September 27, 2002

REPORT OF PRE-CONCEPTUAL GEOTECHNICAL INVESTIGATIONS, ADVANCED HYDROTEST FACILITY PROJECT, TA-53 LOS ALAMOS NATIONAL LABORATORY LOS ALAMOS, NEW MEXICO PROJECT NO. C59010120

Prepared for:
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Submitted to:
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September 27, 2002
Project No. C59010120

Mr C. Robert Hutchins, Project Manager
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800 Trinity Drive, Suite K
Los Alamos, New Mexico 87544

**SUBJECT: REPORT OF PRE-CONCEPTUAL GEOTECHNICAL INVESTIGATIONS
ADVANCED HYDROTEST FACILITY PROJECT, TA-53
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
PROJECT NO. C59010120**

Dear Mr Hutchins:

Submitted herewith is our report of the pre-conceptual geotechnical investigations on the referenced project for your review and comment. The report includes results of test drilling and laboratory tests and our engineering evaluations and preliminary recommendations regarding site geology, subterranean facility depth and layout, tunnel excavation and support, open excavations, and subsequent geotechnical investigations.

We look forward to your comments Please contact us with any questions you might have.

Respectfully submitted,

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SUMMARY OF CONCLUSIONS

The pre-conceptual geotechnical investigations of the AHF Site at TA-53 indicate that the geologic units in which tunnels and shafts will be constructed in the canyons will behave like soil rather than rock. The low strength parameters of the Otowi will require a soft-ground approach to excavation and structural support. If unshielded tunnel construction methods are used (e.g.; roadheader or NATM) the excavation cycle will be short, probably less than 10 feet. If a TBM is used, support immediately behind the shield will be needed. In shafts, shoring or other bracing will be required in each cycle as the shaft is sunk

In open excavations relatively low in-place densities and unconfined strengths might limit cut slope gradients and increase potential for settlement and slumping of ground adjacent to cuts. These same properties could make retained excavation more feasible because support systems like soldier piles or soil nails should be comparatively quick to install.

If the beam line in the tunnel is at elevation 6600, a 15-foot diameter tunnel will break out of the Otowi into the Cerro Toledo in at least one location and come very close to breaking into alluvium in at least one other location in Sandia Canyon. In Mortandad Canyon the base of the Cerro Toledo will be less than one tunnel diameter above the crown of the tunnel in at least one location. It is reasonable to expect that these conditions would occur over a substantial portion of the tunnel alignments under the canyons. Although the laboratory results from these investigations do not show a sharp contrast in geomechanical properties between the Otowi and the Cerro Toledo, it is possible that the stand-up time and stress-strain behaviors of the two units would be different enough to require different primary support and permanent lining designs. To avoid a mixed-face tunneling scenario and lessen the risk of instability in the tunnel above the crown, the tunnel level can be lowered to a depth that would provide at least one diameter (preferably two diameters) below the Otowi/Cerro Toledo or Otowi/ alluvium contact. This can be achieved by either actually lowering the elevation of the tunnel level or by shifting the alignment to avoid the deepest horizons of those contacts, resulting in a new layout with respect to the site topography and geology. An alternative approach would be to assume the certainty of a mixed-face tunnel scenario and to design the tunnels and plan construction for those conditions.

The results of this investigation have identified additional questions and have shown how variable the geotechnical elements of the site are likely to be. Geotechnical uncertainties of primary importance are:

- Parameters related to facility layout and depth – the shape and position of the top of the Otowi and the thickness and continuity of the overlying geologic units
- Primary geomechanical parameters – strength parameters (friction, cohesion, unconfined strength, triaxial maximum deviator stress).
- Major geologic structures – the existence and location of any faults or erosional breaks that could impact the position and continuity of geologic units along the tunnel alignments.

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These data needs can be addressed through a set of geotechnical investigations, starting with the "CD0" phase of the Site Characterization Master Plan (SCMP) described in detail in the TA-53 Integrated Design Studies Report, September, 2001 This phase would identify any site features that could force major realignment or repositioning of AHF facilities. The second SCMP phase is the conceptual design, or CD1, phase. It should be focused on the data requirements of conceptual design and on data needed to determine sizes and shapes of tunnels and shafts, methods of excavation and ground support, and identify potential out-of-limits conditions including unstable slopes and excessive contaminant levels. Specifically, these investigations should include:

- Continuous tube sampling and visual logging
- Video logging
- Downhole seismic logging
- Seismic reflection and refraction surveys
- Laboratory testing

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1 INTRODUCTION

Kleinfelder, Inc. has prepared this Report of Pre-Conceptual Geotechnical Investigations in fulfillment of the deliverable-product requirements under Task 039 of Holmes and Narver/Raytheon's (HNR's) contract with Los Alamos National Laboratory. It addresses the scope and results of geotechnical investigations conducted to support pre-conceptual design studies of the Advanced Hydrotest Facility (AHF) at TA-53.

