	Del $^{15/14}$N-NH_4	Water Type
R-12 (443 ft)	4.9	<0.02	15.2 (3)		perched
R-12 (464 ft)	0.21	13.5	21.3 (2)	1.3 (2)	perched
R-12 (495 ft)	5.5	0.26	20.3 (2)		perched
R-12 (805 ft)	0.46	0.02	11.3 (2)		regional
R-9 (579 ft)	2.4	0.07	3.0 (2)		regional
Stream below Bayo Sewage Treatment Plant in Pueblo Canyon			7.8 (2)		effluent
TW-1A	<0.02	0.29	24.6 (2)		perched
TW-1	5.3	0.04	17.2 (3)		regional
Basalt Spring	4.5	0.02	34.2 (2)		perched
LA Spring	2.8	<0.02	2.8 (2)		perched
TA-50	67.3	4.73	2.1 (2)		effluent
TA-3	1.5	0.12	32.4 (2)		effluent
HNO_3 Std.[c]	5.7	<0.02	1.0 (4)		acid

a. Concentrations of nitrate and ammonium in units of ppm; isotopes in units per mil or parts per thousand

b. Nitrogen isotopic analyses performed by Coastal Science Laboratories, Inc., Austin, Texas. The number of isotopic analyses for each sample are given in parentheses.

c. Laboratory HNO_3 standard prepared at EES-1

The isotopic standard for nitrogen-15/nitrogen-14 is nitrogen in air, which has a nitrogen-15/nitrogen-14 value of zero (Clark and Fritz 1997, 59168). Nitrate derived from treated septic effluent is enriched in nitrogen-15 and depleted in nitrogen-14 and is characterized by positive nitrogen-15/nitrogen-14 ratios (7 to >30 per mil; Clark and Fritz 1997, 59168). During denitrification, which is the reduction of nitrate to nitrogen gas in the presence of organic carbon, residual nitrate becomes enriched in nitrogen-15. Subsequently, nitrogen-15/nitrogen-14 ratios become increasingly more positive with increasing denitrification.

Groundwater samples collected from R-12 (at 443, 464, 495, and 805 ft), Basalt Spring, the TA-3 outfall, TW-1A, and TW-1 have nitrogen-15/nitrogen-14 values ranging from 11.3 to 34.2 per mil (Table 5.2-5). Possible sources of nitrate in these waters, based on their nitrogen isotopic analyses, is septic/effluent derived from sewage treatment plants. This is consistent with known sources of treated effluent discharge from the sewage treatment plant(s) in Pueblo Canyon and the TA-3 discharge in upper Sandia Canyon.

Nitric acid is produced by reacting ammonia gas with oxygen gas. Ammonia is oxidized to nitrate through a series of reactions involving nitrous oxide, nitric oxide, and nitric dioxide, which eventually produces nitric acid. Ammonia is initially produced by reacting nitrogen gas, having a nitrogen-15/nitrogen-14 ratio of zero per mil, with hydrogen gas. Consequently, the nitrogen-15/nitrogen-14 value for nitric acid is close to zero or is slightly enriched with nitrogen-15. A nitric acid standard prepared by EES-1 personnel has an average nitrogen-15/nitrogen-14 value of 1.0 per mil (Table 5.2-5). The treated effluent sampled at TA-50 contains elevated nitrate concentrations and low nitrogen-15/nitrogen-14 (Table 5.2-5) dominantly derived from nitric acid associated with the TA-55 waste stream.

Organic nitrogen derived from soils is enriched in nitrogen-15 and depleted in nitrogen-14. Accordingly, soils containing organic nitrogen are characterized by positive nitrogen-15/nitrogen-14 ratios that typically range from 3 to 7 per mil (Clark and Fritz 1997, 59168). Samples collected from R-9 (at 579 ft), R-12 (at 805 ft) and LA Spring have nitrogen-15/nitrogen-14 ratios consistent with those of nitric acid and perhaps soil organic nitrogen (Table 5.2-5).

Ammonium was detected in R-12 groundwater at a depth of 464 ft. Ammonium is the thermodynamically stable form of nitrogen under reducing conditions. The nitrogen-15/nitrogen-14 ratio for ammonium in this groundwater sample is 1.3 per mil, which implies a different source (abiological) of ammonium than that found in the samples at depths of 443 and 495 ft. The ammonium may be naturally derived from clay minerals through cation exchange or possibly from an industrial source such as laboratory cleaners containing ammonium. More work is required to understand the source(s) of ammonium at the depth of 464 ft in R-12.

5.2.2.5 Summary of Groundwater Chemistry

Solute chemical data show the presence of possible elevated concentrations of some anions (chloride, nitrate, and sulfate) within the four groundwater samples collected during the drilling of R-12. These solutes are probably derived from alluvial groundwater in upper Sandia Canyon. Nitrate concentrations observed in R-12 groundwater at depths of 443 and 495 ft are above background values, which are typically less than 0.5 ppm nitrate as nitrogen. In addition, nitrogen isotopic data for these two samples is consistent with derivation of nitrate from a sewage source, possibly the TA-3 outfall.

Measurable activities of tritium within the two saturated zones at R-12 suggest that a component of groundwater in these zones is less than 50 years old, which is derived from atmospheric fallout (Adams et al. 1995, 47192) and/or from Laboratory discharges (Blake et al. 1995, 49931). Activities of cesium-137; strontium-90; plutonium-238; plutonium-239,240; and americium-241 are generally less than detection in groundwater samples collected from R-12.

Dissolved uranium concentrations of 4.08 µg/L have been measured within the basalt of the Santa Fe Group of R-12. This value is possibly 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.

5.3 Moisture Content of Core and Cuttings

5.3.1 Methods

Moisture content was determined on samples of both core and cuttings. Core was collected from only 10.8% of the borehole, including all the saturated intervals. Therefore, collecting a vertical profile of moisture content for the entire borehole requires that analyses for moisture content 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 with the analytical results in Appendix C.

5.3.2 Results

Moisture contents systematically increase downsection from 2 to 6% within alluvium and Cerro Toledo deposits to 12 to 20% near the base of the ash-flow tuffs in the Otowi Member (Figure 5.3-1). Moisture contents range from 12 to 28% within the Guaje Pumice Bed and underlying soil. A similar pattern of downward increasing moisture was reported for core samples collected from the Otowi Member and Guaje Pumice Bed in LADP-3, approximately 4 km west-northwest of R-12 (Broxton et al. 1995, 50119). Moisture contents for the Otowi Member in LADP-3 range from 10 to 35% and are generally higher than those for R-12, possibly reflecting the wetter conditions beneath Los Alamos Canyon.

Moisture contents are generally low, typically 1 to 3%, within basaltic rocks of the Cerros del Rio volcanic field. Moisture spikes at depths of 262 and 343 ft correlate with clay-rich, vesicular zones associated with basalt flow unit boundaries (Appendix B; Figure 5.3-1). High moisture contents (39 to 59%) were associated with the paleosol separating the upper alkalic flow from the lower alkalic flow.

Moisture contents increase downsection through the Puye Formation. Moisture contents for cuttings from the vitric, upper portion of the Puye Formation are typically 3 to 6%. Moisture contents for cuttings from the argillic, lower part of the Puye Formation range from 9 to 13%, but cores from near the base of the formation yielded markedly higher measurements, ranging from 20 to 42%. These patterns are similar to R-9 and might reflect increased alteration of the Puye Formation downsection.

5.4 Matric Potential

5.4.1 Methods

Matric potential was measured using a chilled-mirror water activity meter as described by Gee et al. (1992, 58717). Samples were sealed in resealable plastic bags and wrapped in packing tape immediately after the core or cuttings were screened for radioactivity. Storage time ranged between 2 and 49 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 0.003 activity units. Samples collected for matric potential analyses are listed in Appendix C.

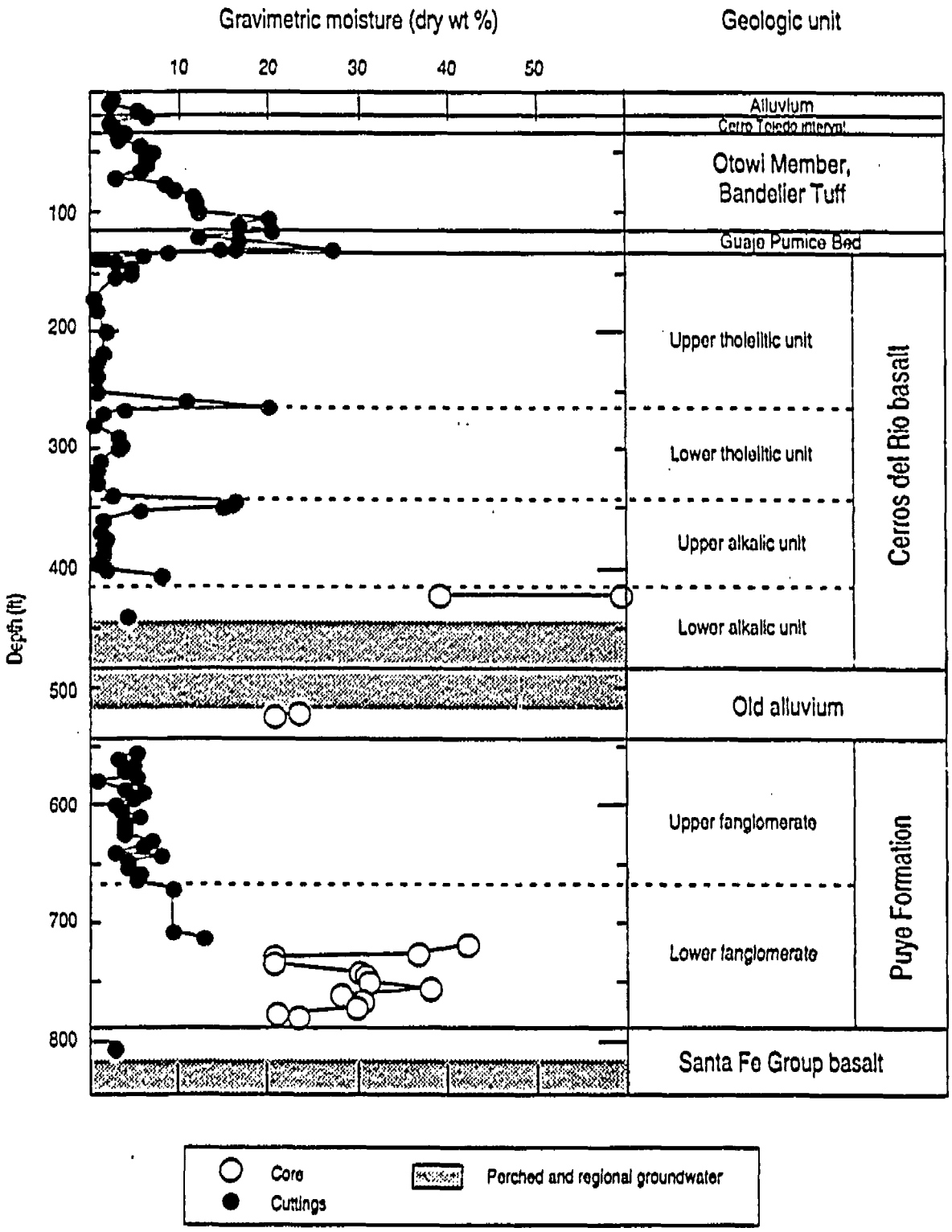


Figure 5.3-1. Moisture content of core and cuttings in R-12.

5.4.2 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.

5.5 Hydraulic Properties

A total of 25 core and cuttings samples were collected and preserved for potential hydraulic property testing and are stored at the FSF. Samples are currently being 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. A listing of samples collected and preserved for future testing is given in Appendix C.

5.5.1 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.
- 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 geotechnical sample as well as the time and date of sample collection were recorded on the liner with indelible ink.
- The capped and labeled liner was inserted into a Coreprotec aluminized sleeves labeled with the same sampling information.
- The ends of the Coreprotec sleeve were melted together 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.

5.5.2 Results

Samples are currently being evaluated for testing 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.

5.6 Borehole Geophysics

5.6.1 Methods

The borehole geophysical methods that were used for measurements during the drilling of borehole R-12 include a color video camera, natural gamma radiation (NGR) measurements, and caliper measurements. All measurements were made inside the drill casing.

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.

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. In R-12, caliper measurements were made within the casing string to detect buildup of clap on the inside walls of the casing.

5.6.2 Results

A color video camera was used to assist in the recovery of a large steel bushing, which was accidentally dropped into the borehole to a depth of 182 ft. The camera was deployed to view the location and alignment of the steel bushing that guided the design of a tool to retrieve the bushing from the borehole. The camera was also deployed into the borehole with the tool to guide the retrieval of the steel bushing.

Measurements with the NGR probe in R-12 were taken twice during the drilling of the borehole. The first NGR measurements (Figure 5.6-1) were performed from the surface to a depth of 405 ft inside the 14-in.-diameter drill casing. The second NGR measurements (Figure 5.6-2) were taken from the surface to a depth of 640 ft inside the 10.75-in.-diameter drill casing. The 10.75-in.-diameter drill casing was telescoped inside the 14-in.-diameter drill casing with the 14-in.-diameter drill casing present to a depth of 449 ft in the borehole.

Comparison of the two figures shows a reduction in measured natural gamma radiation, which occurs because of the drill casings. In Figure 5.6-1 the NGR response for the Otowi Member measured through the 14-in.-diameter drill casing is approximately 90 counts per second (cps). Figure 5.6-2 shows that the NGR response for the Otowi Member measured through both the 14-in.-diameter and the 10.75-in.-diameter drill casings is approximately 40 cps. The NGR measurements in Figure 5.6-1 for R-12 show that the highest counts of natural radiation occur in the Guaje Pumice Bed.

The Cerros del Rio basalt in R-12 has a significantly lower natural gamma radiation than the Otowi Member. For NGR measurements in the 14-in.-diameter drill casing, the natural gamma radiation level in the basalt along the depth interval of 136 to 280 ft was uniform with a value of 15 cps. The level of natural gamma radiation remains low and uniform through the total thickness of the basalt. Below the basalt, the NGR count rate gradually increases from 15 cps in the old alluvium (at a depth of 492 ft) to values of 75 cps at depths of 600 to 670 ft in the Puye Formation.

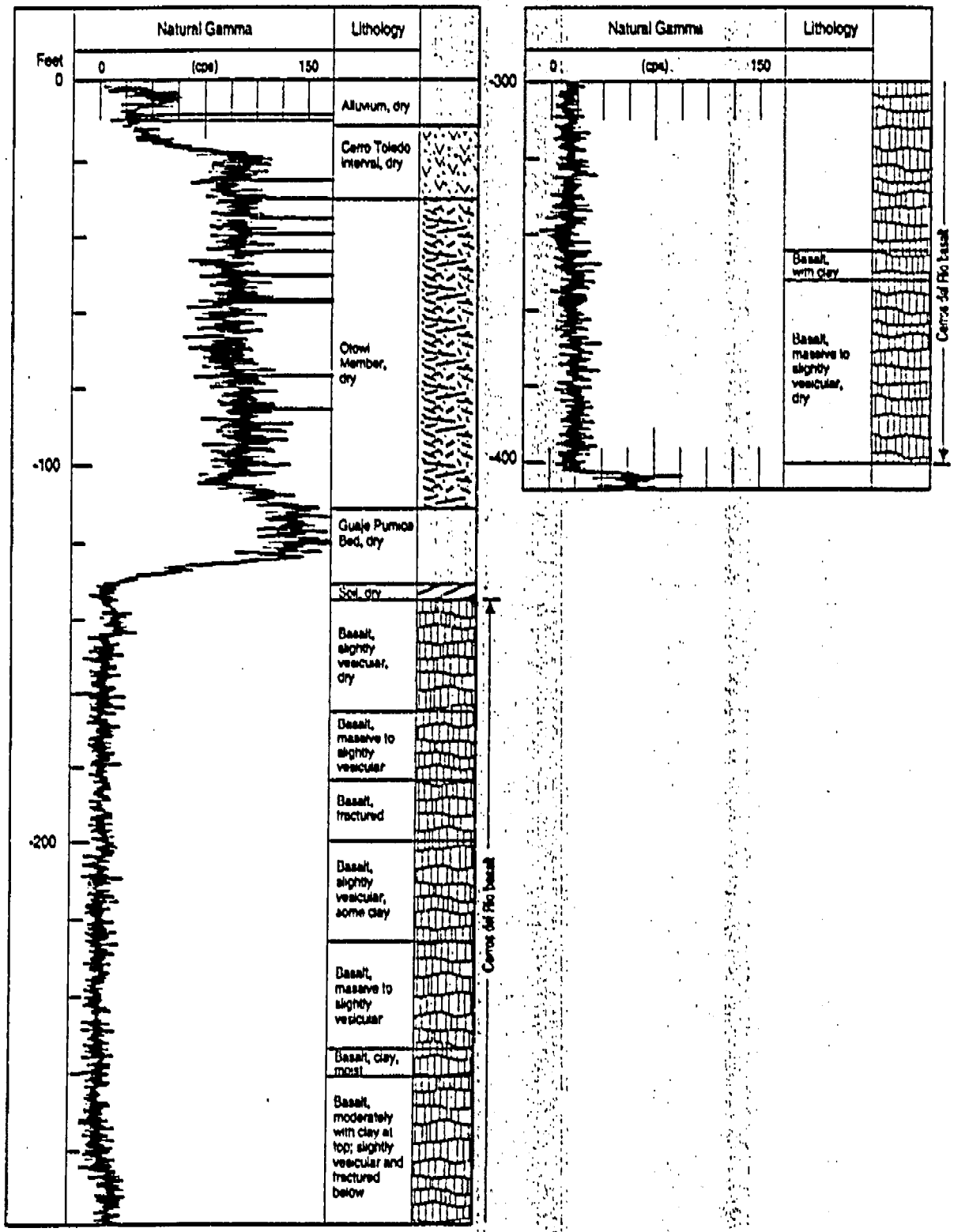
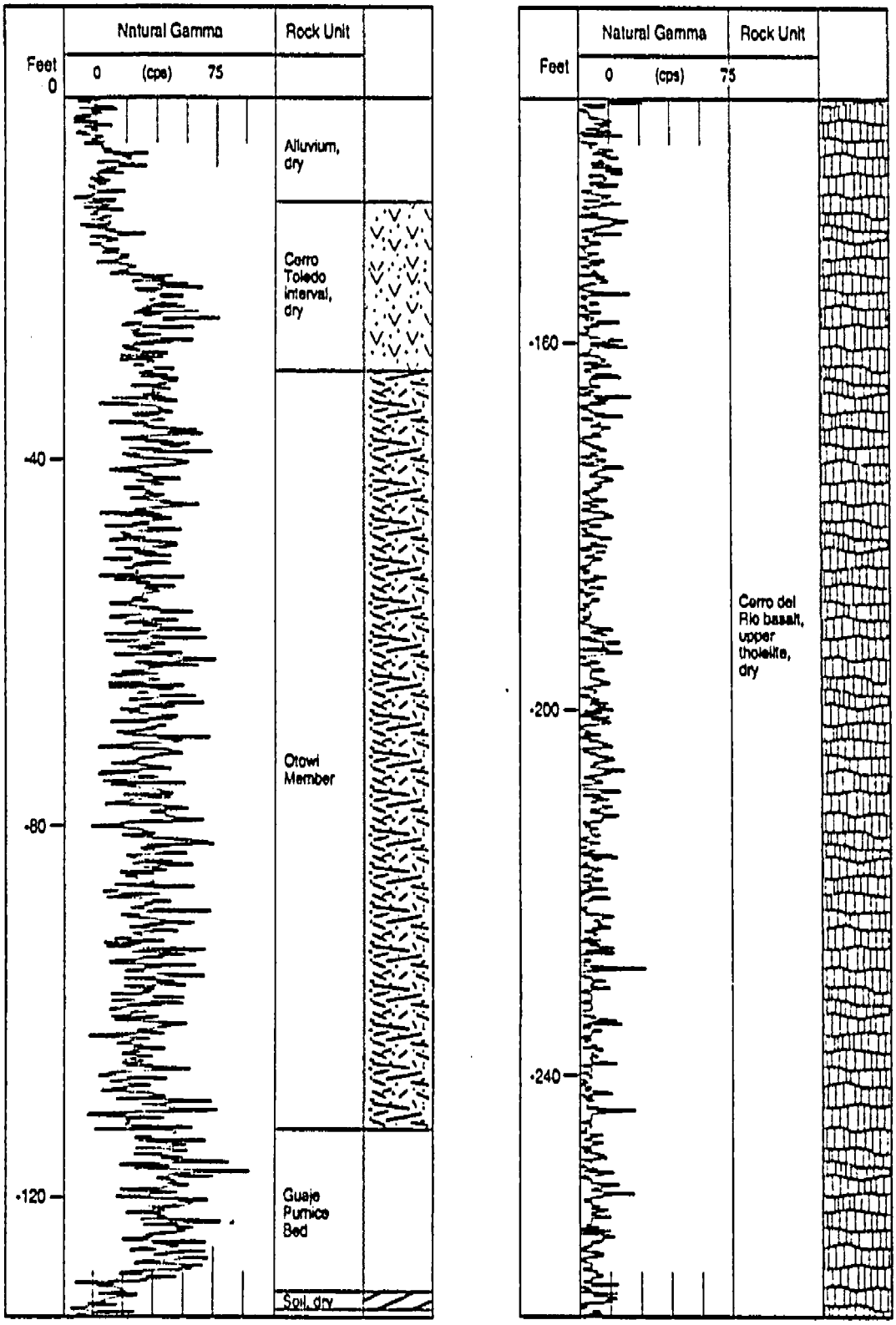


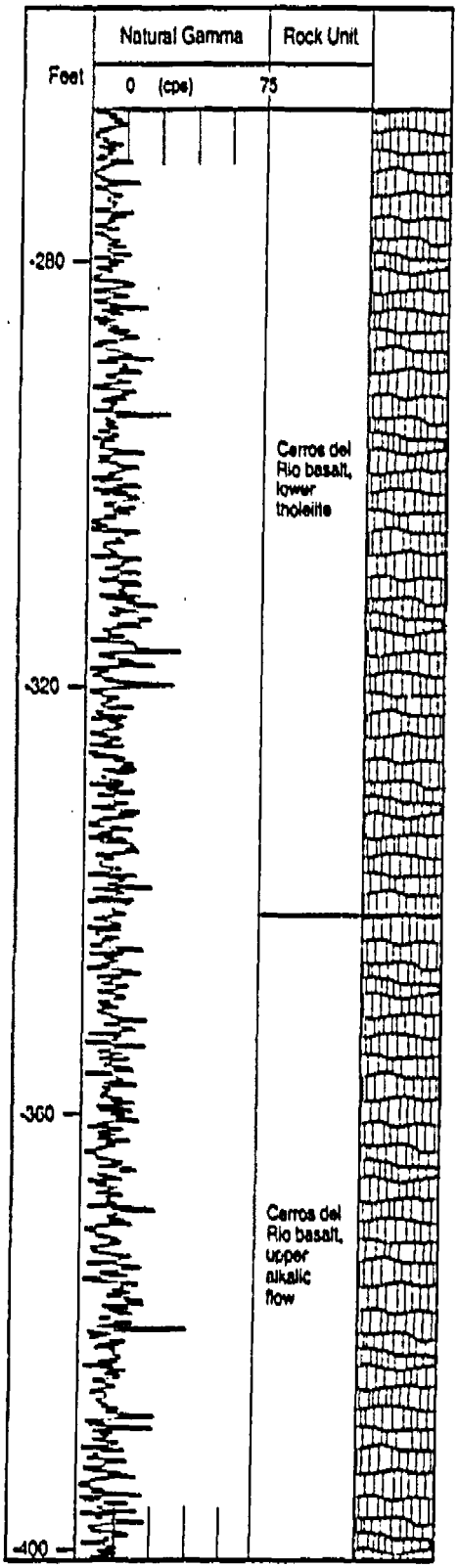
Figure 5.6-1. Borehole natural gamma measurements through 14-in.-diameter steel casing in R-12 for the depth interval of 0 to 405 ft.