1.1 GENERAL DESCRIPTION OF PROJECT

The Advanced Hydrotest Facility (AHF) of the Los Alamos Neutron Science Center (LANSCE) at TA-53 is intended to be a subterranean system of shafts, tunnels, and experiment halls as well as surface support facilities for research associated with the Department of Energy's Stockpile Stewardship program. AHF will have as many as 28 shafts and more than five miles of tunnels under at least 50 feet of cover that is intended to act as a radiation shield. The facility will include two underground test chambers, one tunneled in rock and the other to be constructed at a depth of 180 feet in an open excavation about 600 feet in diameter. The subterranean facilities will include:

- An injector shaft
- A booster ring
- A main ring synchrontron
- Beam ejectors/ splitters
- Beam transport tunnels
- A non-SNM firing site (Firing Site #1, or FS1)
- An SNM firing site (Firing Site #2, or FS2)
- Services shafts with alcoves
- Emergency egress shafts
- One or more access drifts (inclined tunnels)

AHF research will involve a high-energy proton beam and Special Nuclear Materials (SNM), requiring protection from radiation as well as a high level of security. To provide both radiation protection and security, the subterranean facilities must be at least 50 feet below lowest ground surface, or about elevation 6600 feet, and must be in essentially that same plane throughout the entire beam path. No other underground facilities have been constructed at this depth or elevation in the Los Alamos area, and no test borings have been drilled for geotechnical purposes to this elevation in the footprint of the proposed AHF. Consequently, the geologic conditions around the AHF are based on broad-scale studies including surface geologic mapping as well as shallow test borings around the LANSCE complex (TA-53) and test borings in the same vicinity drilled and sampled for environmental and ground water studies.

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1.2 Purpose and Content of Report

This report has been prepared as a record of the geotechnical investigations conducted by Kleinfelder, Inc under subcontract to Holmes and Narver/ Raytheon (HNR) during July-September, 2002. The investigations were performed to:

- Develop an initial understanding of the geotechnical conditions of the site in general and of the canyons in particular, and
- Support a preliminary evaluation of geotechnical design parameters that could impact tunnel layout and depth.

This report presents a description of the investigations, findings, and preliminary conclusions and recommendations concerning ground conditions affecting tunnels, shafts, and open excavations. Implications of the findings on facilities layout and depth are discussed, as well. Data needs identified from these investigations and the types of future geotechnical investigations required to address those needs are described.

In section 2, the physical setting of the AHF site at TA-53 is described. The following section, 3.0, describes the scope of investigations andanalyses. Section 4.0 presents the conclusions and recommendations resulting from the investigations and analyses.

2 SITE DESCRIPTION

These facilities are located across a geographic footprint that is approximately 3700 feet from north to south and nearly 3100 feet east to west, hinging on the linear accelerator of the Los Alamos Neutron Science Center (LANSCE) at TA-53. Within this area the terrain includes two mesas and two canyons, aligned approximately east-west and roughly perpendicular to the axis of the beam transport tunnels system, which constitutes most of the length and footprint of the subterranean facilities. This combination of terrain and facility alignment results in tunnels crossing under both Sandia and Mortandad canyons, with FS2 located in Mortandad Canyon at the south end of the tunnels.

The general geologic setting of the AHF area includes, in descending order:

- Uplands or mesas formed by the Tshirege Member of the Bandelier Tuff, which is several hundred feet thick and will be penetrated by shafts from the TA-53 area. The Tshirege is divisible into several units:

  Unit 4 – absent in the AHF area

  Unit 3 - non-welded to partially weld tuff

  Unit 2 - moderately to strongly welded tuff

  Unit 1v – devitrified, non-welded to slightly welded tuff

  Unit 1g – glassy, non-welded to slightly welded tuff with pumice fragments

- Cerro Toledo interval, a volcano-clastic sedimentary unit between tuffs of the two major eruptions. Bounded by erosional surfaces on bottom and top, it is irregular in thickness and

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lateral extent, and is generally not lithified. Where the Cerro Toledo interval is missing, it may be replaced by Tsankawi Pumice, which otherwise forms a layer up to 1m thick overlying the Cerro Toledo.