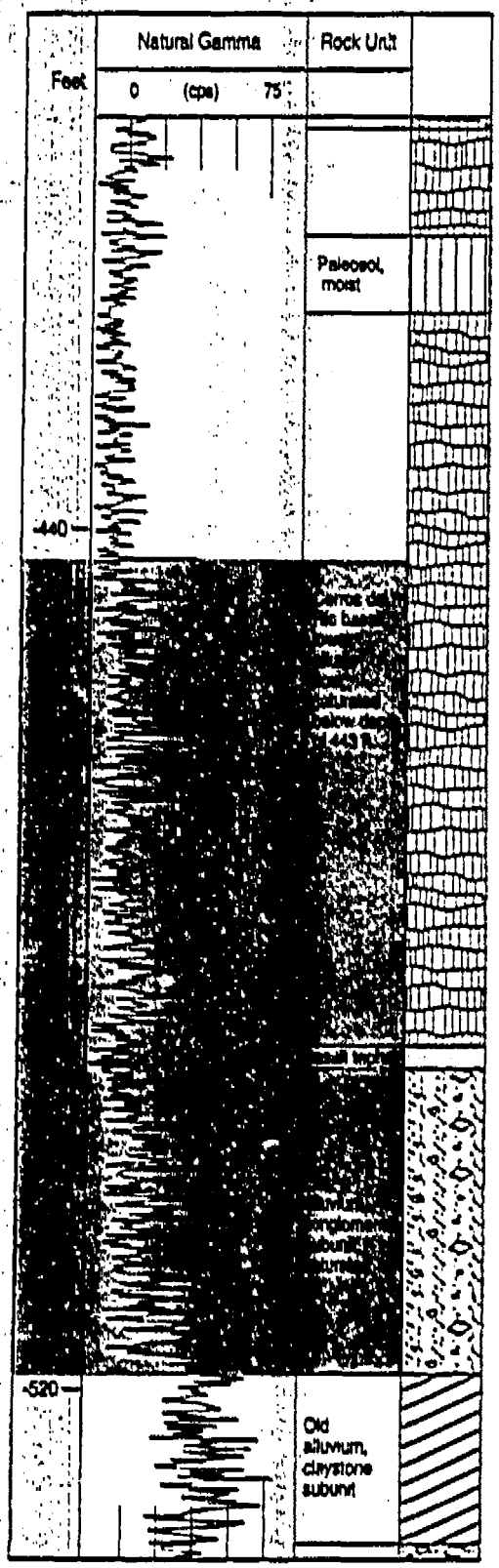


Note: Measurements were taken throught both 14-in.- and 10.75-in.-diameter casing for depths of 0 to 449 ft.

F5.6-2 / R-12 WELL COMPLETION RPT / 091398

Figure 5.6-2. Borehole natural gamma measurements through 10.75-in.-diameter steel casing in R-12 for the depth interval of 0 to 670 ft.



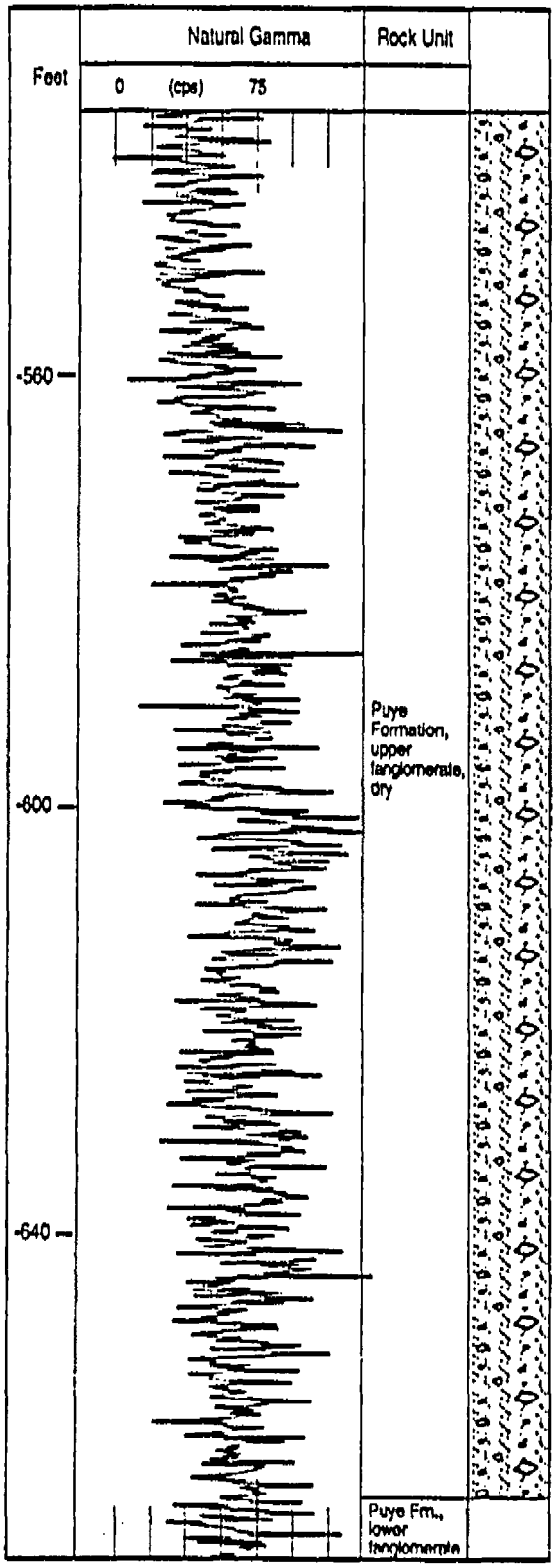


Note: Measurements were taken throught both 14-in.- and 10.75-in.-diameter casing for depths of 0 to 449 ft.

Saturated zone

F5.0-2 / R-12 WELL COMPLETION RPT / 091398

Figure 5.6-2. (continued)



F5.6-2 / R-12 WELL COMPLETION RPT / 091398

Figure 5.6-2. (continued)

Caliper measurements in R-12 (Figure 5.6-3) were made inside the 10.75-in.-diameter drill casing to inspect for the presence of clay-rich cuttings on the inside wall of the drill casing. The presence of clay-rich cuttings could cause anomalous measurements of natural gamma radiation. The 10.75-in.-diameter drill casing was the passage for drill cuttings from operation of core rods inside the 10.75-in.-diameter drill casing. The caliper record shows that the accumulation of drill cuttings inside the 10.75-in.-diameter drill casing occurred only at a depth greater than 645 ft. The effect of clay-rich materials that collected on the inside of the drill casing on the NGR measurements was limited to the depth interval of 645 to 660 ft.

6.0 WASTE MANAGEMENT

Management of waste streams generated during R-12 drilling, sampling, and well installation activities was conducted in accordance with the site-specific Waste Characterization Strategy Form (WCSF). Wastes consisted of borehole materials (drill cuttings), groundwater, disposable sampling equipment, personal protective equipment (PPE), plastic sheeting, sorbent pads, and decontamination water.

- Drill cuttings were collected in 55-gal. drums, directly from the dust-suppression system discharge, and transferred to 20-cubic-yard roll-off bins for containment; two roll-off bins were required. The disposal of the bins is pending final determination.

- Groundwater generated as a result of drilling through saturated zones and from purging operations before groundwater sampling was collected and transferred directly to 3000-gal. storage tanks. Water from different saturated zones was segregated into separate tanks;. 3925 gal. of groundwater was generated. All groundwater was discharged on site through a sprinkler system at a rate of 500 gal. per day in accordance with the WCSF and a Notice of Intent to Discharge (NOI), which was approved by the New Mexico Environment Department.

- Disposable sampling equipment and PPE were placed in drum liners, sealed, and stored on site in accordance with the WCSF. A total of four bags were generated. A waste profile form was prepared and approved for disposal of the bags at the Los Alamos County landfill.

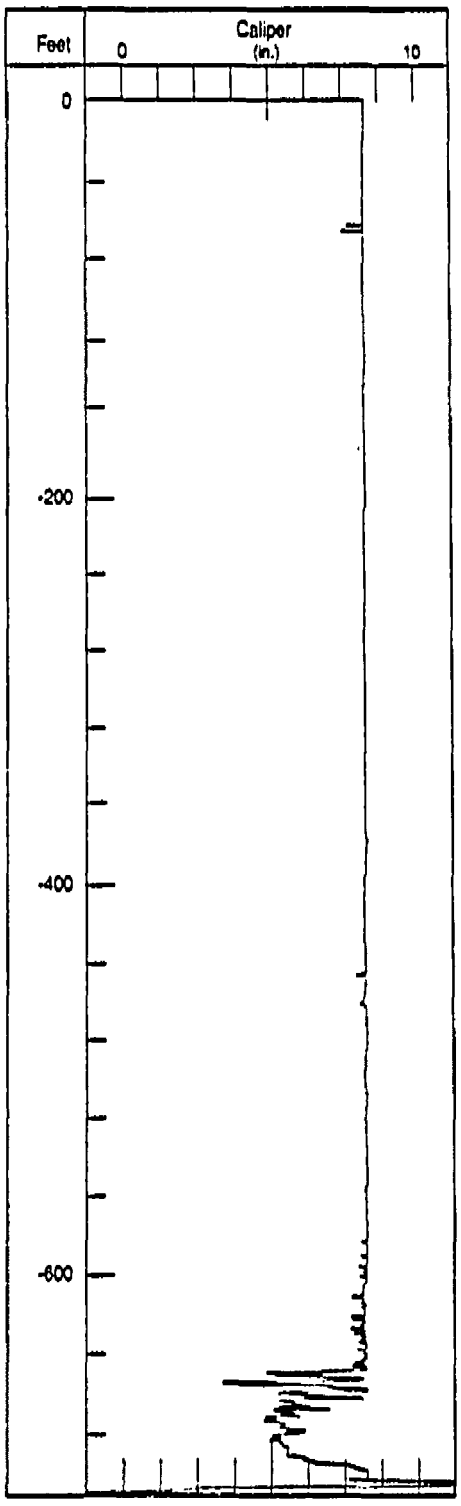
- Plastic sheeting and sorbent pads placed beneath the drill rig and heavy equipment to contain leaking hydraulic fluid, lubricants, and antifreeze were contained in four 55-gal. drums and were managed and disposed of as New Mexico special waste.

In addition, the following unanticipated waste streams were generated and processed in accordance with general waste management guidance.

- Decontamination water generated from cleaning unused auger flights, which were sprayed by hydraulic fluid when a hydraulic line ruptured, was placed in drums, sampled for constituent characterization, and stored on site pending analytical results. A total of two drums were generated and managed as nonregulated waste.

- One drum of grout mixer rinsate was generated from rinsing bentonite residue out of the grout mixer. The rinsate is pending final disposition.

- A total of 18 barrels of soil that was contaminated with spilled diesel fuel were managed and disposed of as New Mexico special waste.



F5.6-3 / R-12 WELL COMPLETION RPT / 091398

Figure 5.6-3. Caliper measurements through steel casing in R-12 for the depth interval of 0 to 670 ft.

7.0 SURVEY ACTIVITIES

7.1 Geodetic Survey

The location of R-12 was surveyed on August 28, 1998, by Surv-Tek, Inc. The survey point is the center of the protective box installed on the well head. Based on this survey, the coordinates for R-12 are X = 1647427.33, Y = 1767907.05, and Z = 6500.78. The X, Y, and Z designations represent easting, northing, and elevation, respectively. The elevation (Z) represents the ground surface at SCOI-3 and can be assumed to be accurate for R-12 to within a few tenths of a foot, based on the proximity of the well and the flat topography of the area. The Facility for Information Management, Analysis, and Display (FIMAD) Location ID for R-12 is SA-0006. The location of SCOI-3 was surveyed on May 13, 1996, by Surv-Tek, Inc. The coordinates recorded for SCOI-3 are X = 1647442.144, Y = 1767902.997, and Z = 6500.780. Location coordinates are based on New Mexico State Plane Grid Coordinates, Central Zone (North American Dadum [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 the Laboratory global positioning system (GPS) monument B0001, which has New Mexico State Plane Grid Coordinates, Central Zone (NAD 83) 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-12 and the elevation of the north side top-of-casing and the surface monument will be resurveyed for the permanent record.

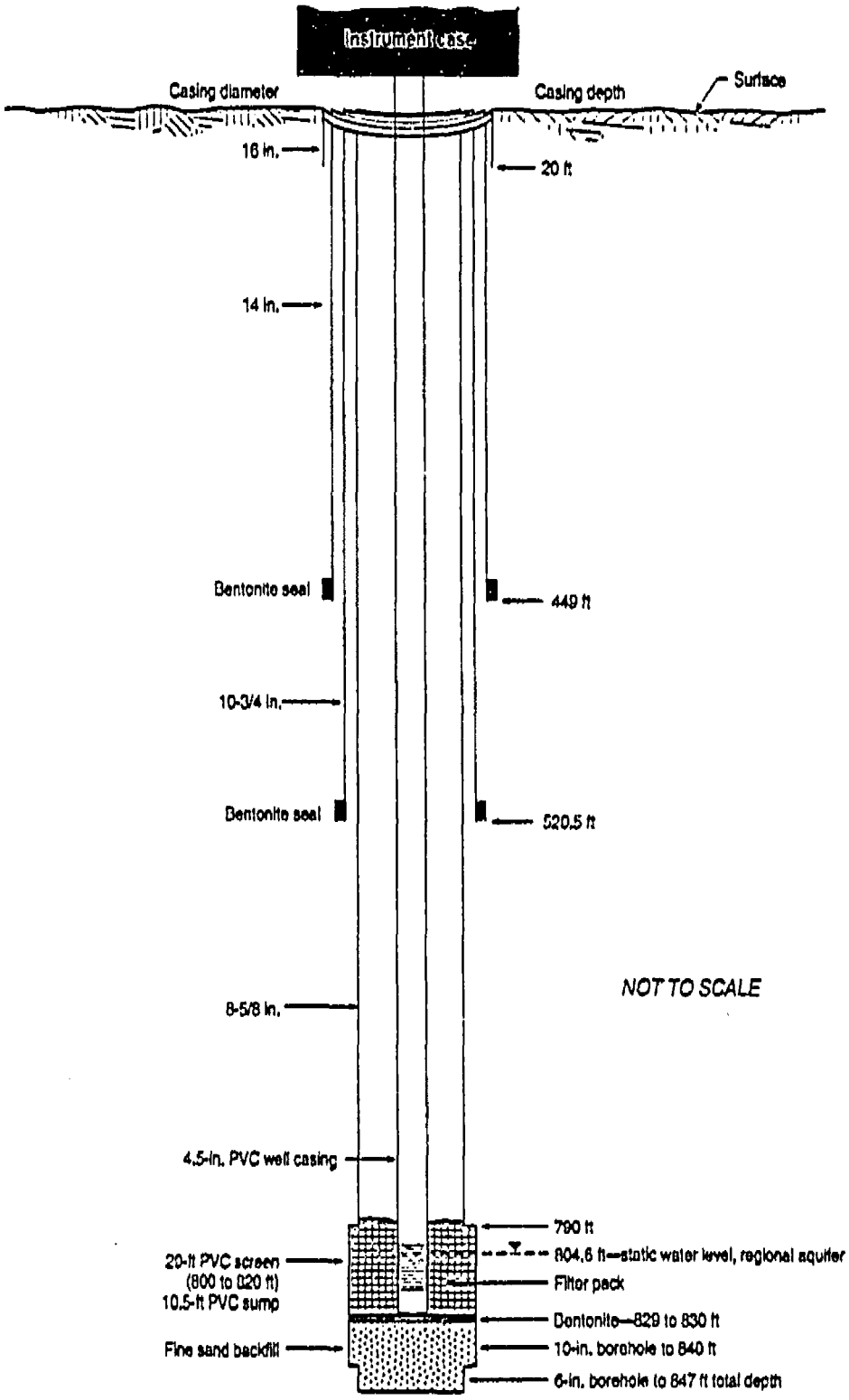
7.2 Surface Radiological Survey

A surface radiological survey was conducted by a radiological control technician before drilling activities began at SCOI-3, which was initially installed before R-12. The predrilling radiation survey was conducted on May 6, 1996, and consisted of collecting alpha, beta, and gamma background measurements and conducting statistical analysis to calculate action levels. Established action levels are used as a basis to determine if borehole materials screened during drilling exhibit radioactivity above surface 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 Model 139 with air proportional probe; beta/gamma was measured using a Ludlum Model 12 with 44-9 probe; dose rate was measured using a Ludlum Model 19 μR/hr meter. Calculated background values for the drill site are 0.4 cpm for alpha, 154 cpm for beta/gamma, and 14.8 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-12. The temporary well completion for R-12 is shown in Figure 8-1. The temporary well at R-12 was constructed in the following manner.

- Approximately 100 gal. of water was air-lifted out of the borehole and casing in preparation for well installation.
- The polyvinyl chloride (PVC) well casing for the temporary well was delivered to the site and assembled in 20-ft sections; all joints were measured and inspected.
- A 1-in. tremie line was tripped into the casing to 800 ft to emplace bentonite and filter-pack materials. The bottom of the borehole was backfilled with sand, and a bentonite bottom seal was emplaced above the fill.



F0-1 / R-12 WELL COMPLETION RPT / 091208

Figure 8-1. Configuration of the temporary well for R-12.

- A 4-in. inside diameter, schedule 40, PVC, monitoring-well casing was tripped in and landed at a depth of 829 ft.
- The well was constructed as the 8-5/8-in.-diameter drill casing was retracted.
- The completed well consists of a 10.5-ft sump, a 20-ft section of 10-slot well screen (0.010-in.) that extends from depths of 800 to 820 ft, and a filter pack consisting of 30-70 grade sand.
- The constructed well was developed by bailing 450 gal. of water from 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-12* ("the field implementation plan"; LANL 1998, 59162) with characterization activities performed in R-12. 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 was the replacement of intermediate-depth well SCIO-3 by the regional aquifer well R-12. In the work plan, SCOI-3 was originally designed to characterize the intermediate-depth perched groundwater zone encountered at a depth of 450 ft by water supply well PM-1 in 1964 (Cooper et al. 1965, 8582). In the *Hydrogeologic Workplan*, the core document, and the field implementation plan, R-12 was redesigned to characterize all perched groundwater zones at this location as well as the regional aquifer. R-12 is presently at a depth of 847 ft. It successfully characterized perched groundwater and penetrated the top of the regional saturated zone. The final depth and completion design of R-12 will be based on ongoing evaluations 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.

The amount of core collected in R-12 was a significant deviation from the amount specified in the *Hydrogeologic Workplan* and the core document. In both documents R-12 is designated as a type 3 well (continuous coring). However, because of the slow coring rates along with the associated high costs of collecting core in the previous borehole, R-9, the amount of core planned for collection in R-12 was reduced from 100% to 50% in the field implementation plan. During actual drilling operations, core was not collected from the upper 132.5 ft of R-12 because this interval was previously cored during drilling of SCOI-3. In R-12, poor performance of the 134-mm coring system, particularly in basalt, led to only 10.8% of the hole being cored. Together, R-12 and SCOI-3 provided core for 26.5% of the rock units to a depth of 847 ft in this area.

TABLE 9-1

ACTIVITIES PLANNED FOR R-12 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeological Workplan and Core Document for Canyons Investigations	R-12 Field Implementation Plan	R-12 Actual Work
Planned Depth (ft)	450	100 to 500 into the regional aquifer	Nominally 1000	Currently 847; into regional saturation
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	100% of the borehole	Approximately 50% of the borehole	10.6% of R-12; 26.5% for this location when core from SCOt-3 is included
Lithologic Log	Log to be prepared from core, cuttings, drilling performance	Log to be prepared from core, cuttings, drilling performance	Log to be prepared from core, cuttings, 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 to be sampled at completion and at 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 six water samples are planned.	To date, five water samples were collected from saturated zones.