- Otowi Member of the Bandelier Tuff, underlying the Cerro Toledo as well as both mesas and canyons. The tunnel horizon will be in the upper portion of the Otowi, which is a non-welded tuff.

Alluvium, soil deposited by streams, forms the bottoms of both canyons. The alluvium is derived primarily from erosion of the Tshirege and consists of mostly silt- and sand-size volcanic ash fragments. In the canyons the alluvium overlies the Unit 1g tuff, the Cerro Toledo, or the Otowi tuff depending on location.

The shallowest cover over the tunnels will be in Sandia Canyon, where the surface elevations are lowest. The bedrock/alluvium contact depth has not been known prior to these investigations, and the physical properties of the alluvium had not been characterized in any previous studies. Consequently, there were insufficient data for determining the depth and physical properties of alluvium in Sandia and Mortandad canyons or the thickness, lateral continuity, and physical properties of the Cerro Toledo interval and the Tsankawi Pumice. It is very important to determine where alluvium, the Cerro Toledo interval, and the tuff units are in relation to the planned AHF subterranean facilities and what properties must be considered in locating and designing the facilities. The scope of these investigations was based on developing this information.

3 SCOPE OF INVESTIGATIONS AND ANALYSES

3.1 DESCRIPTION OF INVESTIGATIONS

The pre-conceptual geotechnical investigations were planned and conducted to:

- Explore the shallow subsurface of Sandia and Mortandad canyons using test borings to establish some bounding limits of the positions, thicknesses and properties of the geologic materials (lower Tshirege Member, alluvium, Tsankawi Pumice, Cerro Toledo interval, and upper Otowi Member) that are likely to surround and overlie the AHF subterranean facilities.
- Determine preliminary ranges of physical properties of geologic materials by performing laboratory tests on selected samples obtained from the test borings.
- Evaluate the geologic conditions that might affect tunnel and shaft layout, depth, design, and construction.
- Prepare recommendations that will be used to support decisions concerning subterranean facility locations, depths, and potential construction methods, and to scope subsequent geotechnical investigations of the Site Characterization Master Plan.

In this pre-conceptual stage of the AHF Project, site characterization efforts have been directed toward determining those geologic conditions that define bounding limits for the physical placement and construction of the subterranean facilities. Accordingly, these investigations were

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limited to delineating major geologic units and their boundaries and general properties (e.g.; what geologic units are present, how thick are they, will they be soft or hard, weak or strong). The investigations consisted of eight test borings drilled through soil and rock to about elevation 6580 or about 15-20 feet below tunnel invert level. Each boring was visually logged and sampled as appropriate for the materials encountered. Limited laboratory testing was performed on selected samples to support soil and rock classification and estimates of unit weight, strength parameters, permeability, and alkali-silica reactivity. Samples splits were made available to LANL ER and ESH groups for chemical testing for environmental contaminants.

3.1.1 Test Borings

Eight test borings were drilled to depths between 84 and 179 feet, sufficient to reach about 15 feet below expected invert elevation (6660 feet), or about elevation 6580 feet. Five of these borings were drilled in Sandia Canyon directly south of TA-53, as shown on Figure 1. Borings in Sandia Canyon were drilled 84 to 150 feet deep and three borings were drilled in Mortandad Canyon to depths of 143 to 179.2 feet. The locations of the eight borings were selected to cover the footprint of the AHF tunnels and other subterranean structures as much as possible and to supplement information previously developed by the LANL Environmental Restoration program.

The test drilling activities were performed in accordance with the requirements of the ESH ID, Excavation Permit, and Activity Hazards Analysis. Each test-boring site was accessed along existing roads and trails, with some overland travel required for short distances at several locations. No earthwork, bridge-building or other special measures were required to get drilling equipment to and from the designated drill sites, and no sites were within stream channels. Consequently, no restoration of access routes or stream channels was needed. Drill site disturbances involved the area immediately around the drillhole where the drill rig and support truck and trailer were parked as well as the space around the collar of the drillhole where cuttings were retained during drilling. No mud pits were used. The typical area of activity around each borehole was about 3600-4000 square feet, at most. Of this area about 100-150 square feet was temporarily covered with cuttings. When each test boring was completed, all cuttings were placed back in the drillhole and the cuttings site was raked. All trash and equipment was removed when the crew left the site. The total area of disturbance for all eight test borings was about 2/3 acre.