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-12 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeological Workplan and Core Document for Canyons Investigations	R-12 Field Implementation Plan	R-12 Actual Work
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, Ti, U, V, Zn **Anions:** Br, ClO_3, Cl, F, NO_3, PO_4, HCO_3, SO_4 **Other Inorganic Chemicals:** Si, cyanide **Radionuclides:** ^3H, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}Pu, $^{238,240}Pu$, ^{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 III analytes; ^3H, 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:** ^3H, ^{90}Sr, ^{137}Cs, ^{241}Am, ^{234}U, ^{235}U, ^{236}U, ^{239}Pu, $^{238,240}Pu$, 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 and $^{15}N/^{14}N$
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 23 core/cuttings samples planned; number of samples dependant on number of saturated zones encountered	To date, 14 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:** ^3H, ^{90}Sr, ^{137}Cs, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{239}Pu, $^{238,240}Pu$, 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 III analytes; ^3H; and metals; four samples to be analyzed for VOCs	**Trace Elements/Metals:** Al, Sb, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Ag, Tl, U, V, Zn **Anions:** Br, Cl, F, SO_4, NO_3 **Other Inorganic Chemicals:** cyanide **Radionuclides:** ^3H, ^{90}Sr, ^{137}Cs, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, ^{239}Pu, $^{238,240}Pu$, gamma spectroscopy, gross-alpha, gross-beta, gross gamma VOAs and SVOCs to be determined in four samples and where PID detects occur	Same as field implementation plan

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-12 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeological Workplan and Core Document for Canyons Investigations	R-12 Field Implementation Plan	R-12 Actual Work
Hydraulic Property Analyses	Bulk density, dry density, Kd, porosity, mineralogy, moisture content, moisture potential, saturated hydraulic conductivity	Physical properties to 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 15 samples of core or cuttings will be selected by the geology project leader for mineralogy, petrography, and rock chemistry.	A total of 25 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 112 samples were collected for moisture content and 111 samples were collected for matric potential. A total of 23 samples were collected for geologic characterization including mineralogy, petrography, and rock chemistry.
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			Waters levels will be determined for each saturated zone by water-level meter or by pressure transducer.	Waters levels were determined for each saturated zone by water-level meter or by pressure transducer.

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-12 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeological Workplan and Core Document for Canyons Investigations	R-12 Field Implementation Plan	R-12 Actual Work
Slug Tests			Slug tests planned for all zones of saturation encountered.	Slug tests were conducted in the perched system, but the applicability of the results is questionable because the tests were conducted at the static water level in a confined system. Because of their questionable utility, the 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.	Anemometry and air permeability were not measured.
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
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 feet 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 feet of 5.56-in.-diameter stainless steel casing below dielectric coupling	Permanent well not completed

TABLE 9-1 (continued)

ACTIVITIES PLANNED FOR R-12 COMPARED WITH WORK PERFORMED

	Work Plan for Los Alamos Canyon and Pueblo Canyon	Hydrogeological Workplan and Core Document for Canyons Investigations	R-12 Field Implementation Plan	R-12 Actual Work
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

Steps are being taken to improve the performance of the 134-mm coring system, but it is unlikely that collection of 100% core in any regional well will be achievable within the financial constraints of the well installation program. The need for core should be considered in light of hydrogeologic characterization requirements on a hole-by-hole basis, and only enough core to satisfy sample and characterization needs should be collected. Based on experience from R-12 and R-9, goals for core collection should be clearly established in the field implementation plans for each well. However, the technical team overseeing drilling operations should have the option to modify coring plans based on drilling performance, geologic and hydrologic conditions encountered during drilling, and overall costs of the borehole.

Other modifications to R-12 planned activities were relatively minor. In some cases, ammonium, 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.

10.0 SUMMARY OF SIGNIFICANT RESULTS

In descending order, geologic units penetrated in R-12 included alluvium, tephras and volcaniclastic sediments of the Cerro Toledo interval, Otowi Member of the Bandelier Tuff (including the Guaje Pumice Bed), 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 encountered:

- Basaltic rocks of the Cerros del Rio volcanic field are 25% thicker in R-12 than in R-9. Also, the basalt sequence in R-12 contains four flow units that are separated by well-defined contacts. These flow units are correlated with four flow units in R-9.

- As in R-9, 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 is expressed by the alteration of volcanic glass to clay minerals. Similar "tuffs" were assigned to the top of the Santa Fe Group in water supply 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 to occur at the base of the Puye Formation in R-12 based on the lithologic log for nearby supply well PM-1. However, these axial deposits were not present.

- Santa Fe Group sedimentary deposits were expected on top of Miocene basalt in R-12 based on the lithologic log for PM-1. However, sedimentary deposits above the basalt are believed to be part of the Puye Formation.

- Like R-9, the top of the Santa Fe Group in R-12 consists of basalt. Samples from R-9 indicate that this basalt has a minimum eruption age of 8.45 to 8.63 Ma. This basalt correlates with basalts in the upper part of the Santa Fe Group in PM-1 (Cooper et al. 1965, 8582).

Two saturated groundwater zones were encountered during R-12 drilling operations. The tops of the saturated zones occurred at depths of 443 and 805 ft. The upper zone contains perched groundwater, and the lower is believed to be associated with the regional aquifer.

The saturated zone at a depth of 443 ft occurs in the lower part of basaltic rocks of the Cerros del Rio volcanic field and in the underlying old alluvium. Water rose in the borehole before stabilizing at a depth of 424 ft after a confining layer of massive basalt was first penetrated. Saturated porosity is provided by

fractures in basalt in the upper part of the perched zone and by unconsolidated sands and gravels in the lower part. The perching layer consists of clay-rich lake beds.

Groundwater compositions in the perched zone are dominantly a calcium-sodium-bicarbonate-chloride type. However, a sodium-calcium-chloride-sulfate-bicarbonate type groundwater also occurs within the perched zone. Tritium activities range from 208.1 ± 7.0 to 254.7 ± 16.6 pCi/L, suggesting the presence of a component of Laboratory-derived contamination in the groundwater. Concentrations of dissolved uranium range from 2.04 ± 0.28 to 2.51 ± 0.34 ppb. Concentrations of nitrate (as nitrogen) range from 0.12 to 5.5 ppm, and concentrations of ammonium (as nitrogen) range from < 0.02 to 13.5 ppm. Results of nitrogen-15/nitrogen-14 isotopic analyses (values ranging from +11.3 to +15.2 per mil) are consistent with the derivation of nitrate from a sewage source(s), possibly including the TA-3 discharge in upper Sandia Canyon. However, nitrogen-15/nitrogen-14 isotopic values of +1.3 per mil for ammonium are not consistent with a sewage source(s).

The saturated zone at a depth of 805 ft occurs in basalt within the Santa Fe Group. Groundwater in this zone is unconfined, and it is almost certainly associated with the regional aquifer. The elevation of the regional water table is the same for R-12 and R-9. The elevation of the regional water table in R-12 and R-9 is 28 to 99 ft lower than that predicted based on water levels in nearby water supply wells and on existing water level maps for the regional aquifer. The higher static water levels in nearby water supply wells are probably due to their long screen lengths, which create a composite hydraulic head for each well. The higher static water levels for the supply wells suggest that a higher hydraulic head occurs at deeper levels of the regional aquifer than those penetrated by R-12 and R-9 and that upward gradients may exist in the regional aquifer in this part of the Pajarito Plateau.

The groundwater composition at the top of the regional saturated zone is dominantly a calcium-sodium-bicarbonate type. Tritium activity was measured at 46.9 ± 1.6 pCi/L, suggesting the presence of a component of groundwater that is less than 50 years old. The concentration of dissolved uranium, 4.08 ± 0.56 ppb, is slightly elevated relative to most groundwater in the regional aquifer. The concentrations of nitrate (as nitrogen) is 0.46 ppm, which is typical of regional groundwater in the Pajarito Plateau area.

11.0 ACKNOWLEDGEMENTS

The authors of this report had the following responsibilities. 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. Broxton was the principal compiler of this report and was the technical team leader for the drilling program. Crowder was the field team leader who provided oversight of the site geologist, site safety officer, sampling, waste management activities, and health safety; he provided the description of survey activities in this report. Everett and Marin were the well-site geologists 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, and he coordinated moisture and matric potential analyses.

In addition to the authors of this report, 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, and Gray Rich.

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 Emily Kluk and Margaret Snow were analysts for moisture and matric potential determinations. Steve Chipera was the analyst for x-ray diffraction of core and cuttings.

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.

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 Fläming 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.

12.0 REFERENCES

Adams, A. I., F. Goff, and D. Counce, February 1995. "Chemical and Isotopic Variations of Precipitation in the Los Alamos Region, New Mexico," Los Alamos National Laboratory Report LA-12895-MS, Los Alamos, New Mexico. (Adams et al. 1995, ER ID 47192)

Allison, J. D., D. S. Brown, and K. J. Novo-Gradac, March 1991. "MINTEQA2/PRODEFA2, A Geochemical Assessment Model for Environmental Systems: Version 3.0 User's Manual," EPA/600/3-91/021, Office of Research and Development, Athens, Georgia. (Allison et al. 1991, ER ID 49930)

Blake, W. D., F. Goff, A. I. Adams, and D. Counce, May 1995. "Environmental Geochemistry for Surface and Subsurface Waters in the Pajarito Plateau and Outlying Areas, New Mexico," Los Alamos National Laboratory Report LA-12912-MS, Los Alamos, New Mexico. (Blake et al. 1995, ER ID 49931)

Brookins, D. G., 1984. *Geochemical Aspects of Radioactive Waste Disposal*, Springer-Verlag, New York, New York. (Brookins 1984, ER ID 12453)

Broxton, D., R. Gilkeson, P. Longmire, J. Marin, R. Warren, A. Crowder, B. Newman, B. Lowry, D. Daymon, and D. Wycoff, September 1998. "Interim Completion Report for Characterization Well R-9," Los Alamos National Laboratory Report LA-UR-98-3569, Los Alamos, New Mexico. (Broxton et al. 1998, ER ID 59158)

Clark, I. D., and P. Fritz, 1997. *Environmental Isotopes in Hydrogeology*, Lewis Publishers, New York, New York. (Clark and Fritz 1997, ER ID 59168)

Environmental Surveillance and Compliance Programs, September 1997. "Environmental Surveillance and Compliance at Los Alamos during 1996," Los Alamos National Laboratory Report LA-13343-ENV, Los Alamos, New Mexico. (Environmental Surveillance and Compliance Programs 1997, ER ID 56684)

EPA (US Environmental Protection Agency), May 1987. "Test Methods for Evaluating Solid Waste, Laboratory Manual, Physical/Chemical Methods," SW-846, Third Edition, Update III, Washington, DC. (EPA 1987, ER ID 57589)

Gee, G. W., M. D. Campbell, G. S. Campbell, and J. H. Campbell, 1992. "Rapid Measurement of Low Soil Water Potentials Using a Water Activity Meter," in *Soil Science Society of America Journal*, Vol. 56, pp. 1068–1070. (Gee et al. 1992, ER ID 58717)

Griggs, R. L., 1964. "Geology and Ground-Water Resources of The Los Alamos Area New Mexico," with a section on Quality of Water by John D. Hem, US Geological Survey Water-Supply Paper 1753, Washington, DC. (Griggs 1964, ER ID 8795)

Langmuir, D., 1997. *Aqueous Environmental Geochemistry*, Prentice-Hall, Inc., Upper Saddle River, New Jersey. (Langmuir 1997, ER ID 56037)

LANL (Los Alamos National Laboratory), October 25, 1995. "Groundwater Protection Management Program Plan" (draft), Revision 2.0, Los Alamos, New Mexico. (LANL 1995, ER ID 50124)

LANL (Los Alamos National Laboratory), November 1995. "Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon," Los Alamos National Laboratory Report LA-UR-95-2053, Los Alamos, New Mexico. (LANL 1995, ER ID 50290)

LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan" (draft), Revision 1.0, Los Alamos, New Mexico. (LANL 1996, ER ID 55430)

LANL (Los Alamos National Laboratory), April 1997. "Core Document for Canyons Investigations," Los Alamos National Laboratory Report LA-UR-96-2083, Los Alamos, New Mexico. (LANL 1997, ER ID 55622)

LANL (Los Alamos National Laboratory), September 1997. "Work Plan for Mortandad Canyon," Los Alamos National Laboratory Report LA-UR-97-3291, Los Alamos, New Mexico. (LANL 1997, ER ID 56835)

LANL (Los Alamos National Laboratory), March 1998. "Field Implementation Plan for the Drilling and Testing of LANL Regional Characterization Well R-12," Los Alamos, New Mexico. (LANL 1998, ER ID 59162)

Rogers, D. B., July 1998. "Impact of Tritium Disposal on Surface Water and Groundwater at Los Alamos National Laboratory Through 1997," Los Alamos National Laboratory Report LA-13465-SR, Los Alamos, New Mexico. (Rogers 1998, ER ID 59169)

Ryti, R. T., P. A. Longmire, D. E. Broxton, S. L. Reneau, and E. V. McDonald, May 7, 1998. "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (draft), Los Alamos National Laboratory Report, Los Alamos, New Mexico. (Ryti et al. 1998, ER ID 58093)

Stimac, J. A., D. E. Broxton, E. C. Kluk, and S. J. Chipera, 1998. "Preliminary Stratigraphy of Tuffs from Borehole 49-2-700-1 at Technical Area 49, Los Alamos National Laboratory, New Mexico," Los Alamos National Laboratory Report, Los Alamos, New Mexico. (Stimac et al. 1998, ER ID 59161)

Waresback, D. B., August 1986. "The Puye Formation, New Mexico: Analysis of a Continental, Rift-Filling, Volcaniclastic Alluvial-Fan Sequence," Master of Science in Geology thesis, University of Texas, Arlington, Texas. (Waresback 1986, ER ID 58715)

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	3/9/93	Mon	Day								Mobilized support equipment to site
1.0	3/9/93	Mon	Day	1800							T-4 drill rig arrived onsite from Salt Lake City
2.0	3/10/93	Tue	Day								Set up drilling rig and support equipment
2.0	3/10/93	Tue	Day	830	1520	0.00	20.00	20.00	410.0	2.93	Drilled open borehole from surface to 20 ft below ground surface (bgs) using 16-in. auger; alluvium, dry
2.0	3/10/93	Tue	Day	1545							Installed 16-in. surface casing from surface to 20 ft bgs
2.0	3/10/93	Tue	Day	1550	1745						Cemented 16-in. surface casing in place
2.0	3/10/93	Tue	Day								Site set up completed
3.0	3/11/93	Wed	Day								Excavated pit for casing jack cellar
3.0	3/11/93	Wed	Day								Cut 5 ft off 16-in. surface casing
3.0	3/11/93	Wed	Day								Built form for concrete base for steel casing jack cellar
3.0	3/11/93	Wed	Day								Poured concrete base for steel liner in casing jack cellar
4.0	3/12/93	Thur	Day	830							Installed steel liner in casing jack cellar
4.0	3/12/93	Thur	Day	1030							Tripped in 14-in. casing from surface to 20 ft
4.0	3/12/93	Thur	Day	1115							Installed hydraulic casing jacks in steel liner in casing jack cellar
4.0	3/12/93	Thur	Day	1430	1615						Prepared 14-in. casing advance system
5.0	3/13/93	Fri	Day	845	1735	20.00	60.00	40.00	530.0	4.53	Drilled 14-in. casing from 20 ft to 60 ft; Otowi Member, Bandelier Tuff
6.0	3/16/93	Mon	Day	725	1145	60.00	112.00	52.00	260.0	12.00	Drilled 14-in. casing from 60 ft to 112 ft; Otowi Member, Bandelier Tuff
6.0	3/16/93	Mon	Day	1145	1500	112.00	131.00	19.00	195.0	5.85	Drilled 14-in. casing from 112 ft to 131 ft; Guaje Pumice Bed of Otowi Member, Bandelier Tuff
6.0	3/16/93	Mon	Day	1500	1515	131.00	132.50	1.50	15.0	6.00	Drilled 14-in. casing from 131 ft to 132.5 ft; Paleosol atop Cerros del Rio Basalt
6.0	3/16/93	Mon	Day	1515	1545	132.50	136.00	3.50	30.0	7.00	Drilled 14-in. casing from 132.5 ft to 140 ft; weathered Cerros del Rio Basalt
6.0	3/16/93	Mon	Day	1545	1630	136.00	140.00	4.00	45.0	5.33	Drilled 14-in. casing from 132.5 ft to 140 ft; fresh Cerros del Rio Basalt
6.0	3/16/93	Mon	Day	1705	1730	140.00	0.00	140.00	35.0	240.00	Tripped out 14-in. casing advance system from 140 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
7.0	3/17/98	Tue	Day	620	750	0.00	140.00	140.00	90.0	93.33	Tripped in percussion hammer on 4-1/2-in. reverse circulation (RC) rods)
7.0	3/17/98	Tue	Day	850	902	141.00	157.00	16.00	12.0	80.00	Drilled open borehole from 141 ft to 157 ft with 4-7/8-in. RC-44 percussion hammer, fresh Cerros del Rio Basalt
7.0	3/17/98	Tue	Day	902	1159	157.00	182.00	25.00	177.0	8.47	Drilled open borehole from 157 ft to 182 ft with 4-7/8-in. RC-44 percussion hammer, fresh Cerros del Rio Basalt
7.0	3/17/98	Tue	Day	1238	1330	182.00	0.00	182.00	52.0	210.00	Tripped out percussion hammer and 4-1/2-in. RC rods from 182 ft to surface
7.0	3/17/98	Tue	Day	1400							Suspended operations to retrieve table bushing dropped in borehole
	3/20/98	Fri	Day	1700							Retrieved table bushing dropped in borehole
8.0	3/23/98	Mon	Day	630	830	0.00	140.00	140.00	120.0	70.00	Tripped in 14-in. casing advance system from surface to 140 ft
8.0	3/23/98	Mon	Day	850	1140	140.00	157.00	17.00	170.0	6.00	Drilled 14-in. casing from 140 ft to 157 ft, Cerros del Rio Basalt, rubble
8.0	3/23/98	Mon	Day	1140	1805	157.00	180.00	23.00	385.0	3.58	Drilled 14-in. casing from 157 ft to 180 ft, Cerros del Rio Basalt, massive, dry
9.0	3/24/98	Tue	Day	700	750	180.00	0.00	180.00	50.0	216.00	Tripped out 14-in. casing advance system from 180 ft to surface
9.0	3/24/98	Tue	Day	830	930	0.00	180.00	180.00	60.0	180.00	Tripped in RC-44 4-7/8-in. hammer from surface to 180 ft on 4-1/2-in. rods
9.0	3/24/98	Tue	Day	940							Stuck on casing shoe
9.0	3/24/98	Tue	Day	1000	1600						Fished with magnet, lost magnet downhole, drilled out magnet
9.0	3/24/98	Tue	Day	1600	1635	0.00	180.00	180.00	35.0	308.57	Tripped in RC-44 4-7/8-in. hammer from surface to 180 ft on 4-1/2-in. rods
9.0	3/24/98	Tue	Day	1635	1740	180.00	202.00	22.00	65.0	20.31	Drilled open borehole from 180 ft to 202 ft with 4-7/8-in. RC-44 percussion hammer, Cerros del Rio Basalt, open 184 to 189 ft
9.0	3/24/98	Tue	Day	1740	1820	202.00	222.00	20.00	40.0	30.00	Drilled open borehole from 202 ft to 222 ft with 4-7/8-in. RC-44 percussion hammer, Cerros del Rio Basalt, massive, dry
10.0	3/25/98	Wed	Day	630	705						Determined that open borehole caved below the 14-in. casing at 180 ft
10.0	3/25/98	Wed	Day	710	745	202.00	0.00	202.00	35.0	346.29	Tripped out percussion hammer and 4-1/2-in. RC rods from 202 ft to surface
10.0	3/25/98	Wed	Day	748	845	0.00	180.00	180.00	57.0	189.47	Tripped in 14-in. casing advance system from surface to 180 ft
10.0	3/25/98	Wed	Day	846	1020	180.00	190.00	10.00	94.0	6.38	Drilled 14-in. casing from 180 ft to 190 ft, Cerros del Rio Basalt, ratty, open from 184 to 189 ft
10.0	3/25/98	Wed	Day	1020	1750	190.00	220.00	30.00	450.0	4.00	Drilled 14-in. casing from 190 ft to 220 ft, Cerros del Rio Basalt, massive, 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
11.0	3/26/98	Thur	Day	630	800				90.0		Repaired seals on 14-in. rotating head to reduce dust emissions
11.0	3/26/98	Thur	Day	800	900	220.00	226.00	6.00	60.0	6.00	Drilled 14-in. casing from 220 ft to 230 ft; Cerros del Rio Basalt, ratty
11.0	3/26/98	Thur	Day	900	940	226.00	230.00	4.00	40.0	6.00	Drilled 14-in. casing from 220 ft to 230 ft; Cerros del Rio Basalt, massive, dry
11.0	3/26/98	Thur	Day	940	1300				200.0		Repaired seals on 14-in. rotating head to reduce dust emissions
11.0	3/26/98	Thur	Day	1300	1814	230.00	250.00	20.00	314.0	3.82	Drilled 14-in. casing from 230 ft to 250 ft; Cerros del Rio Basalt, massive, dry
12.0	3/27/98	Fri	Day	630	750	250.00	0.00	250.00	80.0	187.50	Tripped out 14-in. casing advance system from 250 ft to surface
12.0	3/27/98	Fri	Day	750	845				55.0		Replaced worn HOLTE™ bit on 14-in. casing advance system with new bit and wings
12.0	3/27/98	Fri	Day	845	940	0.00	250.00	250.00	55.0	272.73	Tripped in 14-in. casing advance system from surface to 250 ft
12.0	3/27/98	Fri	Day	950	1320	250.00	257.00	7.00	210.0	2.00	Drilled 14-in. casing from 250 ft to 257 ft; Cerros del Rio Basalt, massive, dry
12.0	3/27/98	Fri	Day	1320	1525	257.00	270.00	13.00	125.0	6.24	Drilled 14-in. casing from 257 ft to 270 ft; Cerros del Rio Basalt, rubble
12.0	3/27/98	Fri	Day	1525	1900	270.00	280.00	10.00	215.0	2.79	Drilled 14-in. casing from 270 ft to 280 ft; Cerros del Rio Basalt, massive, dry
13.0	3/28/98	Sat	Day	620	940	280.00	288.00	8.00	175.0	2.74	Drilled 14-in. casing from 280 ft to 313 ft, Cerros del Rio Basalt, massive, dry
13.0	3/28/98	Sat	Day	940	1400	288.00	296.00	8.00	260.0	1.85	Drilled 14-in. casing from 280 ft to 313 ft; Cerros del Rio Basalt, rubble
13.0	3/28/98	Sat	Day	1400	1800	296.00	313.00	17.00	240.0	4.25	Drilled 14-in. casing from 280 ft to 313 ft; Cerros del Rio Basalt, massive, dry
14.0	3/29/98	Sun	Day	645	800	313.00	316.50	3.50	75.0	2.80	Drilled 14-in. casing from 313 ft to 316.5 ft; fractured Cerros del Rio Basalt
14.0	3/29/98	Sun	Day	800	1615	316.50	340.00	23.50	435.0	2.85	Drilled 14-in. casing from 316.5 ft to 340 ft; massive Cerros del Rio Basalt
15.0	3/30/98	Mon	Day	900	930	340.00	342.30	2.30	30.0	4.60	Drilled 14-in. casing from 340 ft to 342.3 ft; Cerros del Rio Basalt, massive, dry
15.0	3/30/98	Mon	Day	930	1300	342.30	351.00	8.70	210.0	2.49	Drilled 14-in. casing from 342.3 ft to 351 ft, Cerros del Rio Basalt, clay-rich, mudstone, moist
15.0	3/30/98	Mon	Day	1300	1800	351.00	365.00	14.00	300.0	2.80	Drilled 14-in. casing from 351 ft to 365 ft; Cerros del Rio Basalt, massive, dry
16.0	3/31/98	Tue	Day	630	1800	365.00	397.00	32.00	690.0	2.78	Drilled 14-in. casing from 365 ft to 397 ft; Cerros del Rio Basalt, massive, 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
17.0	4/1/98	Wed	Day	640	915	397.00	400.00	3.00	155.0	1.16	Drilled 14-in. casing from 397 ft to 400 ft; Cerros del Rio Basalt, massive, dry
17.0	4/1/98	Wed	Day	915	1330				255.0		Repaired cyclone on dust suppression system
17.0	4/1/98	Wed	Day	1330	1545	400.00	405.00	5.00	255.0	1.18	Drilled 14-in. casing from 400 ft to 405 ft; Cerros del Rio Basalt, massive, dry
17.0	4/1/98	Wed	Day	1545	1810	405.00	410.00	5.00	145.0	2.07	Drilled 14-in. casing from 405 ft to 410 ft; Cerros del Rio Basalt, rubble, clay-rich, moist
18.0	4/2/98	Thur	Day	620	940	410.00	411.00	1.00	80.0	0.75	Drilled 14-in. casing from 410 ft to 411 ft; Cerros del Rio Basalt, rubble, clay-rich, moist
18.0	4/2/98	Thur	Day	940	1100				60.0		Centered 14in HOLTE™ bit in 14-in. casing
18.0	4/2/98	Thur	Day	1115	1230	412.00	0.00	412.00	75.0	329.60	Tripped out 14 in. casing advance system from 412 ft to surface
18.0	4/2/98	Thur	Day	1330	1530				120.0		Performed downhole geophysics from surface to 400 ft
18.0	4/2/98	Thur	Day	1545	1630	0.00	411.00	411.00	75.0	328.60	Tripped in IR 360 6-in. percussion hammer from surface to 411 ft on 7-in. RC rods
18.0	4/2/98	Thur	Day	1630	1645	411.00	415.00	4.00	15.0	16.00	Drilled IR. 360 percussion hammer from 411 ft to 415 ft
18.0	4/2/98	Thur	Day	1645	1735	415.00	0.00	415.00	50.0	498.00	Tripped out IR. 360 percussion hammer from 415 ft to surface on 7-in. RC rods
19.0	4/3/98	Fri	Day	648	858				130.0		Prepared Geobarrel™ 134 mm coring system
19.0	4/3/98	Fri	Day	858	1100	0.00	415.00	415.00	122.0	204.10	Tripped in Geobarrel™ 134 mm coring system from surface to 415 ft
19.0	4/3/98	Fri	Day	1100	1200	415.00	421.00	6.00	60.0	6.00	Cored from 415 ft to 421 ft with Geobarrel 134 mm coring system; recovery = 10% in saturated mudstone and basalt rubble
19.0	4/3/98	Fri	Day	1200							Dropped core tube down core rods
19.0	4/3/98	Fri	Day	1245	1330						Fished for core tube
19.0	4/3/98	Fri	Day	1330	1430	421.00	0.00	421.00	60.0	421.00	Tripped out Geobarrel 134 mm coring system from 421 ft to surface
19.0	4/3/98	Fri	Day	1635	1750	0.00	421.00	421.00	75.0	336.80	Tripped in Geobarrel 134 mm coring system from surface to 421 ft
20.0	4/6/98	Mon	Day	725							Measured depth to water (DTW) at nondetect (dry)
20.0	4/6/98	Mon	Day	726							Measured depth to bottom (DTBot) at 411.96 ft below ground zero (bgz); max core penetration=421 ft
20.0	4/6/98	Mon	Day	810	915						Cleaned corehole from 414 ft to 421 ft
20.0	4/6/98	Mon	Day	915	925	421.00	421.50	0.50	10.0	3.00	Cored from 421 ft to 421.5 ft, vesicular basalt rubble in wet clay/silt matrix
20.0	4/6/98	Mon	Day	925	1210	421.50	422.00	0.50	165.0	0.18	Coring refused
20.0	4/6/98	Mon	Day	1250	1500	422.00	0.00	422.00	130.0	194.77	Tripped out core system from 422 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
20.0	4/6/98	Mon	Day	1530	1630	0.00	410.00	410.00	60.0	410.00	Tripped in 14-in. casing advance system from surface to 410 ft
20.0	4/6/98	Mon	Day	1630	1645						Replaced core bit and prepare new 134 mm core barrel
20.0	4/6/98	Mon	Day	1645	1830	410.00	415.00	5.00	105.0	2.86	Drilled 14-in. casing from 410 ft to 415 ft; basalt with clay
21.0	4/7/98	Tue	Day	700	1028	415.00	418.00	3.00	208.0	0.87	Drilled 14-in. casing from 415 ft to 418 ft; clay plugged casing advance system
21.0	4/7/98	Tue	Day	1030	1150	418.00	0.00	418.00	80.0	313.50	Tripped out 14-in. casing advance system from 418 ft to surface
21.0	4/7/98	Tue	Day	1130	1220				50.0		Cleaned off mud packed on HOLTE™ 14-in. casing advance bit
21.0	4/7/98	Tue	Day	1250	1425	0.00	418.00	418.00	95.0	264.00	Tripped in 14-in. casing advance system from surface to 418 ft
21.0	4/7/98	Tue	Day	1455	1830	418.00	422.00	4.00	215.0	1.12	Drilled 14-in. casing from 418 ft to 422 ft; basalt and wet clay
22.0	4/8/98	Wed	Day	645	905	422.00	0.00	422.00	140.0	180.86	Tripped out 14-in. casing advance system from 244 ft to surface
22.0	4/8/98	Wed	Day	905							Obtained approval to inject 2-3 gallons of water per minute during casing advance
22.0	4/8/98	Wed	Day	915							Prepared Geobarrel™ 134 mm coring system
22.0	4/8/98	Wed	Day	1020	1200	0.00	422.00	422.00	100.0	253.20	Tripped in Geobarrel™ 134 mm coring system from surface to 422 ft
22.0	4/8/98	Wed	Day	1300	1530	422.00	423.50	1.50	150.0	0.60	Cored from 422 ft to 423.5 ft; refusal; vesicular basalt, dry
22.0	4/8/98	Wed	Day	1555	1700	423.50	0.00	423.50	65.0	390.92	Tripped out core system from 423.5 ft to surface
22.0	4/8/98	Wed	Day	1740	1810	0.00	400.00	400.00	90.0	266.67	Tripped in RC-44 4-7/8-in. hammer from surface to 400 ft on 4-1/2-in. rods
23.0	4/9/98	Thur	Day	730	750	400.00	425.00	25.00	20.0	75.00	Tripped in RC-44 4-7/8-in. hammer from 400 ft to 425 ft on 4-1/2-in. rods
23.0	4/9/98	Thur	Day	750	840	425.00	444.00	19.00	50.0	22.80	Drilled open borehole from 425 ft to 444 ft with 4-7/8-in. RC-44 percussion hammer; fresh Cerros del Rio Basalt
23.0	4/9/98	Thur	Day	840							Encountered water in borehole at 443 ft
23.0	4/9/98	Thur	Day	935	945	444.00	450.00	6.00	10.0	36.00	Drilled open borehole from 444 ft to 450 ft with 4-7/8-in. RC-44 percussion hammer; fresh Cerros del Rio Basalt
23.0	4/9/98	Thur	Day	1015	1030				15.0		Cleaned out borehole from 425 ft to 450 ft with percussion hammer
23.0	4/9/98	Thur	Day	1030	1120	450.00	0.00	450.00	50.0	540.00	Tripped out percussion hammer and 4-1/2-in. RC rods from 450 ft to surface
23.0	4/9/98	Thur	Day	1130	1200						Fished for water meter probe; lost stainless steel weight downhole
23.0	4/9/98	Thur	Day	1210					20.0		Measured DTW in 1st perched water zone (PWZ) at 424.89 ft bgz
23.0	4/9/98	Thur	Day	1230		424.89	424.59	0.30	20.0	0.9000	Measured DTW in 1st PWZ at 424.59 ft bgz
23.0	4/9/98	Thur	Day	1300		424.59	424.52	0.07	30.0	0.1400	Measured DTW in 1st PWZ at 424.52 ft bgz
23.0	4/9/98	Thur	Day	1315	1500	0.00	422.00	422.00	105.0	241.14	Tripped in 134 mm core rods from surface to 422 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
23.0	4/9/98	Thur	Day	1515	1750				155.0		Purged ~35 gal of water from 1st perched water zone (PWZ)
	4/10/98	Fri	Day	815		424.52	424.68	0.16	1155.0	0.0083	Measured DTW in 1st PWZ at 424.68 ft bgz
	4/10/98	Fri	Day	1230		424.68	424.47	0.21	255.0	0.0494	Measured DTW in 1st PWZ at 424.47 ft bgz
	4/10/98	Fri	Day	1500	1730				150.0		Purged ~25 gal of water from 1st perched water zone (PWZ)
	4/11/98	Sat	Day	1040		424.47	424.33	0.14	1330.0	0.0063	Measured DTW in 1st PWZ at 424.33 ft bgz
	4/11/98	Sat	Day	1200							Set transducer at 438 ft bgz
	4/11/98	Sat	Day	1230							Set slug bottom at 437 ft bgz; 10 ft long, 2-in.-diameter PVC filled with sand
	4/12/98	Sun	Day	1000							Withdrew slug 12 ft and ran 1st slug test on 1st PWZ
	4/12/98	Sun	Day	1330							Reset slug bottom at 437 ft bgz
	4/12/98	Sun	Day	1848							Withdrew slug 12 ft and ran 2nd slug test on 1st PWZ
24.0	4/13/98	Mon	Day	715							Withdrew slug and transducer from borehole
24.0	4/13/98	Mon	Day	745		424.33	424.36	0.03	2315.0	0.0008	Measured DTW in 1st PWZ at 424.36 ft bgz
24.0	4/13/98	Mon	Day	920	1015						Collected 15 gal of 1st PWZ using 5 ft, 4-in. bottom filling stainless steel bailer w/ closed lifting sub & Teflon bottom cap and ball
24.0	4/13/98	Mon	Day	1100	1230						Tripped out 134 mm core rods from 422 ft to surface
24.0	4/13/98	Mon	Day	1330	1500	0.00	422.00	422.00	90.0	332.00	Tripped in 14-in. casing advance system from surface to 422 ft
25.0	4/14/98	Tue	Day	745	845	422.00	425.00	3.00	60.0	3.00	Drilled 14-in. casing from 422 ft to 440 ft; fresh Cerros del Rio Basalt, local clay
25.0	4/14/98	Tue	Day	845	1500	425.00	448.00	23.00	375.0	3.68	Drilled 14-in. casing from 425 ft to 448 ft; fresh massive Cerros del Rio Basalt
25.0	4/14/98	Tue	Day	1500	1600				160.0		Centered 14-in. HOLTE™ bit in 14-in. casing
26.0	4/15/98	Wed	Day	600	730				90.0		Centered 14-in. HOLTE™ bit in 14-in. casing
26.0	4/15/98	Wed	Day	730	845	448.00	449.00	1.00	75.0	0.80	Drilled 14-in. casing from 448 ft to 449 ft; fresh massive Cerros del Rio Basalt
26.0	4/15/98	Wed	Day	845	900				15.0		Centered 14-in. HOLTE™ bit in 14-in. casing
26.0	4/15/98	Wed	Day	900	1030	449.00	0.00	449.00	90.0	299.33	Tripped out 14-in. casing advance system from 449 ft to surface
26.0	4/15/98	Wed	Day	1110		424.36	427.75	3.33	3070.0	0.0663	Measured DTW in 1st PWZ at 427.75 ft bgz
26.0	4/15/98	Wed	Day	1145		427.75	427.36	0.33	35.0	0.6686	Measured DTW in 1st PWZ at 427.36 ft bgz
26.0	4/15/98	Wed	Day	1215		427.36	427.22	0.14	30.0	0.2800	Measured DTW in 1st PWZ at 427.22 ft bgz
26.0	4/15/98	Wed	Day	1245		427.22	426.94	0.28	30.0	0.5600	Measured DTW in 1st PWZ at 426.94 ft bgz
26.0	4/15/98	Wed	Day	1315		426.94	426.86	0.08	30.0	0.1600	Measured DTW in 1st PWZ at 426.86 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
26.0	4/15/93	Wed	Day	1315	1355				40.0		Prepared to mill 14-in. bit
26.0	4/15/93	Wed	Day	1355	1530	0.00	448.00	448.00	95.0	282.95	Tripped in 14-in. casing shoe milling bit from surface to 448 ft on 7-in. RC rods
26.0	4/15/98	Wed	Day	1530	1730	448.00	448.30	0.30	120.0	0.15	Milled 14-in. casing shoe
27.0	4/16/93	Thur	Day	630	1830	448.30	449.00	0.70	720.0	0.06	Milled 14-in. casing shoe
28.0	4/17/98	Fri	Day	630	805				90.0		Tripped out 14-in. casing shoe milling bit from 449 ft to surface on 7-in. RC rods
28.0	4/17/98	Fri	Day	830		426.66	427.24	0.38	2595.0	0.0068	Measured DTW in 1st PWZ at 427.24 ft bgz
28.0	4/17/93	Fri	Day	845							Measured 14 in. milling bit and rebuild
28.0	4/17/93	Fri	Day	925		427.24	426.96	0.28	55.0	0.3055	Measured DTW in 1st PWZ at 427.24 ft bgz
28.0	4/17/98	Fri	Day	935	1025	0.00	448.00	448.00	50.0	537.60	Tripped in 14-in. casing shoe milling bit from surface to 448 ft on 7-in. RC rods
28.0	4/17/93	Fri	Day	1030	1100				30.0		Milled lost DTW meter weight
28.0	4/17/98	Fri	Day	1100	1305	449.00	0.00	449.00	125.0	215.52	Tripped out 14-in. casing shoe milling bit from 449 ft to surface on 7-in. RC rods
28.0	4/17/93	Fri	Day	1320		443.00	446.50	2.50			Added 3 sacks of sand from 443 ft to 446.5 ft
28.0	4/17/93	Fri	Day	1330		426.96	425.43	1.47	245.0	0.3600	Measured DTW in 1st PWZ at 425.43 ft bgz
28.0	4/17/98	Fri	Day	1400	1420	443.00	446.50	2.50	20.0	7.5000	Pulled back 14-in. casing from 443 ft to 446.5 ft
28.0	4/17/93	Fri	Day	1425	1435	0.00	447.20	447.20	10.0	2683.20	Tripped in grout packer from surface to 446.5 ft
28.0	4/17/93	Fri	Day	1445							Mixed grout; 40 gal water to 3-50 lb bags of Baroid Aquaguard (granular bentonite); grout mixture on mud balance = 9.9 lbs/gal
28.0	4/17/93	Fri	Day	1715	1730				15.0		Pumped grout down center tube in 4.5-in. RC rods followed by 120 gals water and rubber cement "rabbit"
28.0	4/17/93	Fri	Day	1730	1805	446.50	448.00	1.50	35.0	2.57	Drove 14-in. casing from 446.5 ft to 448 ft using RC-44 percussion hammer atop drive plate at rig table
28.0	4/17/98	Fri	Day	1805							Landed 14-in. casing at 449 ft
28.0	4/17/93	Fri	Day	1815		425.43	422.00	3.43	265.0	0.7347	Measured DTW in 1st PWZ at 419.14 ft bgz
29.0	4/20/93	Mon	Day	635		422.00	421.95	0.05	3620.0	0.0008	Measured DTW in 1st PWZ at 419.09 ft bgz
29.0	4/20/98	Mon	Day	645	805	449.00	0.00	449.00	80.0	336.75	Tripped out grout packer from 449 ft to surface
29.0	4/20/93	Mon	Day	810		421.95	425.60	3.65	95.0	2.3063	Measured DTW in 1st PWZ at 425.6 ft bgz
29.0	4/20/93	Mon	Day	850	940	0.00	446.00	446.00	50.0	535.20	Tripped in 8-in. percussion bit from surface to 446 ft on 7-in. RC rods
29.0	4/20/93	Mon	Day	945	1000				15.0		Airlifted water out of 14-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
29.0	4/20/98	Mon	Day	1000	1045	448.00	458.00	10.00	45.0	13.33	Drilled open borehole from 448 ft to 458 ft with 8-in. percussion hammer; no recovery of cuttings; ratty from 450 ft to 458 ft
29.0	4/20/98	Mon	Day	1105	1145	458.00	0.00	458.00	40.0	687.00	Tripped out 8-in. percussion hammer from 458 ft to surface on 7-in. RC rods
29.0	4/20/98	Mon	Day	1147		425.60	433.80	8.20	217.0	2.2673	Measured DTW in 1st PWZ at 433.8 ft bgz
29.0	4/20/98	Mon	Day	1220		433.80	439.80	6.00	33.0	10.9091	Measured DTW in 1st PWZ at 439.8 ft bgz
29.0	4/20/98	Mon	Day	1245		439.80	436.80	3.00	25.0	7.2000	Measured DTW in 1st PWZ at 436.8 ft bgz
29.0	4/20/98	Mon	Day	1305		436.80	435.80	1.00	20.0	3.0000	Measured DTW in 1st PWZ at 436.8 ft bgz
29.0	4/20/98	Mon	Day	1410		435.80	430.12	5.68	65.0	5.2431	Measured DTW in 1st PWZ at 430.12 ft bgz
29.0	4/20/98	Mon	Day	1430	1750	0.00	140.00	140.00	200.0	42.00	Tripped in 12-3/4 in. casing from surface to 140 ft
29.0	4/20/98	Mon	Day	1755		430.12	425.69	4.43	225.0	1.1813	Measured DTW in 1st PWZ at 425.69 ft bgz
30.0	4/21/98	Tue	Day	645		425.69	424.68	1.01	770.0	0.0787	Measured DTW in 1st PWZ at 424.68 ft bgz
30.0	4/21/98	Tue	Day	715	1110	140.00	310.00	170.00	235.0	43.40	Tripped in 12-3/4-in. casing from 140 ft to 310 ft
30.0	4/21/98	Tue	Day	1125		424.68	424.71	0.03	280.0	0.0064	Measured DTW in 1st PWZ at 424.68 ft bgz
30.0	4/21/98	Tue	Day	1230	1500	310.00	448.00	138.00	150.0	55.20	Tripped in 12-3/4-in. casing from 310 ft to 448 ft
30.0	4/21/98	Tue	Day	1500	1810				190.0		Repaired 12-3/4-in. casing advance system packoff
31.0	4/22/98	Wed	Day	645	1300				375.0		Opened 12-3/4-in. casing advance bit at 448 ft
31.0	4/22/98	Wed	Day	1500	1700	448.00	459.00	11.00	120.0	5.50	Drilled 12-3/4-in. casing from 448 ft to 459 ft; fresh massive Cerros del Rio Basalt, dry
32.0	4/23/98	Thur	Day	645	1115	459.00	464.00	5.00	210.0	1.43	Drilled 12-3/4 in. casing from 459 ft to 464 ft; fresh massive Cerros del Rio Basalt, dry
32.0	4/23/98	Thur	Day	1400	1530	464.00	0.00	464.00	90.0	309.33	Tripped out 12-3/4-in. casing from 464 ft to surface
32.0	4/23/98	Thur	Day	1545	1630				45.0		Prepared grout packer for 12-3/4-in. casing seal
32.0	4/23/98	Thur	Day	1630		424.71	425.43	0.78	3165.0	0.0147	Measured DTW in 1st PWZ at 425.43 ft bgz
32.0	4/23/98	Thur	Day	1635	1730	0.00	464.00	464.00	55.0	506.18	Tripped in grout packer from surface to 464 ft
32.0	4/23/98	Thur	Day	1640							Lost steel weight from DTW meter probe
32.0	4/23/98	Thur	Day	1730	1800				30.0		Mixed grout; 75 gal from 4-50 lb bags of Baroid Aquaguard (granular bentonite)
32.0	4/23/98	Thur	Day	1800	1830						Pumped grout down center tube in 4.5-in. RC rods followed by 150 gal's water and rubber cement "rabbit"
32.0	4/23/98	Thur	Day	1830		425.43	428.14	2.65	120.0	1.3250	Measured DTW in 1st PWZ at 428.14 ft bgz
33.0	4/24/98	Fri	Day	630		428.14		#VALUE!	425.0	#VALUE!	Measured DTW in 1st PWZ at _____ 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
33.0	4/24/98	Fri	Day	635	745	464.00	0.00	464.00	70.0	397.71	Tripped out grout packer from 464 ft to surface
33.0	4/24/98	Fri	Day	745			424.69	#VALUE!	75.0	#VALUE!	Measured DTW in 1st PWZ at 424.69 ft bgz
33.0	4/24/98	Fri	Day	945		424.69	424.73	0.04	120.0	0.0200	Measured DTW in 1st PWZ at 424.73 ft bgz
33.0	4/24/98	Fri	Day	1010	1120	0.00	464.00	464.00	70.0	397.71	Tripped in 6-in. IR 360 percussion hammer & centralizer on 7-in. RC rods
33.0	4/24/98	Fri	Day	1135	1225	464.00	472.00	8.00	50.0	9.60	Drilled open borehole from 464 ft to 472 ft with 6-in. IR-360 percussion hammer; fresh Cerros del Rio Basalt, airlifted – 200 gal water during drilling
33.0	4/24/98	Fri	Day	1320	1400	472.00	0.00	472.00	40.0	708.00	Tripped out 6-in. IR-360 percussion hammer from 474 ft to surface on 7-in. RC rods
33.0	4/24/98	Fri	Day	1615		424.73	467.68	42.95	330.0	6.6077	Measured DTW in 1st PWZ at 457.68 ft bgz
33.0	4/24/98	Fri	Day	1630	1735	0.00	472.00	472.00	65.0	435.69	Tripped in 134 mm core rods from surface to 472 ft
34.0	4/27/98	Mon	Day	650		467.63	447.23	20.40	3740.0	0.3273	Measured DTW in 1st PWZ at 447.23 ft bgz
34.0	4/27/98	Mon	Day	700	805	472.00	473.00	1.00	65.0	0.92	Cored from 472 ft to 473 ft; no recovery
34.0	4/27/98	Mon	Day	820	1000	473.00	0.00	473.00	100.0	283.80	Tripped out 134 mm core system from 473 ft to surface; recovered 8-in. of dry, fractured slightly vesicular basalt & 3-in. on stainless steel DTW meter probe weight
34.0	4/27/98	Mon	Day	1030							Collected 5 gal of 1st PWZ using 10 ft, 4-in. top filling stainless steel bailer w/ open lifting sub
34.0	4/27/98	Mon	Day	1045	1200	0.00	464.00	464.00	75.0	371.20	Tripped in 12-3/4-in. casing advance system from surface to 464 ft
34.0	4/27/98	Mon	Day	1240	1815	464.00	474.00	10.00	335.0	1.79	Drilled 12-3/4-in. casing from 464 ft to 474 ft; fresh massive Cerros del Rio Basalt, dry
35.0	4/28/98	Tue	Day	700	1200	474.00	483.00	9.00	300.0	1.80	Drilled 12-3/4-in. casing from 474 ft to 483 ft; fresh massive Cerros del Rio Basalt, wet
35.0	4/28/98	Tue	Day	1300	1400	483.00	0.00	483.00	60.0	483.00	Tripped out 12-3/4-in. casing advance system from 483 ft to surface
35.0	4/28/98	Tue	Day	1355		447.23	425.60	21.43	1665.0	0.6910	Measured DTW in 1st PWZ at 425.8 ft bgz
35.0	4/28/98	Tue	Day	1400							Added 1/2 bag of granular Benseal bentonite at base of 12-3/4-in. casing
35.0	4/28/98	Tue	Day	1425		425.80	425.45	0.35	30.0	0.7000	Measured DTW in 1st PWZ at 425.45 ft bgz
35.0	4/28/98	Tue	Day	1500	1550	0.00	483.00	483.00	50.0	579.60	Tripped in 134 mm core rods with cutting shoe from surface to 483 ft
35.0	4/28/98	Tue	Day	1715	1800	0.00	483.00	483.00	45.0	644.00	Tripped in 101 mm core system from surface to 483 ft
35.0	4/28/98	Tue	Day	1615		425.45	424.72	0.73	60.0	0.7300	Measured DTW between 134 mm core rods and 12-3/4-in. casing at 424.72 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
35.0	4/28/98	Tue	Day	1825			483.00				Measured DTW inside 101 mm core rods at dry (nondetect)
35.0	4/28/98	Tue	Day	1826							Measured DTBot inside 101 mm core rods at 483 ft bgz
36.0	4/29/98	Wed	Day	635		424.72	424.92	0.20	740.0	0.0162	Measured DTW between 134 mm core rods and 12-3/4-in. casing at 424.92 ft bgz
36.0	4/29/98	Wed	Day	645		483.00	483.00	0.00			Measured DTW inside 101 mm core rods at dry (nondetect)
36.0	4/29/98	Wed	Day	700	915	483.00	485.70	2.70	135.0	1.20	Cored from 483 ft to 485.7 ft with 101 mm core system; massive basalt, local saturation
36.0	4/29/98	Wed	Day	917		483.00	428.46	54.54	92.0	35.57	Measured DTW inside 101 mm core rods at 428.46 ft bgz
36.0	4/29/98	Wed	Day	930	1630	485.70	495.30	9.60	420.0	1.37	Cored from 485.7 ft to 495.3 w/ft 101 mm core system; massive basalt w/ local saturation to 488.2 ft; clay-rich basalt breccia to 488.9 ft; vitric basaltic ash to 491.6 ft; sandstone to 495.0 ft; and quartzitic gravel to 495.3 ft, all saturated
36.0	4/29/98	Wed	Day	1700	1840				100.0		Collected 10 gal from 1st PWZ using
37.0	4/30/98	Thur	Day	630	830	495.30	0.00	495.30	120.0	247.65	Tripped out 101 mm coring system from 495.3 ft to surface
37.0	4/30/98	Thur	Day	830	1010	483.00	0.00	483.00	100.0	289.80	Tripped out 134 mm coring system from 483.0 ft to surface
37.0	4/30/98	Thur	Day	1030	1200	0.00	483.00	483.00	90.0	322.00	Tripped in 12-3/4-in. casing advance system from surface to 483.0 ft
37.0	4/30/98	Thur	Day	1340	1800	483.00	486.00	3.00	260.0	0.69	Drilled 12-3/4-in. casing from 483.0 ft to 486.0 ft
38.0	5/1/98	Fri	Day	640	830	486.00	486.00	0.00	110.0		Drilled 12-3/4-in. casing from 486.0 ft to 486.0 ft
38.0	5/1/98	Fri	Day	830							12-3/4-in. casing separated
	5/2/98	Sat	Day								Fished for separated 12-3/4-in. casing
	5/3/98	Sun	Day								Fished for separated 12-3/4-in. casing
39.0	5/4/98	Mon	Day	630	830	486.00	0.00	486.00	120.0	243.00	Tripped out fishing tool (spear) to recover 12-3/4-in. casing
39.0	5/4/98	Mon	Day	900	1030	0.00	486.00	486.00	90.0	324.00	Tripped in fishing tool (spear) to recover 12-3/4-in. casing
39.0	5/4/98	Mon	Day	1040	1800	486.50	243.00	243.00	440.0	33.14	Fished for separated 12-3/4-in. casing
40.0	5/5/98	Tue	Day	640	930				110.0		Fished for and recovered all separated 12-3/4-in. casing
40.0	5/5/98	Tue	Day	1000	1800				560.0		Recovered fishing spear from 12-3/4-in. casing and prepared 10-3/4-in. casing for mobilization to site
41.0	5/6/98	Wed	Day	745	1430	0.00	460.00	460.00	405.0	71.11	Tripped in 10-3/4-in. casing from surface to 460 ft
41.0	5/6/98	Wed	Day	1445	1700	0.00	460.00	460.00	135.0	213.33	Tripped in 10-3/4-in. casing advance system from surface to 460 ft
41.0	5/6/98	Wed	Day	1850				0.00			Added 2 bags of 3/8-in. bentonite chips between 14-in. and 10-3/4-in. casings
42.0	5/7/98	Thur	Day	630	1200				330.0		Realigned drill rig on borehole