The test borings were drilled with a Strata-Star 10 drill rig using an 8.0 inch O.D./4.0 inch I.D. hollow stem auger in accordance with ASTM Method D6151-97. Drill cuttings were retained within 10-20 feet of the borehole during drilling and placed in the borehole as backfill at the completion of drilling of each hole. Samples were obtained by continuous tube sampler advanced inside the auger, by Standard Penetration Test (SPT) drive sampler (ASTM D1586-99), by California drive sampler (ASTM D3550-01) and by grab sampling of auger cuttings. SPT sampling or California ring barrel sampling at five-foot intervals was the usual testing/sampling method applied in alluvium intervals of all test borings and, at the discretion of the field geologist, in some sections of the Cerro Toledo and tuff units encountered in the borings. Grab samples were taken to provide large volumes of material for testing the compaction characteristics of soil and tuff.

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Sampling in the Otowi Member usually employed the continuous tube method. Continuous tube samples provide a more complete record of the materials penetrated, making it possible to develop more detailed descriptions of the subsurface conditions. Continuous tube samples were considered to be undisturbed and were sealed and handled in accordance with ASTM D4220-95. When the tubes are removed from the borehole, they were capped and sealed with tape on both ends, labeled, and transported for safekeeping and later testing. Although this ASTM procedure is intended for use with undisturbed soil samples, it was used for samples of tuff, as well, because of the soft soil-like consistency of the tuffs.

Some rock coring was attempted using a NQ wireline core barrel with a diamond or carbide bit per ASTM D2113-99. Due to the softness of the tuffs, rock coring using the standard rock core barrel with air as the drilling fluid was not successful and was abandoned in favor of continuous tube sampling with the hollow stem auger.

A Kleinfelder geologist visually logged all borings. On a standard log form, the geologist recorded:

- Number and location of boring
- Date of start and completion
- Names of driller and geologist
- Boring collar elevation and total depth
- Sampling methods and depth/interval of each sample
- Sample recovery – percentage recovered
- Classification of material – Unified Soil Classification System for soils, petrologic description for rock
- Visual description including color, moisture content, stiffness/density/hardness, grain sizes, structural features (roots, fractures, bedding, etc.), weathering, and visible minerals
- Penetration resistance (SPT blow counts) or advance rate
- Lithologic boundaries or contacts
- Depth of groundwater
- Graphic log illustrating different materials encountered

Additional notes will be added to logs when needed for explanation or clarification of log entries.

Daily field reports were also prepared on which the geologist recorded work started and completed, problems encountered and actions taken, and hours worked.

Upon completion of each test boring, the samples were removed from the site and transported by truck to the Kleinfelder Albuquerque laboratory. All tube samples were maintained in an upright position throughout handling, transportation and storage to retain the undisturbed characteristics of the samples as much as possible. The location and disposition of samples were recorded on a sample inventory/ custody log. LANL's ESH-10 group obtained splits of 32 samples for their use in testing for geochemical characterization and environmental contaminants.

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3.1.2 Laboratory Testing

A limited program of laboratory testing was performed on selected samples obtained from the test-boring program. The specific tests included:

- Grain size analysis
- Atterberg limits
- Moisture-density
- Unit weight
- Direct shear
- Unconfined Compression
- Triaxial Compression
- Hydraulic Conductivity
- Alkali-soil reactivity (ASR)

In the investigation program plan, combined hardness and tensile strength tests were to be performed on tuff if suitable samples were obtained. Due to the softness of the tuff, these tests could not be performed.

All geomechanical and ASR testing was performed in Kleinfelder laboratories in Albuquerque, New Mexico and Pleasanton, California.

3.2 Geotechnical Analyses and Findings

The investigations described above were intended to provide information about the geologic setting and geomechanical properties of geologic units in the canyons of the AHF site at TA-53. As such, they provide the basis for some geotechnical analyses and findings that are general and preliminary. Additional, more detailed investigations will build on this basis to develop the geotechnical parameters needed for conceptual and higher levels of design. The following describes the analyses performed and the resulting preliminary findings.