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
42.0	5/7/98	Thur	Day	1245	1430	486.00	508.00	22.00	105.0	12.57	Drilled 10-3/4-in. casing from 486.0 ft to 508 ft; quartzitic gravel from 435.3 ft to 505 ft; and axial Rio Grande cobbles w/ local thin silty sand to 508 ft; all saturated
42.0	5/7/98	Thur	Day	1600	1730	508.00	0.00	508.00	90.0	338.67	Tripped out 10-3/4-in. casing advance system from 508.0 ft to surface
43.0	5/8/98	Fri	Day	630		428.46	424.00	4.46	12793.0	0.0209	Measured DTW inside 10-3/4-in. casing at 428.46 ft bgz
43.0	5/8/98	Fri	Day	645	805	0.00	508.00	508.00	60.0	381.00	Tripped in drive sampler in 4-in. RC rods from surface to 508 ft
43.0	5/8/98	Fri	Day	810	823	508.00	510.70	2.70	13.0	12.46	Drilled drive sampler from 508.0 ft to 510.7 ft; axial Rio Grande cobbles w/ local thin silty sand to 509 ft; fine-med grained sandstone to 510.7 ft; all saturated
43.0	5/8/98	Fri	Day	823	920	510.70	0.00	510.70	57.0	537.58	Tripped out drive sampler on 4-in. RC rods from 510.7 ft to surface
43.0	5/8/98	Fri	Day	1020		424.00	423.66	0.34	230.0	0.0887	Measured DTW inside 10-3/4-in. casing at 423.66 ft bgz
43.0	5/8/98	Fri	Day	1030	1305	0.00	512.50	512.50	155.0	198.39	Tripped in 134 mm core rods w/ shoe from surface to 512.5 ft
43.0	5/8/98	Fri	Day	1420		423.66	426.87	3.21	240.0	0.8025	Measured DTW inside 134 mm core rods at 426.87 ft bgz
43.0	5/8/98	Fri	Day	1421							Measured DTBot inside 134 mm core rods at 511.04 ft. bgz
43.0	5/8/98	Fri	Day	1430	1530	0.00	511.00	511.00	60.0	511.00	Tripped in 101 mm core system from surface to 511.0 ft
43.0	5/8/98	Fri	Day	1545	1600	511.00	520.00	9.00	135.0	4.00	Cored from 511.0 ft to 520.0 ft; pinkish orange fine-med grained silty sandstone to 519.1 ft; no recovery from 519.1 ft to 520.0 ft
43.0	5/8/98	Fri	Day	1815		426.87	444.18	17.31	235.0	4.4196	Measured DTW inside 101 mm core rods at 444.18 ft bgz
44.0	5/11/98	Mon	Day	720		444.18	425.63	18.43	765.0	1.41	Measured DTW inside 101 mm core rods at 425.94 ft bgz
44.0	5/11/98	Mon	Day	740	900	520.00	0.00	520.00	60.0	330.00	Tripped out 101 mm core system from 520 ft to surface
44.0	5/11/98	Mon	Day	1000	1100	520.00	0.00	520.00	60.0	520.00	Tripped out 134 mm core system from 520 ft to surface
44.0	5/11/98	Mon	Day	1720	1750	0.00	520.00	520.00	30.0	1040.00	Tripped drive sampler system to 520 ft
45.0	5/12/98	Tue	Day	635				0.00			Measured DTW inside casing at nondetect (dry at 500 ft. bgz)
45.0	5/12/98	Tue	Day	915				0.00			Measured DTW inside casing at nondetect (dry at 521.21 ft. TOC)
45.0	5/12/98	Tue	Day	930	1500			0.00			Mobilized 8-5/8-in. casing to drill site
45.0	5/12/98	Tue	Day	1515	1520	520.00	520.50	0.50	5.0	6.0000	Drilled 10-3/4-in. with top hammer
45.0	5/12/98	Tue	Day	1515	1700			0.00			Assembled 8-in. drilling system
45.0	5/12/98	Tue	Day	1705				0.00			Measured DTW inside casing at 518.83 ft. bgz
45.0	5/12/98	Tue	Day	1705	1740	0.00	520.00	520.00	35.0	891.43	Tripped in 8-in. drilling system
45.0	5/12/98	Tue	Day	1740	1750	520.00	523.00	3.00	10.0	18.00	Drilled 8-5/8-in. pilot hole for casing in clay
45.0	5/12/98	Tue	Day					0.00			
46.0	5/13/98	Wed	Day	635	740	523.00	0.00	523.00	65.0	482.77	Tripped out 8-in. hammer bit

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
51.0	5/20/98	Wed	Day	928	1000	741.30	746.00	4.70	32.0	8.81	Cored from 741.3 to 746 with 101 mm core system
51.0	5/20/98	Wed	Day	1040	1120	746.00	751.30	5.30	30.0	10.60	Cored from 746 to 751.3 with the 101 mm core system
51.0	5/20/98	Wed	Day	1120	1205	751.30	756.00	4.70	45.0	6.27	Cored from 751.3 to 756 with the 101 mm core system
51.0	5/20/98	Wed	Day	1250	1305	756.00	761.00	5.00	15.0	20.00	Cored from 756 to 761 with the 101 mm core system
51.0	5/20/98	Wed	Day	1330	1408	761.00	766.00	5.00	33.0	7.83	Cored from 761 to 766 with the 101 mm core system
51.0	5/20/98	Wed	Day	1408	1445	766.00	771.00	5.00	37.0	8.11	Cored from 766 to 771 with the 101 mm core system
51.0	5/20/98	Wed	Day	1445	1540	771.00	776.00	5.00	55.0	5.45	Cored from 771 to 776 with the 101 mm core system
51.0	5/20/98	Wed	Day	1545	1720			0.00			Ream hole and casing
51.0	5/20/98	Wed	Day	1755	1820	776.00	776.80	0.80	25.0	1.92	Cored from 776 to 776.8 with the 101 mm core system
	5/20/98	Wed	Day	1830				0.00			Measured DTW at dry to 776.8
52.0	5/21/98	Thur	Day	650				0.00			Measured DTW at dry to 776.8
52.0	5/21/98	Thur	Day	1030	1320	773.50	0.00	773.50	170.0	275.12	Tripped out 101 mm core system
55.0	5/26/98	Tue	Day	930	1000			0.00			Set up for borehole geophysics
55.0	5/26/98	Tue	Day	1000	1100	0.00	655.00	655.00	60.0	655.00	Run natural gamma log inside casing
55.0	5/26/98	Tue	Day	1100	1315	710.00	0.00	710.00	135.0	315.56	Run caliper from bottom of 8-5/8-in. casing to surface
56.0	5/27/98	Wed	Day	740	1100	0.00	710.00	710.00	200.0	213.00	Tripped in 8-5/8-in. drill system
56.0	5/27/98	Wed	Day	1130	1205	710.00	720.00	10.00	35.0	17.14	Drilled 8-5/8-in. casing while injecting water at 1.5 gpm
56.0	5/27/98	Wed	Day	1205	1255	720.00	730.00	10.00	50.0	12.00	Drilled 8-5/8-in. casing while injecting water at 1.5 gpm
56.0	5/27/98	Wed	Day	1400	1600	730.00	740.00	10.00	120.0	5.00	Drilled 8-5/8-in. casing while injecting water at 1.5 gpm
56.0	5/27/98	Wed	Day	1600	1830	740.00	630.00	50.00	150.0	20.00	Ream hole back to 630
57.0	5/28/98	Thur	Day	645	900	690.00	640.00	50.00	135.0	22.22	Tripped out 8-5/8-in. casing from 690 to 640
57.0	5/28/98	Thur	Day	900	1030	640.00	737.00	97.00	90.0	64.67	Tripped in 8-5/8-in. drill system
57.0	5/28/98	Thur	Day	1030	1040	737.00	740.00	3.00	10.0	18.00	Clean out bottom of hole
57.0	5/28/98	Thur	Day	1110	1150	740.00	750.00	10.00	40.0	15.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1225	1245	750.00	753.00	3.00	20.0	9.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1315	1330	753.00	760.00	7.00	15.0	28.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1410	1440	760.00	770.00	10.00	30.0	20.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1440	1540	770.00	780.00	10.00	60.0	10.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1600	1615	780.00	785.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1650	1705	785.00	790.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing through basalt. Injecting water
57.0	5/28/98	Thur	Day	1720	1810	790.00	795.00	5.00	50.0	6.00	Drilled 8-5/8-in. casing through basalt. 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
57.0	5/28/93	Thur	Day	1810	1825	795.00	800.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	640				0.00			Measured DTW at dry to 730
58.0	5/29/93	Fri	Day	700	715	800.00	805.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	715	740	805.00	810.00	5.00	25.0	12.00	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	754	837	810.00	815.00	5.00	43.0	6.98	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	837	910	815.00	820.00	5.00	33.0	9.09	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	1000				0.00			Encountered water in borehole at 804.64 ft
58.0	5/29/93	Fri	Day	1015	1040	820.00	823.00	3.00	25.0	7.20	Drilled 8-5/8-in. casing through basalt. Formation water
58.0	5/29/93	Fri	Day	1143	1230	830.00	835.00	5.00	50.0	6.00	Drilled 8-5/8-in. casing through basalt. Formation water
58.0	5/29/93	Fri	Day	1230	1344	835.00	840.00	5.00	74.0	4.05	Drilled 8-5/8-in. casing through basalt. Formation water
58.0	5/29/93	Fri	Day	1440				0.00			Measured DTW at 807.17' bgz
58.0	5/29/93	Fri	Day	1500	1545			0.00			Collect water sample from cyclone
58.0	5/29/93	Fri	Day	1545	1645			0.00			Ream borehole
58.0	5/29/93	Fri	Day	1645	1758	840.00	0.00	840.00	73.0	690.41	Tripped out 8-5/8-in. drilling system
59.0	6/1/93	Mon	Day	700				0.00			Measured DTW at 804.79' bgz
59.0	6/1/93	Mon	Day	1000	1120	847.00	0.00	847.00	80.0	635.25	Tripped out 6-in. hammer bit
59.0	6/1/93	Mon	Day	1225	1335	0.00	840.00	840.00	70.0	720.00	Tripped in 8-5/8 in. drill system
59.0	6/1/93	Mon	Day	1335	1615			0.00	160.0		Unscheduled repairs: hydraulic line behind control panel broke
59.0	6/1/93	Mon	Day	1615	1805	840.00	830.00	10.00	110.0	5.45	Retracted 8-5/8-in. casing
60.0	6/2/93	Tue	Day	700	1125	830.00	740.00	90.00	265.0	20.38	Retracted 8-5/8-in. casing
60.0	6/2/93	Tue	Day	1247	1300	740.00	720.00	20.00	13.0	92.31	Retracted 8-5/8-in. casing
60.0	6/2/93	Tue	Day	1300	1430	720.00	833.00	113.00	90.0	75.33	Reamed borehole
60.0	6/2/93	Tue	Day	1500	1600			0.00	60.0		Airlift development
60.0	6/2/93	Tue	Day	1645	1750	833.00	0.00	833.00	65.0	768.92	Tripped out 8-5/8-in. drill system
61.0	6/3/93	Wed	Day	910	1030	0.00	800.00	800.00	80.0	600.00	Tripped in 1-in. tremmie pipe
61.0	6/3/93	Wed	Day	1055	1200			0.00	65.0		Emplaced bottom sand pack and bentonite seal upto 829.93 ft bgz
61.0	6/3/93	Wed	Day	1240	1447	0.00	830.00	830.00	127.0	392.13	Tripped 4-in. schedule 40 PVC casing in the hole.
61.0	6/3/93	Wed	Day	1600	1700			0.00			Emplaced bentonite upto 826.5 ft bgz
61.0	6/3/93	Wed	Day	1745	1820			0.00			Emplaced sand pack across screened interval.
62.0	6/4/93	Thur	Day	730				0.00			Measured DTW at 804.42 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
62.0	6/4/98	Thur	Day	730	950			0.00			Emplaced sand pack across screened interval. Temporary well completed
62.0	6/4/98	Thur	Day	950	1030	795.00	790.00	5.00	40.0	7.50	Retracted 8-5/8-in. casing
62.0	6/4/98	Thur	Day	1030	1145	800.00	0.00	800.00	75.0	640.00	Tripped out tremmie pipe
62.0	6/4/98	Thur	Day	1245	1630			0.00			Rig down
63.0	6/5/98	Fri	Day	730	920			0.00			Site cleanup
63.0	6/5/98	Fri	Day	1000	1155			0.00			Bail well for water sample
63.0	6/5/98	Fri	Day	1240	1735			0.00			Bail well for water sample
64.0	6/8/98	Mon	Day	800				0.00			Measured DTW at 801.64 ft(?). This measurement questionable because other DTWs are typically ~805 ft
64.0	6/8/98	Mon	Day	835	850			0.00	15.0		Water sample collection
64.0	6/8/98	Mon	Day	900	1630			0.00	450.0		Site cleanup
65.0	6/9/98	Tue	Day	800	1535			0.00	455.0		Site cleanup, including spilled diesel

Appendix B

Lithologic Log

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System)

GROUND ELEVATION: 6500.73' (based on SCOI-3)

TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
0	6500						ALLUVIUM: (0-12.5 ft) Sandy, dry alluvium, predominantly quartz and feldspar grains.		Qal
5	6495					-122 (5.0'-5.1')			
10	6490					-123 (10.0'-10.1')			
15	6485					-124 (15.0'-15.1')	CERRO TOLEDO INTERVAL: (12.5-31.3 ft) Vitric reworked tuff with common tiny pumice to 1 mm and scarce lithics to 1.5 mm. A pumice-rich zone occurs between 27-28' and a clast-rich zone occurs between 28-31.3'.		Qct
20	6480					-125 (19.9'-20.0')			
25	6475				Geochem (-0001)	-126 (24.9'-25.0')			
30	6470					-127 (29.9'-30.0')			
35	6465				Geochem (-0002)	-128 (33.9'-34.0')	OTOWI MEMBER OF BANDELIER TUFF: (31.3-102 ft) Vitric nonwelded tuff with common pumice to 7 mm and less common lithics of intermediate composition.		Qbo
40	6460					-129 (39.9'-40.0')			
45	6455					-130 (43.9'-44.0')			
50	6450					-131 (48.9'-49.0')			
55	6445					-132 (54.9'-55.0')			
60	6440					-133 (59.9'-60.0')			
65	6435					-134 (64.9'-65.0')			
70	6430					-135 (69.9'-70.0')			
75	6425					-136 (74.9'-75.0')			
80	6420					-137 (79.9'-80.0')			
85	6415					-138 (84.9'-85.0')			
90	6410					-139 (89.9'-90.0')			
95	6405					-140 (94.9'-95.0')			
100	6400					-141 (99.0'-100.0')			
105	6395					-142 (104.9'-105.0')	OTOWI MEMBER OF BANDELIER TUFF: (102-112 ft) Variably pumice-rich nonwelded ash flow tuff. Very pumice rich at 104.9 to 105'.		Qbo
110	6390					-143 (109.0'-110.0')			
115	6385					-144 (114.9'-115.0')	GUAJE PUMICE BED: (112-131 ft) Vitric bedded tuff, including laminated vitric ash. Lithics include basalt.		Qbog
120	6380					-201 (118.3'-120.0') -202 (121.0'-122.0')			
125	6375				Geochem (-0003)				

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geochemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
130	6370					-203 (129.0-130.0) -204 (130.0-131.0) -205 (131.3-131.0)			
135	6365				Geochem (-0004)	-206 (132.0-134.0) -207 (134.0-135.0) -208 (135.0-137.0) -209 (138.3-138.0) -210 (139.0-140.0)	PALEOSOL: (131-132.5 ft) Mostly fine sand, with coarse sand-sized argillic pumice and basalt clasts.		
140	6360						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (132.5-134.5 ft) Basalt with clay coatings.		
145	6355					-211 (146.0-147.0)			
150	6350					-212 (150.0-152.0)	UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (134.5-162 ft) Slightly vesicular basalt. Rough drilling 142-157'.		Tcb
155	6345					-213 (152.0-157.0)			
160	6340								
165	6335						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (162-184 ft) Massive, non-vesicular to slightly vesicular basalt.		
170	6330					-214 (170.0-172.0)			
175	6325								
180	6320					-215 (180.0-182.0)			
185	6315						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (184-189 ft) Lost circulation zone probably caused by open fractures within basalt.		
190	6310								
195	6305						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (189-202 ft) Fractured basalt, poor recovery.		
200	6300					-1 (200.0-202.0)			Tcb
205	6295						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (202-226 ft) Slightly vesicular basalt. Clay on some chip surfaces.		
210	6290								
215	6285								
220	6280					-2 (218.0-222.0)			
225	6275								
230	6270					-3 (227.3-229.0)	UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (226-237 ft) Massive, slightly vesicular basalt. Drilling indicates relatively unfractured.		
235	6265					-4 (234.0-237.0)			
240	6260						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (237-253.5 ft) Massive, non-vesicular basalt.		
245	6255								
250	6250					-6 (248.0-250.0)			Tcb

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
255	6245						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (253.5-260.5 ft) Basalt, possibly moist, with clay coatings that are thin at top of interval, thicker towards the bottom.		
260	6240					-8 (256.0'-258.0')			
265	6235					-8 (261.5'-262.0')			
270	6230					-7 (265.0'-266.0')	LOWER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (260.5-262 ft) Moderately vesicular, clay-rich basalt. Clay ranges between 3-30% of chip surfaces.		
275	6225					-9 (269.0'-270.0')			
280	6220					-10 (277.5'-280.0')	LOWER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (262-342.3 ft) Slightly vesicular basalt. Thin clay near top of interval, clay absent toward bottom. Rough drilling (fractured) 288-293' and 294-316.5'.		
285	6215								
290	6210					-11 (287.5'-290.0')			
295	6205								
300	6200					-12 (297.0'-298.5') -13 (299.2'-300.0')			Tcb
305	6195								
310	6190					-14 (307.5'-310.0')			
315	6185								
320	6180					-15 (317.5'-320.0')			
325	6175								
330	6170					-16 (327.0'-330.0')			
335	6165								
340	6160					-17 (338.0'-340.0')			
345	6155					-18 (342.95'-343.0') -19 (345.5'-346.0')	UPPER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (342.3-351 ft) Moderately vesicular basalt with some clay.		
350	6150					-20 (348.3'-349.0') -21 (351.5'-352.0')			Tcb
355	6145						UPPER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (351-405 ft) Slightly vesicular basalt at the top of interval, with thin clay zone, massive basalt at the base.		
360	6140					-22 (358.0'-358.5')			
365	6135								
370	6130					-23 (369.2'-370.0')			
375	6125					-24 (374.5'-375.5')			
380	6120					-27 (379.2'-380.0')			

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

BOREHOLE ID: R-12	TA/OU: TA-72/OU-1049	Page 4 of 7
DRILLING COMPANY: Tonto Drilling Co.	START DATE: March 10, 1998	END DATE: June 4, 1998
DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX	SAMPLING EQ/METHOD: Wireline core barrel sampling	
LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System)	GROUND ELEVATION: 6500.78' (based on SCOI-3) TOTAL DEPTH = 847'	
DRILLER: Larry Thoren	GEOLOGY P.I.: Rick Warren	SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geochemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
385	6115								
390	6110					-38 (388.0'-388.0')			
395	6105					-39 (393.3'-397.0')			
400	6100					-40 (400.0'-401.0')			Tcb
405	6095					-41 (406.0'-406.0')	UPPER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (405-411 ft) Moist basalt. Some clay present.		
410	6090								
415	6085	C-1(0/0.0)					PALEOSOL: (411-419.2 ft) Drilling performance indicates entire interval is similar to 0.1' of massive clay recovered. Clay probably of lacustrine origin or is a soil.		
420	6080	C-2(1.3/1.8) C-3(0.2/1.0) C-4(1.0/1.0)			Geotech (-0013) Geotech (-0014)	-216 (420.8'-420.8') -217 (421.2'-421.22')			
425	6075	C-5(1.0/1.0) C-6(0.7/1.5)					LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (419.2-425 ft) Moderately vesicular basaltic breccia, with local clay in fractures and vesicles. Moist near top.		
430	6070								
435	6065				Geochem (-0008)				
440	6060					-42 (438.0'-442.0')	LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (425-450 ft) Dry, massive basalt with minor clay on fractures. First perched water at 443', static @ 424.36 bgz.		
445	6055					-44 (442.0'-444.0') -43 (444.0'-449.0')			
450	6050								Tcb
455	6045				Geotech (-0007)		LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (450-488.2 ft) Saturated, massive basalt. Slightly vesicular near base, with some calcite infilling. Fractured, based on drilling performance.		
460	6040					-45 (458.0'-459.0')			
465	6035								
470	6030	C-7(0.7/1.0)							
475	6025								
480	6020								
485	6015	C-8(2.4/2.7) C-9(1.1/1.0)			Geotech (-0021) Geotech (-0022)				
490	6010	C-10(0.3/1.3) C-11(1.3/0.4) C-12(2.3/1.0)			Geotech (-0023) Geotech (-0024)		LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (488.2-488.9 ft) Moist basaltic breccia, with lenses of underlying tephra.		
495	6005	C-13(1.5/2.0) C-14(1.4/2.0)							
500	6000						LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (488.9-491.6 ft) Basaltic tephra; fine- to coarse-grained basaltic ash, glassy, moist. Fine ash forms discontinuous lenses.		
505	5995								

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
510	5990	C-14.9(2.7/2.7) C-15(2.84.84)			Hydrology (-0029) Geotech (-0029) Geotech (-0027)		OLD ALLUVIUM: (491.6-495 ft) Fine grained sand, some clasts of intermediate volcanics.		Ta
515	5985	C-16(1.9/3.2)							
520	5980	C-17(0.1/1.0)			Geochem (-0008) Geotech (-0030)	-33 (520.4'-520.8')	OLD ALLUVIUM: (495-509 ft) Sandy gravel of quartzite, granite, gneiss, and intermediate volcanics to 37 mm, all well rounded. Axial deposit of ancestral Rio Grande.		
525	5975	C-18(4.0/4.0)			Hydrology (-0031)	-34 (523.7'-523.8')			
530	5970						OLD ALLUVIUM: (509-519.1 ft) Fine to medium sand, silt- and clay-rich, saturated, cohesive, with some subrounded clasts of basalt to 10 mm.		Ta
535	5965								
540	5960						OLD ALLUVIUM: (519.1-535.5 ft) Micaceous claystone, dry below 520'. Some zones contain fine sand. Laminae suggest lake deposition.		
545	5955								
550	5950								
555	5945					-35 (553.5'-555.0')	OLD ALLUVIUM: (535.5-545 ft) Gravelly sand with clasts that include devitrified dacitic lava (Tschicoma Formation), and somewhat lesser moderately-vesicular, argillic to unaltered basalt.		
560	5940				Geochem (-0032 & 0034)	-36 (559.0'-560.0')			
565	5935					-49 (564.0'-565.0')	PUYE FORMATION: (545-560 ft) Conglomerate with sandy matrix, abundant moderately-well-rounded clasts to 15 mm, and small vitric pumice. Clasts are dominately devitrified lava with lesser vitric lava of intermediate composition.		Tp
570	5930				Geochem (-0033)	-50 (569.0'-570.0')			
575	5925					-51 (574.0'-575.0')			
580	5920					-52 (578.55'-580.0')	PUYE FORMATION: (560-584.3 ft) Pebbly sand with common subrounded to angular clasts to 13 mm, and small vitric pumice.		
585	5915					-53 (584.3'-585.0')			
590	5910					-54 (589.3'-590.0')	PUYE FORMATION: (584.3-628.7 ft) Slightly pumiceous gravel with sandy matrix, abundant subangular clasts to 14 mm, and some vitric pumice. Near base, clasts to 10 mm.		
595	5905					-55 (594.3'-595.0')			
600	5900					-56 (599.04'-600.0')			
605	5895					-57 (604.13'-605.0')			
610	5890					-58 (609.49'-610.0')			
615	5885					-59 (614.0'-615.0')			
620	5880					-60 (618.7'-620.0')			
625	5875					-61 (624.2'-625.0')			Tp
630	5870					-62 (629.75'-630.0')	PUYE FORMATION: (628.7-637.3 ft) Gravelly sand with common, moderately well-rounded clasts, and lesser vitric pumice.		
635	5865					-63 (633.75'-635.0')			

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geochemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
640	5860					-64 (636.0'-646.0')	PUYE FORMATION: (637.3-666 ft) Slightly pumiceous gravel with sandy matrix and abundant subangular clasts to 15 mm, and minor vitric pumice.		
645	5855					-65 (643.9'-653.0')			
650	5850					-66 (646.9'-656.0')			
655	5845					-67 (653.75'-666.0')			
660	5840					-68 (656.9'-666.0')			
665	5835					-69 (663.87'-666.0')	PUYE FORMATION: (666-712.5 ft) Moderately-calcareous, argillic, pebbly sandstone. Common clasts are devitrified intermediate composition lava. Rare to common pumice is vitric near top, argillic below.		
670	5830					-70 (672.2'-673.0')			
675	5825								Tp
680	5820								
685	5815								
690	5810								
695	5805								
700	5800								
705	5795								
710	5790					-71 (709.2'-710.0')			
715	5785	C-19(4.0/5.0)				-72 (713.9'-715.0')	PUYE FORMATION: (712.5-726.4 ft) Argillic, highly pumiceous sandstone. Clasts of devitrified lava are rare. Base of interval (726.2-726.4') is an argillic pumice fall.		
720	5780	C-20(4.0/5.0)			Geotech (-0041)	-224 (719.75'-720.0')			
725	5775	C-21(4.0/5.0)			Geotech (-0046)	-223 (725.45'-725.65')			Tp
730	5770	C-22(2.2/5.0)			Geotech (-0049)	-222 (730.3'-730.6')	PUYE FORMATION: (726.4-746.4 ft) A series of reworked generally argillic pumiceous deposits; upward fining cycles, each grading from sandstone at the top to conglomerate at the base. Base of interval (746.1-746.4') is an argillic pumice fall.		
735	5765	C-23(0.3/5.0)				-221 (733.0'-733.2')			
740	5760	C-24(0.3/0.3)				-122 (742.1'-742.2')			
745	5755	C-25(4.7/4.7) C-26(5.1/5.3)			Geotech (-0047) Geotech (-0043)	-123 (743.8'-746.0')			
750	5750	C-27(4.7/4.7)				-220 (750.7'-751.1')	PUYE FORMATION: (746.4-764 ft) A series of reworked generally argillic pumiceous deposits; upward fining cycles, each grading from sandstone at the top to conglomerate at the base.		
755	5745	C-28(5.0/5.0)			Geotech (-0044)	-5201A (755.9'-756.0')			
760	5740	C-29(5.0/5.0)				-273 (760.85'-761.0')			

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05
(NAD83, NM State Plane Coordinate System)

GROUND ELEVATION: 6500.78' (based on SCOI-3)
TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
765	5735	C-30(5.0/5.0)			Geotech (-0046)	-274 (765.7'-766.0')	PUYE FORMATION: (764-784 ft) Pumiceous sandstone with common argillic pumice, generally to 6 mm, rarely to 28 mm. Clasts of devitrified lava up to 3.5 mm are scarce near top, and up to 12 mm are common near base.		Tp
770	5730	C-31(4.4/5.0)			Geotech (-0042)	-275 (770.6'-771.0')			
775	5725	C-32(0.8/0.8)			Geotech (-0039)	-276 (775.28'-775.48')			
780	5720	C-33(2.7/2.7)			Geotech (-0040)	-277 (779.2'-779.5')			
785	5715						SANTA FE GROUP BASALT: (784-830 ft) Slightly scoriaceous, coarse-grained basalt with very irregular vesicles to 1 mm length. Saturated zone encountered at 804.84'; unconfined.		Tsfb
790	5710								
795	5705				Geotech (-0097)				
800	5700				Geotech (-0096)				
805	5695					-124 (804.66'-805.0')			
810	5690					-125 (809.84'-810.0')			
815	5685				Geotech (-0055 & -0054)				
820	5680								
825	5675								
830	5670						SANTA FE GROUP BASALT: (830-847 ft) Slightly vesicular, coarse grained basalt with round to slightly elongate vesicles to 6 mm, some coated with white clay, which also occurs as cuttings to 5 mm.		
835	5665								
840	5660								
845	5655								

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 %)
R12-122	5	5	5	2.48	
R12-123	10	10	10	2.12	
R12-124	15	15	15	4.99	
R12-125	20	20	20	6.04	
R12-126	24.9	25	24.95	1.90	
R12-127	29.9	30	29.95	2.59	
R12-128	33.8	34	33.9	3.80	
R12-129	39.5	40	39.75	2.98	
R12-130	43.9	44	43.95	5.49	
R12-131	48.9	49	48.95	6.85	
R12-132	54.8	55	54.9	6.29	
R12-133	59.8	60	59.9	6.28	
R12-134	64.8	65	64.9	5.36	
R12-135	69.8	70	69.9	2.65	
R12-136	74.9	75	74.95	8.33	
R12-137	79.8	80	79.9	9.21	
R12-138	84.8	85	84.9	11.48	
R12-139	89.9	90	89.95	11.50	
R12-140	94.5	95	94.75	11.70	
R12-141	99	100	99.5	12.14	
R12-142	104.9	105	104.95	19.76	
R12-143	109	110	109.5	16.61	
R12-144	114.8	115	114.9	20.11	
R12-201	119.3	120	119.65	12.09	
R12-202	121	122	121.5	16.55	
R12-203	129	130	129.5	27.20	
R12-204	130.5	131	130.75	14.24	
R12-205	131.3	131.5	131.4	16.22	
R12-206	133.5	134	133.75	8.61	
R12-207	135.8	136	135.9	5.71	
R12-208	136.8	137	136.9	1.40	
R12-209	138.3	138.5	138.4	0.61	
R12-210	139.9	140	139.95	2.65	
R12-211	146	147	146.5	4.30	
R12-212	150	152	151	4.34	
R12-213	152	157	154.5	2.77	

*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 %)
R12-214	170	172	171	0.43	
R12-215	180	182	181	0.52	
R12-1	200	202	201	1.74	
R12-2	218	222	220	1.32	
R12-3	227.3	228	227.65	0.52	
R12-4	236.6	237.5	237.05	0.78	
R12-5	248	250	249	0.85	
R12-6	256	258	257	10.56	
R12-8	261.5	262	261.75	20.04	
R12-7	265	266	265.5	3.83	
R12-9	269	270	269.5	1.31	
R12-10	277.5	280	278.75	0.43	
R12-11	287.5	290	288.75	3.11	
R12-12	297	298.5	297.75	3.31	
R12-13	299.2	300	299.6	3.24	
R12-14	307.8	310	308.9	1.05	
R12-15	317.8	320	318.9	0.81	
R12-16	327	330	328.5	0.75	
R12-17	338	340	339	2.50	
R12-18	342.95	343	342.975	16.26	
R12-19	345.6	346	345.8	15.76	
R12-20	348.3	349	348.65	14.66	
R12-21	351.9	352	351.95	5.46	
R12-22	358	358.5	358.25	1.21	
R12-23	369.2	370	369.6	1.04	
R12-24	374.5	375.5	375	1.58	
R12-37	379.2	380	379.6	1.21	
R12-38	386.8	388	387.4	1.39	
R12-39	395.3	397	396.15	0.70	
R12-40	400	401	400.5	1.69	
R12-41	406	408	407	8.03	
R12-216	420.5	420.8	420.65		39.04
R12-217	421.2	421.33	421.265		59.42
R12-42	438	442	440	4.15	
R12-33	520.4	520.5	520.45		23.46
R12-34	523.7	523.8	523.75		20.70
R12-35	553.5	555	554.25	5.01	
R12-36	559	560	559.5	3.23	
R12-49	564	565	564.5	4.72	

*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 %)
R12-50	569	570	569.5	3.90	
R12-51	574	575	574.5	5.15	
R12-52	578.85	580	579.425	0.61	
R12-53	584.3	585	584.65	3.85	
R12-54	589.3	590	589.65	5.92	
R12-55	594.3	595	594.65	4.75	
R12-56	599.04	600	599.52	2.75	
R12-57	604.13	605	604.565	3.44	
R12-58	609.45	610	609.725	5.35	
R12-59	614	615	614.5	3.67	
R12-60	618.7	620	619.35	3.91	
R12-61	624.2	625	624.6	3.83	
R12-62	628.75	630	629.375	6.74	
R12-63	633.75	635	634.375	5.95	
R12-64	639	640	639.5	2.72	
R12-65	643.9	645	644.45	7.95	
R12-66	648.9	650	649.45	3.97	
R12-67	653.75	655	654.375	3.98	
R12-68	658.9	660	659.45	5.56	
R12-69	663.67	665	664.335	5.28	
R12-70	672.2	673	672.6	9.09	
R12-71	709.2	710	709.6	9.26	
R12-72	713.9	715	714.45	12.70	
R12-224	719.78	720	719.89		42.22
R12-223	725.45	725.65	725.55		36.52
R12-222	730.3	730.6	730.45		20.61
R12-221	733	733.2	733.1		20.60
R12-122	742.1	742.2	742.15		30.22
R12-123	745.8	746	745.9		30.70
R12-220	750.7	751.1	750.9		31.35
R12-5201A	755.9	756	755.95		38.04
R12-273	760.85	761	760.925		28.16
R12-274	765.7	766	765.85		30.41
R12-275	770.8	771	770.9		29.70
R12-276	775.25	775.45	775.35		20.86
R12-277	779.2	779.5	779.35		23.26
R12-124	804.66	805	804.83	2.85	

*See Appendix B

TABLE C-2

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R12-122	Cuttings	5	5	5
R12-123	Cuttings	10	10	10
R12-124	Cuttings	15	15	15
R12-125	Cuttings	20	20	20
R12-126	Cuttings	24.9	25	24.95
R12-127	Cuttings	29.9	30	29.95
R12-128	Cuttings	33.8	34	33.9
R12-129	Cuttings	39.5	40	39.75
R12-130	Cuttings	43.9	44	43.95
R12-131	Cuttings	48.9	49	48.95
R12-132	Cuttings	54.8	55	54.9
R12-133	Cuttings	59.8	60	59.9
R12-134	Cuttings	64.8	65	64.9
R12-135	Cuttings	69.8	70	69.9
R12-136	Cuttings	74.9	75	74.95
R12-137	Cuttings	79.8	80	79.9
R12-138	Cuttings	84.8	85	84.9
R12-139	Cuttings	89.9	90	89.95
R12-140	Cuttings	94.5	95	94.75
R12-141	Cuttings	99	100	99.5
R12-142	Cuttings	104.9	105	104.95
R12-143	Cuttings	109	110	109.5
R12-144	Cuttings	114.8	115	114.9
R12-201	Cuttings	119.3	120	119.65
R12-202	Cuttings	121	122	121.5
R12-203	Cuttings	129	130	129.5
R12-204	Cuttings	130.5	131	130.75
R12-205	Cuttings	131.3	131.5	131.4
R12-206	Cuttings	133.5	134	133.75
R12-207	Cuttings	135.8	136	135.9
R12-208	Cuttings	136.8	137	136.9
R12-209	Cuttings	138.3	138.5	138.4
R12-210	Cuttings	139.9	140	139.95
R12-211	Cuttings	146	147	146.5
R12-212	Cuttings	150	152	151
R12-213	Cuttings	152	157	154.5
R12-214	Cuttings	170	172	171
R12-215	Cuttings	180	182	181
R12-1	Cuttings	200	202	201

*See Appendix B

TABLE C-2 (continued)

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R12-2	Cuttings	218	222	220
R12-3	Cuttings	227.3	228	227.65
R12-4	Cuttings	236.6	237.5	237.05
R12-5	Cuttings	248	250	249
R12-6	Cuttings	256	258	257
R12-7	Cuttings	265	266	265.5
R12-8	Cuttings	261.5	262	261.75
R12-9	Cuttings	269	270	269.5
R12-10	Cuttings	277.5	280	278.75
R12-11	Cuttings	287.5	290	288.75
R12-12	Cuttings	297	298.5	297.75
R12-13	Cuttings	299.2	300	299.6
R12-14	Cuttings	307.8	310	308.9
R12-15	Cuttings	317.8	320	318.9
R12-16	Cuttings	327	330	328.5
R12-17	Cuttings	338	340	339
R12-18	Cuttings	342.95	343	342.975
R12-19	Cuttings	345.6	346	345.8
R12-20	Cuttings	348.3	349	348.65
R12-21	Cuttings	351.9	352	351.95
R12-22	Cuttings	358	358.5	358.25
R12-23	Cuttings	369.2	370	369.6
R12-24	Cuttings	374.5	375.5	375
R12-37	Cuttings	379.2	380	379.6
R12-38	Cuttings	386.8	388	387.4
R12-39	Cuttings	395.3	397	396.15
R12-40	Cuttings	400	401	400.5
R12-41	Cuttings	406	408	407
R12-216	Core	420.5	420.8	420.65
R12-217	Core	421.2	421.33	421.265
R12-33	Core	520.4	520.5	520.45
R12-34	Core	523.7	523.8	523.75
R12-35	Cuttings	553.5	555	554.25
R12-36	Cuttings	559	560	559.5
R12-49	Cuttings	564	565	564.5
R12-50	Cuttings	569	570	569.5
R12-51	Cuttings	574	575	574.5
R12-52	Cuttings	578.85	580	579.425
R12-53	Cuttings	584.3	585	584.65

*See Appendix B

TABLE C-2 (continued)

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R12-54	Cuttings	589.3	590	589.65
R12-55	Cuttings	594.3	595	594.65
R12-56	Cuttings	599.04	600	599.52
R12-57	Cuttings	604.13	605	604.565
R12-58	Cuttings	609.45	610	609.725
R12-59	Cuttings	614	615	614.5
R12-60	Cuttings	618.7	620	619.35
R12-61	Cuttings	624.2	625	624.6
R12-62	Cuttings	628.75	630	629.375
R12-63	Cuttings	633.75	635	634.375
R12-64	Cuttings	639	640	639.5
R12-65	Cuttings	643.9	645	644.45
R12-66	Cuttings	648.9	650	649.45
R12-67	Cuttings	653.75	655	654.375
R12-68	Cuttings	658.9	660	659.45
R12-69	Cuttings	663.67	665	664.335
R12-70	Cuttings	672.2	673	672.6
R12-71	Cuttings	700.2	710	709.6
R12-72	Cuttings	713.9	715	714.45
R12-224	Core	719.78	720	719.89
R12-223	Core	725.45	725.65	725.55
R12-222	Core	730.3	730.6	730.45
R12-221	Core	733	733.2	733.1
R12-122	Core	742.1	742.2	742.15
R12-123	Core	745.8	746	745.9
R12-220	Core	750.7	751.1	750.9
R12-5201	Core	755.9	756	755.95
R12-273	Core	760.85	761	760.925
R12-274	Core	765.7	766	765.85
R12-275	Core	770.8	771	770.9
R12-276	Core	775.25	775.45	775.35
R12-277	Core	779.2	779.5	779.35
R12-124	Cuttings	804.66	805	804.83

*See Appendix B

TABLE C-3

SAMPLES PRESERVED FOR POTENTIAL HYDRAULIC PROPERTY TESTING

ID (CASA-98-)*	Matrix Type	Start Depth (ft)	End Depth (ft)	Average Depth (ft)
0013	Core	421.33	421.66	421.49
0014	Core	421.66	422.0	421.83
0007	Core	455.0	456.5	455.75
0021	Core	483.05	483.5	483.28
0022	Core	484.15	484.6	484.38
0023	Core	490.3	490.8	490.55
0024	Core	491.3	491.8	491.55
0029	Core	509.17	509.55	509.36
0026	Core	509.55	510.2	509.88
0027	Core	511.9	512.4	512.15
0030	Core	522.0	523.0	522.50
0031	Core	522.8	523.5	523.15
0041	Core	719.28	719.78	719.53
0048	Core	724.6	725.1	724.85
0049	Core	729.55	730.0	729.78
0047	Core	744.2	744.7	744.45
0043	Core	747.5	748.0	747.75
0044	Core	754.9	755.4	755.15
0046	Core	765.1	765.5	765.30
0042	Core	770.1	770.6	770.35
0039	Core	774.45	774.95	774.70
0040	Core	777.5	778.0	777.75
0057	Cuttings	791.0	792.5	791.75
0054	Cuttings	812.0	814.6	813.3
0055 (dup)	Cuttings	812.0	814.6	813.3

*See Appendix B

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CORRECTION

START

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
48.0	5/15/98	Fri	Day	1115	1145	640.00	645.00	5.00	30.0	10.00	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1145	1155	645.00	650.00	5.00	10.0	30.00	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1155	1225	650.00	655.00	5.00	30.0	10.00	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1225	1245	655.00	660.00	5.00	20.0	15.00	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1245	1355	660.00	665.00	5.00	70.0	4.29	Drilled 8-5/8-in. casing (lunch break?). Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1355	1415	665.00	666.00	1.00	20.0	3.00	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1415	1440	666.00	670.00	4.00	25.0	9.60	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
48.0	5/15/98	Fri	Day	1745	1920	673.00	0.00	673.00	95.0	425.05	Tripped 8-in. drill system out of hole, plugged bit
49.0	5/18/98	Mon	Day		915	0.00	653.00	653.00		#DIV/0!	Tripped 8 in. drill system in the hole
49.0	5/18/98	Mon	Day	1040	1050	673.00	675.00	2.00	10.0	12.00	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1050	1110	675.00	678.00	3.00	20.0	9.00	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1110	1300			0.00	110.0		Repaired hydraulic line
49.0	5/18/98	Mon	Day	1300	1310	678.00	680.00	2.00	10.0	12.00	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1310	1340	680.00	685.00	5.00	30.0	10.00	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1340	1400	685.00	690.00	5.00	20.0	15.00	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1400	1435	690.00	695.00	5.00	35.0	8.57	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1435	1450	695.00	700.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing injecting water. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1450	1625	700.00	705.00	5.00	95.0	3.16	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1625	1650	705.00	710.00	5.00	25.0	12.00	Drilled 8-5/8-in. casing. Sand and gravel (Puye)
49.0	5/18/98	Mon	Day	1650	1755	710.00	715.00	5.00	65.0	4.62	Drilled 8-5/8-in. casing. Tuffaceous Clay
49.0	5/18/98	Mon	Day	1755	1835	715.00	716.00	1.00	40.0	1.50	Drilled 8-5/8-in. casing, rods plugged. Tuffaceous clay
50.0	5/19/98	Tue	Day	940				0.00			Measured DTW at nondetect
50.0	5/19/98	Tue	Day	1030	1215	0.00	716.00	716.00	105.0	409.14	Tripped in 101 mm core system from surface to TD=716
50.0	5/19/98	Tue	Day	1330	1353	716.00	721.00	5.00	23.0	13.04	Cored from 716 to 721 with 101 mm core system. Tuffaceous clay
50.0	5/19/98	Tue	Day	1420	1443	721.00	726.00	5.00	29.0	10.34	Cored from 721 to 726 with 101 mm core system. Tuffaceous clay
50.0	5/19/98	Tue	Day	1526	1600	726.00	731.00	5.00	34.0	8.82	Cored from 726 to 731 with 101 mm core system
50.0	5/19/98	Tue	Day	1615	1637	731.00	736.00	5.00	22.0	13.64	Cored from 731 to 736 with 101 mm core system
50.0	5/19/98	Tue	Day	1655	1740	736.00	741.00	5.00	45.0	6.67	Cored from 736 to 741 with 101 mm core system
51.0	5/20/98	Wed	Day	635				0.00			Measured DTW at 733.8 bgz
51.0	5/20/98	Wed	Day	851	905	733.50	741.00	1.50	14.0	6.43	Retrieved core from last run
51.0	5/20/98	Wed	Day	910	920	741.00	741.30	0.30	10.0	1.80	Cored from 741 to 741.3 with 101 mm 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
51.0	5/20/98	Wed	Day	923	1000	741.30	746.00	4.70	32.0	8.81	Cored from 741.3 to 746 with 101 mm core system
51.0	5/20/98	Wed	Day	1040	1120	746.00	751.30	5.30	30.0	10.60	Cored from 746 to 751.3 with the 101 mm core system
51.0	5/20/98	Wed	Day	1120	1205	751.30	756.00	4.70	45.0	6.27	Cored from 751.3 to 756 with the 101 mm core system
51.0	5/20/98	Wed	Day	1250	1305	756.00	761.00	5.00	15.0	20.00	Cored from 756 to 761 with the 101 mm core system
51.0	5/20/98	Wed	Day	1330	1408	761.00	766.00	5.00	38.0	7.63	Cored from 761 to 766 with the 101 mm core system
51.0	5/20/98	Wed	Day	1408	1445	766.00	771.00	5.00	37.0	8.11	Cored from 766 to 771 with the 101 mm core system
51.0	5/20/98	Wed	Day	1445	1540	771.00	776.00	5.00	55.0	5.45	Cored from 771 to 776 with the 101 mm core system
51.0	5/20/98	Wed	Day	1545	1720			0.00			Ream hole and casing
51.0	5/20/98	Wed	Day	1755	1820	776.00	776.80	0.80	25.0	1.92	Cored from 776 to 776.8 with the 101 mm core system
	5/20/98	Wed	Day	1830				0.00			Measured DTW at dry to 776.8
52.0	5/21/98	Thur	Day	650				0.00			Measured DTW at dry to 776.8
52.0	5/21/98	Thur	Day	1030	1320	779.50	0.00	779.50	170.0	275.12	Tripped out 101 mm core system
55.0	5/26/98	Tue	Day	930	1000			0.00			Set up for borehole geophysics
55.0	5/26/98	Tue	Day	1000	1100	0.00	655.00	655.00	60.0	655.00	Run natural gamma log inside casing
55.0	5/26/98	Tue	Day	1100	1315	710.00	0.00	710.00	135.0	315.56	Run caliper from bottom of 8-5/8-in. casing to surface
56.0	5/27/98	Wed	Day	740	1100	0.00	710.00	710.00	200.0	213.00	Tripped in 8-5/8-in. drill system
56.0	5/27/98	Wed	Day	1130	1205	710.00	720.00	10.00	35.0	17.14	Drilled 8-5/8-in. casing while injecting water at 1.5 gpm
56.0	5/27/98	Wed	Day	1205	1255	720.00	730.00	10.00	50.0	12.00	Drilled 8-5/8-in. casing while injecting water at 1.5 gpm
56.0	5/27/98	Wed	Day	1400	1600	730.00	740.00	10.00	120.0	5.00	Drilled 8-5/8-in. casing while injecting water at 1.5 gpm
56.0	5/27/98	Wed	Day	1600	1830	740.00	690.00	50.00	150.0	20.00	Ream hole back to 690
57.0	5/28/98	Thur	Day	645	900	690.00	640.00	50.00	135.0	22.22	Tripped out 8-5/8-in. casing from 690 to 640
57.0	5/28/98	Thur	Day	900	1030	640.00	737.00	97.00	90.0	64.67	Tripped in 8-5/8-in. drill system
57.0	5/28/98	Thur	Day	1030	1040	737.00	740.00	3.00	10.0	18.00	Clean out bottom of hole
57.0	5/28/98	Thur	Day	1110	1150	740.00	750.00	10.00	40.0	15.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1225	1245	750.00	753.00	3.00	20.0	9.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1315	1330	753.00	760.00	7.00	15.0	28.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1410	1440	760.00	770.00	10.00	30.0	20.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1440	1540	770.00	780.00	10.00	60.0	10.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1600	1615	780.00	785.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing. Injecting water
57.0	5/28/98	Thur	Day	1650	1705	785.00	790.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing through basalt. Injecting water
57.0	5/28/98	Thur	Day	1720	1810	790.00	795.00	5.00	50.0	6.00	Drilled 8-5/8-in. casing through basalt. 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
57.0	5/28/93	Thur	Day	1810	1825	795.00	800.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	640				0.00			Measured DTW at dry to 790
58.0	5/29/93	Fri	Day	700	715	800.00	805.00	5.00	15.0	20.00	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	715	740	805.00	810.00	5.00	25.0	12.00	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	754	837	810.00	815.00	5.00	43.0	6.93	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	837	910	815.00	820.00	5.00	33.0	9.09	Drilled 8-5/8-in. casing through basalt. Dry
58.0	5/29/93	Fri	Day	1000				0.00			Encountered water in borehole at 804.84 ft
58.0	5/29/93	Fri	Day	1015	1040	820.00	823.00	3.00	25.0	7.20	Drilled 8-5/8-in. casing through basalt. Formation water
58.0	5/29/93	Fri	Day	1140	1230	830.00	835.00	5.00	50.0	6.00	Drilled 8-5/8-in. casing through basalt. Formation water
58.0	5/29/93	Fri	Day	1230	1344	835.00	840.00	5.00	74.0	4.05	Drilled 8-5/8-in. casing through basalt. Formation water
58.0	5/29/93	Fri	Day	1440				0.00			Measured DTW at 807.17' bgz
58.0	5/29/93	Fri	Day	1500	1545			0.00			Collect water sample from cyclone
58.0	5/29/93	Fri	Day	1545	1645			0.00			Ream borehole
58.0	5/29/93	Fri	Day	1645	1753	840.00	0.00	840.00	73.0	690.41	Tripped out 8-5/8-in. drilling system
59.0	6/1/93	Mon	Day	700				0.00			Measured DTW at 804.79' bgz
59.0	6/1/93	Mon	Day	1000	1120	847.00	0.00	847.00	60.0	635.25	Tripped out 6-in. hammer bit
59.0	6/1/93	Mon	Day	1225	1335	0.00	840.00	840.00	70.0	720.00	Tripped in 8-5/8-in. drill system
59.0	6/1/93	Mon	Day	1335	1615			0.00	160.0		Unscheduled repairs: hydraulic line behind control panel broke
59.0	6/1/93	Mon	Day	1615	1805	840.00	830.00	10.00	110.0	5.45	Retracted 8-5/8-in. casing
60.0	6/2/93	Tue	Day	700	1125	830.00	740.00	90.00	265.0	20.33	Retracted 8-5/8-in. casing
60.0	6/2/93	Tue	Day	1247	1300	740.00	720.00	20.00	13.0	92.31	Retracted 8-5/8-in. casing
60.0	6/2/93	Tue	Day	1300	1430	720.00	833.00	113.00	90.0	75.33	Reamed borehole
60.0	6/2/93	Tue	Day	1500	1600			0.00	60.0		Airlift development
60.0	6/2/93	Tue	Day	1645	1750	833.00	0.00	833.00	65.0	768.92	Tripped out 8-5/8-in. drill system
61.0	6/3/93	Wed	Day	910	1030	0.00	600.00	600.00	80.0	600.00	Tripped in 1-in. tremmie pipe
61.0	6/3/93	Wed	Day	1055	1200			0.00	65.0		Emplaced bottom sand pack and bentonite seal upto 829.93 ft bgz
61.0	6/3/93	Wed	Day	1240	1447	0.00	830.00	830.00	127.0	392.13	Tripped 4-in. schedule 40 PVC casing in the hole.
61.0	6/3/93	Wed	Day	1600	1700			0.00			Emplaced bentonite upto 826.5 ft bgz
61.0	6/3/93	Wed	Day	1745	1820			0.00			Emplaced sand pack across screened interval.
62.0	6/4/93	Thur	Day	730				0.00			Measured DTW at 804.42 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
62.0	6/4/98	Thur	Day	730	950			0.00			Emplaced sand pack across screened interval. Temporary well completed
62.0	6/4/98	Thur	Day	950	1030	795.00	790.00	5.00	40.0	7.50	Retracted 8-5/8-in. casing
62.0	6/4/98	Thur	Day	1030	1145	800.00	0.00	800.00	75.0	640.00	Tripped out tremmie pipe
62.0	6/4/98	Thur	Day	1245	1630			0.00			Rig down
63.0	6/5/98	Fri	Day	730	920			0.00			Site cleanup
63.0	6/5/98	Fri	Day	1000	1155			0.00			Bail well for water sample
63.0	6/5/98	Fri	Day	1240	1735			0.00			Bail well for water sample
64.0	6/8/98	Mon	Day	800				0.00			Measured DTW at 801.64 ft(?). This measurement questionable because other DTW's are typically ~805 ft
64.0	6/8/98	Mon	Day	835	850			0.00	15.0		Water sample collection
64.0	6/8/98	Mon	Day	900	1630			0.00	450.0		Site cleanup
65.0	6/9/98	Tue	Day	800	1535			0.00	455.0		Site cleanup, including spilled diesel

Appendix B

Lithologic Log

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System)

GROUND ELEVATION: 6500.78' (based on SCOI-3)

TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
0	6500						ALLUVIUM: (0-12.5 ft) Sandy, dry alluvium, predominantly quartz and feldspar grains.		Qal
5	6495					•122 (5.0'-8.1')			
10	6490					•123 (10.0'-10.1')			
15	6485					•124 (15.0'-15.1')	CERRO TOLEDO INTERVAL: (12.5-31.3 ft) Vitric reworked tuff with common tiny pumice to 1 mm and scarce lithics to 1.5 mm. A pumice-rich zone occurs between 27-28' and a clast-rich zone occurs between 28-31.3'.		Qct
20	6480					•125 (19.9'-20.0')			
25	6475				Geochem (-0001)	•126 (24.9'-25.0')			
30	6470					•127 (29.9'-30.0')			
35	6465				Geochem (-0002)	•128 (33.9'-34.0')	OTOWI MEMBER OF BANDELIER TUFF: (31.3-102 ft) Vitric nonwelded tuff with common pumice to 7 mm and less common lithics of intermediate composition.		Qbo
40	6460					•129 (39.9'-40.0')			
45	6455					•130 (43.9'-44.0')			
50	6450					•131 (48.9'-49.0')			
55	6445					•132 (54.9'-55.0')			
60	6440					•133 (59.9'-60.0')			
65	6435					•134 (64.9'-65.0')			
70	6430					•135 (69.9'-70.0')			
75	6425					•136 (74.9'-75.0')			
80	6420					•137 (79.9'-80.0')			
85	6415					•138 (84.9'-85.0')			
90	6410					•139 (89.9'-90.0')			
95	6405					•140 (94.9'-95.0')			
100	6400					•141 (99.0'-100.0')			
105	6395					•142 (104.9'-105.0')	OTOWI MEMBER OF BANDELIER TUFF: (102-112 ft) Variably pumice-rich nonwelded ash flow tuff. Very pumice rich at 104.9 to 105'.		Qbo
110	6390					•143 (109.0'-110.0')			
115	6385					•144 (114.9'-115.0')	GUAJE PUMICE BED: (112-131 ft) Vitric bedded tuff, including laminated vitric ash. Lithics include basalt.		Qbog
120	6380					•201 (119.3'-120.0') •202 (121.0'-122.0')			
125	6375				Geochem (-0003)				

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (aml.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
130	6370					-203 (129.0\-130.0') -204 (130.0\131.0) -205 (131.3\131.7')			
135	6365				Geochem (-0004)	-206 (133.0\134.0') -207 (134.0\136.0) -208 (136.0\137.0') -209 (138.3\138.8') -210 (139.0\140.0')	PALEOSOL: (131-132.5 ft) Mostly fine sand, with coarse sand-sized argillic pumice and basalt clasts.		
140	6360						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (132.5-134.5 ft) Basalt with clay coatings.		
145	6355					-211 (146.0\147.0')			
150	6350					-212 (150.0\152.0')	UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (134.5-162 ft) Slightly vesicular basalt. Rough drilling 142-157'.		Tcb
155	6345					-213 (152.0\157.0')			
160	6340								
165	6335						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (162-184 ft) Massive, non-vesicular to slightly vesicular basalt.		
170	6330					-214 (170.0\172.0')			
175	6325								
180	6320					-215 (180.0\182.0')			
185	6315						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (184-189 ft) Lost circulation zone probably caused by open fractures within basalt.		
190	6310								
195	6305						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (189-202 ft) Fractured basalt, poor recovery.		
200	6300					-1 (200.0\202.0')			Tcb
205	6295						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (202-226 ft) Slightly vesicular basalt. Clay on some chip surfaces.		
210	6290								
215	6285								
220	6280					-2 (219.0\222.0')			
225	6275								
230	6270					-3 (227.3\229.0')	UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (226-237 ft) Massive, slightly vesicular basalt. Drilling indicates relatively unfractured.		
235	6265								
240	6260					-4 (236.0\237.5')	UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (237-253.5 ft) Massive, non-vesicular basalt.		
245	6255								
250	6250					-5 (248.0\250.0')			Tcb

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft) / Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
255 / 6245						UPPER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (253.5-260.5 ft) Basalt, possibly moist, with clay coatings that are thin at top of interval, thicker towards the bottom.		
260 / 6240					-6 (256.0'-258.0')			
265 / 6235					-8 (261.5'-262.0')	LOWER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (260.5-262 ft) Moderately vesicular, clay-rich basalt. Clay ranges between 3-30% of chip surfaces.		
270 / 6230					-7 (265.0'-266.0')			
275 / 6225					-9 (269.0'-270.0')			
280 / 6220					-10 (277.5'-280.0')	LOWER THOLEIITE OF CERROS DEL RIO VOLCANIC FIELD: (262-342.3 ft) Slightly vesicular basalt. Thin clay near top of interval, clay absent toward bottom. Rough drilling (fractured) 288-293' and 294-316.5'.		
285 / 6215								
290 / 6210					-11 (287.5'-290.0')			
295 / 6205								
300 / 6200					-12 (297.0'-298.5') -13 (299.2'-300.0')			Tcb
305 / 6195								
310 / 6190					-14 (307.5'-310.0')			
315 / 6185								
320 / 6180					-15 (317.5'-320.0')			
325 / 6175								
330 / 6170					-16 (327.0'-330.0')			
335 / 6165								
340 / 6160					-17 (339.0'-340.0')			
345 / 6155					-18 (342.95'-343.0') -19 (345.6'-346.0')	UPPER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (342.3-351 ft) Moderately vesicular basalt with some clay.		
350 / 6150					-20 (348.3'-349.0') -21 (351.9'-352.0')			Tcb
355 / 6145						UPPER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (351-405 ft) Slightly vesicular basalt at the top of interval, with thin clay zone, massive basalt at the base.		
360 / 6140					-22 (358.0'-358.5')			
365 / 6135								
370 / 6130					-23 (369.2'-370.0')			
375 / 6125					-24 (374.5'-375.0')			
380 / 6120					-37 (379.2'-380.0')			

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

BOREHOLE ID: R-12	TA/OU: TA-72/OU-1049	Page 4 of 7
DRILLING COMPANY: Tonto Drilling Co.	START DATE: March 10, 1998	END DATE: June 4, 1998
DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX	SAMPLING EQ/METHOD: Wireline core barrel sampling	
LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System)	GROUND ELEVATION: 6500.78' (based on SCOI-3) TOTAL DEPTH = 847'	
DRILLER: Larry Thoren	GEOLOGY P.I.: Rick Warren	SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
385	6115								
390	6110					-38 (386.8'-386.8')			
395	6105					-39 (396.3'-397.0')			
400	6100					-40 (400.0'-401.0')			Tcb
405	6095					-41 (406.0'-406.0')	UPPER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (405-411 ft) Moist basalt. Some clay present.		
410	6090								
415	6085	C-1(0/0.0) C-4(1.3/1.5)					PALEOSOL: (411-419.2 ft) Drilling performance indicates entire interval is similar to 0.1' of massive clay recovered. Clay probably of lacustrine origin or is a soil.		
420	6080	C-2(0.2/1.0) C-3(1.0/1.0)			Geotech (-0013) Geotech (-0014)	-216 (420.8'-420.8') -217 (421.2'-421.33')			
425	6075	C-5(1.0/1.0) C-6(0.7/1.5)					LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (419.2-425 ft) Moderately vesicular basaltic breccia, with local clay in fractures and vesicles. Moist near top.		
430	6070								
435	6065				Geotech (-0006)				
440	6060					-42 (436.0'-442.0') -44 (442.0'-444.0')	LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (425-450 ft) Dry, massive basalt with minor clay on fractures. First perched water at 443', static @ 424.36 bgz.		
445	6055					-43 (444.0'-449.0')			
450	6050								Tcb
455	6045				Geotech (-0007)		LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (450-468.2 ft) Saturated, massive basalt. Slightly vesicular near base, with some calcite infilling. Fractured, based on drilling performance.		
460	6040					-45 (458.0'-459.0')			
465	6035								
470	6030	C-7(0.7/1.0)							
475	6025								
480	6020								
485	6015	C-8(2.4/2.7) C-9(1.1/1.0)			Geotech (-0021) Geotech (-0022)				
490	6010	C-10(0.3/1.3) C-11(1.3/0.4) C-12(2.3/1.9)			Geotech (-0023) Geotech (-0024)		LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (468.2-488.9 ft) Moist basaltic breccia, with lenses of underlying tephra.		
495	6005	C-13(1.5/2.0) C-14(1.4/2.0)							
500	6000						LOWER ALKALIC BASALT OF CERROS DEL RIO VOLCANIC FIELD: (488.9-491.6 ft) Basaltic tephra; fine- to coarse-grained basaltic ash, glassy, moist. Fine ash forms discontinuous lenses.		
505	5995								

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System)

GROUND ELEVATION: 6500.78' (based on SCOI-3)

TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
510	5990	C-14.8(2.7/2.7) C-15(2.8/4.84)			Hydrology (-0029) Geotech (-0026) Geotech (-0027)		OLD ALLUVIUM: (491.6-495 ft) Fine grained sand, some clasts of intermediate volcanics.		Ta
515	5985	C-16(1.8/3.2)					OLD ALLUVIUM: (495-509 ft) Sandy gravel of quartzite, granite, gneiss, and intermediate volcanics to 37 mm, all well rounded. Axial deposit of ancestral Rio Grande.		
520	5980	C-17(0.1/1.0)			Geochem (-0008) Geotech (-0030)	-33 (520.4'-520.8')			
525	5975	C-18(4.05/4.06)			Hydrology (-0031)	-34 (523.7'-523.8')	OLD ALLUVIUM: (509-519.1 ft) Fine to medium sand, silt- and clay-rich, saturated, cohesive, with some subrounded clasts of basalt to 10 mm.		Ta
530	5970						OLD ALLUVIUM: (519.1-535.5 ft) Micaceous claystone, dry below 520'. Some zones contain fine sand. Laminae suggest lake deposition.		
535	5965								
540	5960								
545	5955						OLD ALLUVIUM: (535.5-545 ft) Gravelly sand with clasts that include devitrified dacitic lava (Tschicoma Formation), and somewhat lesser moderately-vesicular, argillic to unaltered basalt.		
550	5950								
555	5945					-35 (553.9'-555.0')			
560	5940				Geochem (-0032 & 0034)	-36 (558.0'-560.0')	PUYE FORMATION: (545-560 ft) Conglomerate with sandy matrix, abundant moderately-well-rounded clasts to 15 mm, and small vitric pumice. Clasts are dominately devitrified lava with lesser vitric lava of intermediate composition.		Tp
565	5935					-49 (564.0'-565.0')			
570	5930				Geochem (-0033)	-50 (569.0'-570.0')			
575	5925					-51 (574.0'-575.0')			
580	5920					-52 (579.85'-580.0')	PUYE FORMATION: (560-584.3 ft) Pebbly sand with common subrounded to angular clasts to 13 mm, and small vitric pumice.		
585	5915					-53 (584.3'-585.0')			
590	5910					-54 (589.3'-590.0')			
595	5905					-55 (594.3'-595.0')	PUYE FORMATION: (584.3-628.7 ft) Slightly pumiceous gravel with sandy matrix, abundant subangular clasts to 14 mm, and some vitric pumice. Near base, clasts to 10 mm.		
600	5900					-56 (599.04'-600.0')			
605	5895					-57 (604.13'-605.0')			
610	5890					-58 (609.45'-610.0')			
615	5885					-59 (614.0'-615.0')			
620	5880					-60 (619.7'-620.0')			
625	5875					-61 (624.2'-625.0')			Tp
630	5870					-62 (629.75'-630.0')	PUYE FORMATION: (628.7-637.3 ft) Gravelly sand with common, moderately well-rounded clasts, and lesser vitric pumice.		
635	5865					-63 (633.75'-635.0')			

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geochemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
640	5860			■		-64 (638.0'-640.0')	PUYE FORMATION: (637.3-666 ft) Slightly pumiceous gravel with sandy matrix and abundant subangular clasts to 15 mm, and minor vitric pumice.		
645	5855			■		-65 (643.9'-645.0')			
650	5850			■		-66 (648.9'-650.0')			
655	5845			■		-67 (653.79'-655.0')			
660	5840			■		-68 (658.9'-660.0')			
665	5835			■		-69 (663.97'-665.0')	PUYE FORMATION: (666-712.5 ft) Moderately-calcareous, argillic, pebbly sandstone. Common clasts are devitrified intermediate composition lava. Rare to common pumice is vitric near top, argillic below.		
670	5830			■		-70 (672.2'-673.0')			
675	5825			■					Tp
680	5820			■					
685	5815			■					
690	5810			■					
695	5805			■					
700	5800			■					
705	5795			□					
710	5790			■		-71 (709.2'-710.0')			
715	5785	C-19(4.0/5.0)	■	■		-72 (713.9'-715.0')	PUYE FORMATION: (712.5-726.4 ft) Argillic, highly pumiceous sandstone. Clasts of devitified lava are rare. Base of interval (726.2-726.4') is an argillic pumice fall.		
720	5780	C-20(4.5/5.0)	■		Geotech (-0041)	-224 (719.79'-720.0')			
725	5775	C-21(4.6/5.0)	■		Geotech (-0048)	-223 (725.49'-726.66')			Tp
730	5770	C-22(2.2/5.0)	■		Geotech (-0049)	-222 (730.3'-730.6')	PUYE FORMATION: (726.4-746.4 ft) A series of reworked generally argillic pumiceous deposits; upward fining cycles, each grading from sandstone at the top to conglomerate at the base. Base of interval (746.1-746.4') is an argillic pumice fall.		
						-221 (733.0'-733.2')			
735	5765	C-23(0.2/5.0)	■						
740	5760	C-24(0.3/0.3)	■						
		C-25(4.7/4.7)	■			-122 (742.1'-742.2')			
745	5755	C-26(5.1/5.3)	■		Geotech (-0047)	-123 (745.9'-746.0')			
					Geotech (-0043)		PUYE FORMATION: (746.4-764 ft) A series of reworked generally argillic pumiceous deposits; upward fining cycles, each grading from sandstone at the top to conglomerate at the base.		
750	5750	C-27(4.7/4.7)	■			-220 (750.7'-751.1')			
755	5745	C-28(5.0/5.0)	■		Geotech (-0044)	-220A (755.9'-756.0')			
760	5740	C-29(5.0/5.0)	■			-273 (760.88'-761.0')			

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

BOREHOLE ID: R-12 | TA/OU: TA-72/OU-1049 |

DRILLING COMPANY: Tonto Drilling Co. | START DATE: March 10, 1998 | END DATE: June 4, 1998

DRILLING EQ/METHOD: Ingersoll-Rand T-4/ODEX | SAMPLING EQ/METHOD: Wireline core barrel sampling

LOCATION: x = 1,647,427.33 y = 1,767,907.05 (NAD83, NM State Plane Coordinate System) | GROUND ELEVATION: 6500.78' (based on SCOI-3) | TOTAL DEPTH = 847'

DRILLER: Larry Thoren | GEOLOGY P.I.: Rick Warren | SITE GEOLOGIST(S): Jon Marin/Mark Everett

Depth (ft)	Elevation (ft)	Core Run # (amt.-recov./amt. attemp.)	Core Run	Cuttings Collected	Hydrologic Property (Geotech) and Geo-chemical (Geochem) Samples (CASA-98-xxxx)	Moisture/Matric Pot. R-12-xxx (depth)	Lithology	Graphic Log	Lithologic Symbol
765	5735	C-30(5.0/5.0)			Geotech (-0046)	-274 (765.7'-766.0')	PUYE FORMATION: (764-784 ft) Pumiceous sandstone with common argillic pumice, generally to 6 mm, rarely to 28 mm. Clasts of devitrified lava up to 3.5 mm are scarce near top, and up to 12 mm are common near base.		Tp
770	5730	C-31(4.4/5.0)			Geotech (-0042)	-275 (770.8'-771.0')			
775	5725	C-32(0.8/0.8)			Geotech (-0039)	-276 (775.28'-775.45')			
780	5720	C-33(2.7/2.7)			Geotech (-0040)	-277 (779.2'-779.5')			
785	5715						SANTA FE GROUP BASALT: (784-830 ft) Slightly scoriaceous, coarse-grained basalt with very irregular vesicles to 1 mm length. Saturated zone encountered at 804.84'; unconfined.		Tsfb
790	5710								
795	5705				Geotech (-0057)				
800	5700				Geotech (-0058)				
805	5695					-124 (804.88'-805.0')			
810	5690					-125 (809.84'-810.0')			
815	5685				Geotech (-0055 & -0064)				
820	5680								
825	5675								
830	5670						SANTA FE GROUP BASALT: (830-847 ft) Slightly vesicular, coarse grained basalt with round to slightly elongate vesicles to 6 mm, some coated with white clay, which also occurs as cuttings to 5 mm.		
835	5665								
840	5660								
845	5655								

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 %)
R12-122	5	5	5	2.48	
R12-123	10	10	10	2.12	
R12-124	15	15	15	4.99	
R12-125	20	20	20	6.04	
R12-126	24.9	25	24.95	1.90	
R12-127	29.9	30	29.95	2.59	
R12-128	33.8	34	33.9	3.80	
R12-129	39.5	40	39.75	2.98	
R12-130	43.9	44	43.95	5.49	
R12-131	48.9	49	48.95	6.85	
R12-132	54.8	55	54.9	6.29	
R12-133	59.8	60	59.9	6.28	
R12-134	64.8	65	64.9	5.36	
R12-135	69.8	70	69.9	2.65	
R12-136	74.9	75	74.95	8.33	
R12-137	79.8	80	79.9	9.21	
R12-138	84.8	85	84.9	11.48	
R12-139	89.9	90	89.95	11.50	
R12-140	94.5	95	94.75	11.70	
R12-141	99	100	99.5	12.14	
R12-142	104.9	105	104.95	19.76	
R12-143	109	110	109.5	16.61	
R12-144	114.8	115	114.9	20.11	
R12-201	119.3	120	119.65	12.09	
R12-202	121	122	121.5	16.55	
R12-203	129	130	129.5	27.20	
R12-204	130.5	131	130.75	14.24	
R12-205	131.3	131.5	131.4	16.22	
R12-206	133.5	134	133.75	8.61	
R12-207	135.8	136	135.9	5.71	
R12-208	136.8	137	136.9	1.40	
R12-209	138.3	138.5	138.4	0.61	
R12-210	139.9	140	139.95	2.65	
R12-211	146	147	146.5	4.30	
R12-212	150	152	151	4.34	
R12-213	152	157	154.5	2.77	

*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 %)
R12-214	170	172	171	0.43	
R12-215	180	182	181	0.52	
R12-1	200	202	201	1.74	
R12-2	218	222	220	1.32	
R12-3	227.3	228	227.65	0.52	
R12-4	236.6	237.5	237.05	0.78	
R12-5	248	250	249	0.85	
R12-6	256	258	257	10.56	
R12-8	261.5	262	261.75	20.04	
R12-7	265	266	265.5	3.83	
R12-9	269	270	269.5	1.31	
R12-10	277.5	280	278.75	0.43	
R12-11	287.5	290	288.75	3.11	
R12-12	297	298.5	297.75	3.31	
R12-13	299.2	300	299.6	3.24	
R12-14	307.8	310	308.9	1.05	
R12-15	317.8	320	318.9	0.81	
R12-16	327	330	328.5	0.78	
R12-17	338	340	339	2.56	
R12-18	342.95	343	342.975	16.26	
R12-19	345.6	346	345.8	15.76	
R12-20	348.3	349	348.65	14.66	
R12-21	351.9	352	351.95	5.46	
R12-22	358	358.5	358.25	1.21	
R12-23	369.2	370	369.6	1.04	
R12-24	374.5	375.5	375	1.58	
R12-37	379.2	380	379.6	1.21	
R12-38	386.8	388	387.4	1.39	
R12-39	395.3	397	396.15	0.70	
R12-40	400	401	400.5	1.69	
R12-41	406	408	407	8.03	
R12-216	420.5	420.8	420.65		39.04
R12-217	421.2	421.33	421.265		59.42
R12-42	438	442	440	4.15	
R12-33	520.4	520.5	520.45		23.46
R12-34	523.7	523.8	523.75		20.70
R12-35	553.5	555	554.25	5.01	
R12-36	559	560	559.5	3.23	
R12-49	564	565	564.5	4.72	

*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 %)
R12-50	569	570	569.5	3.90	
R12-51	574	575	574.5	5.15	
R12-52	578.85	580	579.425	0.61	
R12-53	584.3	585	584.65	3.85	
R12-54	589.3	590	589.65	5.92	
R12-55	594.3	595	594.65	4.75	
R12-56	599.04	600	599.52	2.75	
R12-57	604.13	605	604.565	3.44	
R12-58	609.45	610	609.725	5.35	
R12-59	614	615	614.5	3.67	
R12-60	618.7	620	619.35	3.91	
R12-61	624.2	625	624.6	3.83	
R12-62	628.75	630	629.375	6.74	
R12-63	633.75	635	634.375	5.95	
R12-64	639	640	639.5	2.72	
R12-65	643.9	645	644.45	7.95	
R12-66	648.9	650	649.45	3.97	
R12-67	653.75	655	654.375	3.98	
R12-68	658.9	660	659.45	5.56	
R12-69	663.67	665	664.335	5.28	
R12-70	672.2	673	672.6	9.09	
R12-71	709.2	710	709.6	9.26	
R12-72	713.9	715	714.45	12.70	
R12-224	719.78	720	719.89		42.22
R12-223	725.45	725.65	725.55		36.52
R12-222	730.3	730.6	730.45		20.61
R12-221	733	733.2	733.1		20.60
R12-122	742.1	742.2	742.15		30.22
R12-123	745.8	746	745.9		30.70
R12-220	750.7	751.1	750.9		31.35
R12-5201A	755.9	756	755.95		38.04
R12-273	760.85	761	760.925		28.16
R12-274	765.7	766	765.85		30.41
R12-275	770.8	771	770.9		29.70
R12-276	775.25	775.45	775.35		20.86
R12-277	779.2	779.5	779.35		23.26
R12-124	804.66	805	804.83	2.85	

*See Appendix B

TABLE C-2

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R12-122	Cuttings	5	5	5
R12-123	Cuttings	10	10	10
R12-124	Cuttings	15	15	15
R12-125	Cuttings	20	20	20
R12-126	Cuttings	24.9	25	24.95
R12-127	Cuttings	29.9	30	29.95
R12-128	Cuttings	33.8	34	33.9
R12-129	Cuttings	39.5	40	39.75
R12-130	Cuttings	43.9	44	43.95
R12-131	Cuttings	48.9	49	48.95
R12-132	Cuttings	54.8	55	54.9
R12-133	Cuttings	59.8	60	59.9
R12-134	Cuttings	64.8	65	64.9
R12-135	Cuttings	69.8	70	69.9
R12-136	Cuttings	74.9	75	74.95
R12-137	Cuttings	79.8	80	79.9
R12-138	Cuttings	84.8	85	84.9
R12-139	Cuttings	89.9	90	89.95
R12-140	Cuttings	94.5	95	94.75
R12-141	Cuttings	99	100	99.5
R12-142	Cuttings	104.9	105	104.95
R12-143	Cuttings	109	110	109.5
R12-144	Cuttings	114.8	115	114.9
R12-201	Cuttings	119.3	120	119.65
R12-202	Cuttings	121	122	121.5
R12-203	Cuttings	129	130	129.5
R12-204	Cuttings	130.5	131	130.75
R12-205	Cuttings	131.3	131.5	131.4
R12-206	Cuttings	133.5	134	133.75
R12-207	Cuttings	135.8	136	135.9
R12-208	Cuttings	136.8	137	136.9
R12-209	Cuttings	138.3	138.5	138.4
R12-210	Cuttings	139.9	140	139.95
R12-211	Cuttings	146	147	146.5
R12-212	Cuttings	150	152	151
R12-213	Cuttings	152	157	154.5
R12-214	Cuttings	170	172	171
R12-215	Cuttings	180	182	181
R12-1	Cuttings	200	202	201

*See Appendix B

TABLE C-2 (continued)

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R12-2	Cuttings	218	222	220
R12-3	Cuttings	227.3	228	227.65
R12-4	Cuttings	236.6	237.5	237.05
R12-5	Cuttings	248	250	249
R12-6	Cuttings	256	258	257
R12-7	Cuttings	265	266	265.5
R12-8	Cuttings	261.5	262	261.75
R12-9	Cuttings	269	270	269.5
R12-10	Cuttings	277.5	280	278.75
R12-11	Cuttings	287.5	290	288.75
R12-12	Cuttings	297	298.5	297.75
R12-13	Cuttings	299.2	300	299.6
R12-14	Cuttings	307.8	310	308.9
R12-15	Cuttings	317.8	320	318.9
R12-16	Cuttings	327	330	328.5
R12-17	Cuttings	338	340	339
R12-18	Cuttings	342.95	343	342.975
R12-19	Cuttings	345.6	346	345.8
R12-20	Cuttings	348.3	349	348.65
R12-21	Cuttings	351.9	352	351.95
R12-22	Cuttings	358	358.5	358.25
R12-23	Cuttings	369.2	370	369.6
R12-24	Cuttings	374.5	375.5	375
R12-37	Cuttings	379.2	380	379.6
R12-38	Cuttings	386.8	388	387.4
R12-39	Cuttings	395.3	397	396.15
R12-40	Cuttings	400	401	400.5
R12-41	Cuttings	406	408	407
R12-216	Core	420.5	420.8	420.65
R12-217	Core	421.2	421.33	421.265
R12-33	Core	520.4	520.5	520.45
R12-34	Core	523.7	523.8	523.75
R12-35	Cuttings	553.5	555	554.25
R12-36	Cuttings	559	560	559.5
R12-49	Cuttings	564	565	564.5
R12-50	Cuttings	569	570	569.5
R12-51	Cuttings	574	575	574.5
R12-52	Cuttings	578.85	580	579.425
R12-53	Cuttings	584.3	585	584.65

*See Appendix B

TABLE C-2 (continued)

MATRIC POTENTIAL SAMPLES

Sample ID*	Matrix Type	Upper Depth (ft)	Lower Depth (ft)	Average Depth (ft)
R12-54	Cuttings	589.3	590	589.65
R12-55	Cuttings	594.3	595	594.65
R12-56	Cuttings	599.04	600	599.52
R12-57	Cuttings	604.13	605	604.565
R12-58	Cuttings	609.45	610	609.725
R12-59	Cuttings	614	615	614.5
R12-60	Cuttings	618.7	620	619.35
R12-61	Cuttings	624.2	625	624.6
R12-62	Cuttings	628.75	630	629.375
R12-63	Cuttings	633.75	635	634.375
R12-64	Cuttings	639	640	639.5
R12-65	Cuttings	643.9	645	644.45
R12-66	Cuttings	648.9	650	649.45
R12-67	Cuttings	653.75	655	654.375
R12-68	Cuttings	658.9	660	659.45
R12-69	Cuttings	663.67	665	664.335
R12-70	Cuttings	672.2	673	672.6
R12-71	Cuttings	709.2	710	709.6
R12-72	Cuttings	713.9	715	714.45
R12-224	Core	719.78	720	719.89
R12-223	Core	725.45	725.65	725.55
R12-222	Core	730.3	730.6	730.45
R12-221	Core	733	733.2	733.1
R12-122	Core	742.1	742.2	742.15
R12-123	Core	745.8	746	745.9
R12-220	Core	750.7	751.1	750.9
R12-5201	Core	755.9	756	755.95
R12-273	Core	760.85	761	760.925
R12-274	Core	765.7	766	765.85
R12-275	Core	770.8	771	770.9
R12-276	Core	775.25	775.45	775.35
R12-277	Core	779.2	779.5	779.35
R12-124	Cuttings	804.66	805	804.83

*See Appendix B

TABLE C-3

SAMPLES PRESERVED FOR POTENTIAL HYDRAULIC PROPERTY TESTING

ID (CASA-98-)*	Matrix Type	Start Depth (ft)	End Depth (ft)	Average Depth (ft)
0013	Core	421.33	421.66	421.49
0014	Core	421.66	422.0	421.83
0007	Core	455.0	456.5	455.75
0021	Core	483.05	483.5	483.28
0022	Core	484.15	484.6	484.38
0023	Core	490.3	490.8	490.55
0024	Core	491.3	491.8	491.55
0029	Core	509.17	509.55	509.36
0026	Core	509.55	510.2	509.88
0027	Core	511.9	512.4	512.15
0030	Core	522.0	523.0	522.50
0031	Core	522.8	523.5	523.15
0041	Core	719.28	719.78	719.53
0048	Core	724.6	725.1	724.85
0049	Core	729.55	730.0	729.78
0047	Core	744.2	744.7	744.45
0043	Core	747.5	748.0	747.75
0044	Core	754.9	755.4	755.15
0046	Core	765.1	765.5	765.30
0042	Core	770.1	770.6	770.35
0039	Core	774.45	774.95	774.70
0040	Core	777.5	778.0	777.75
0057	Cuttings	791.0	792.5	791.75
0054	Cuttings	812.0	814.6	813.3
0055 (dup)	Cuttings	812.0	814.6	813.3

*See Appendix B

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CORRECTION

END