3.2.1 Results of Test Boring Program

The results of the test-boring program are summarized in Table 1 and illustrated in Figures 2, 3 and 4. The test boring logs, from which Table 1 and Figures 2, 3 and 4 are derived, are included in Appendix B. Borehole BH-7 was drilled at LANSCE in July, 2002 as part of the LANL Environmental Restoration Program at the south edge of the lagoons at TA-53, about 700 feet north-northeast of test boring SC1 of this program; the graphic log of the lower part of BH-7 is included on Figure 2 as supplemental information.

Sandia Canyon (SC) Borings

Borings SC1 through SC5 were drilled in Sandia Canyon at the locations shown on Figure 1 in Appendix A. All SC borings encountered alluvium and tuff of the Otowi Member. The alluvium is primarily silty sand with varying amounts of silt and clay. Colluvium consisting of rock fall and talus from adjacent slopes is randomly interbedded within the alluvium. Thickness of alluvium increases from about 23 feet at SC2, near the west end of the tunnel footprint, to 50 feet at SC4 and SC5.

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In the west half of the footprint area, Unit 1g of the Tshirege Member underlies the alluvium, thinning eastward from about 29 feet thickness at SC2 to about 12 feet at SC3. The 1g Unit appears to have been eroded away from the eastern half of the footprint in Sandia Canyon, but it is at least 80 feet thick under the lagoons at TA-53 in BH-7. The 1g Unit is pinkish to reddish brown, non-welded to partially welded ash flow tuff.

The Cerro Toledo interval consists of a variety of non-welded sediments, primarily reddish brown silty sand with fragments of gravel up to one inch in size. Although the Tsankawi Pumice overlies the Cerro Toledo, it is less than three feet thick and not readily distinguishable from the Cerro Toledo; therefore, for the purposes of this report the Tsankawi is treated as part of the Cerro Toledo. Like Unit 1g, the Cerro Toledo interval was found in borings SC2 and SC3 but not in borings in the eastern half of the footprint in Sandia Canyon (SC1, SC4, and SC5), but the Cerro Toledo is approximately 40 feet thick in BH-7. Evidently the Cerro Toledo, like the 1g Unit, has been eroded from Sandia Canyon in the east half of the AHF footprint. The vertical position of the Cerro Toledo is lowest in SC3, where its base elevation is about 6605, putting the Cerro Toledo within the tunnel excavation horizon at that location if the beam line follows elevation 6600. The extreme variability in the elevations of the base of the Cerro Toledo between SC2 and SC3, 51 feet over 1200 feet distance, shows that the Cerro Toledo was deposited on an irregular erosional surface and was, itself, eroded before deposition of the Tshirege tuffs.

The tuff of the Otowi Member was found in all SC borings either below the Cerro Toledo in the western half of the footprint area or below the alluvium in the eastern half. The Otowi is pinkish orange (salmon) colored, non-welded ash flow tuff. It was difficult to sample using air coring, but good sample recovery was achieved using continuous tube sampling with the hollow stem auger. The Otowi is consistently soft and breaks easily. This formation will be the host unit for the AHF underground facilities, but as shown by SC3 and SC5, the depth of the facilities will have to be increased to avoid encountering Cerro Toledo or alluvium in tunnel excavation.

Water was encountered only in boring SC3. The water level was 35 feet depth during drilling, but by the time the boring was completed, the water had drained to some level below the bottom of the borehole. This water was probably transient, arising from rapid infiltration of rainfall and local runoff.

The geologic profile along Sandia Canyon that can be interpreted from the SC borings is shown in Figure 3.

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Table 1
AHF Boring Log Summary

Boring	Surface elevation	Depth (ft)	Notes	Water
SC-1	~6591	0 - 17.5	Alluvium; silty sand w/ gravel to poorly graded sand w/ trace gravel	NE
		17.5 - 20	Colluvium; block of ash-flow tuff from above vapor-phase notch	
		20 - 23	Alluvium; silty sand w/ gravel to poorly graded sand w/ trace gravel	
		23 - 114	Otowi Member, ash flow tuff, light red to reddish orange, fine grained, ashy matrix w/ phenocrysts of quartz and sanidine, avg. 1mm, up to 2mm; glassy pumice up to 1 cm, slightly weathered, very to extremely weak. Grades to light reddish pink to light gre	
SC-2	~6723	0 - 25	Alluvium; silty sand to sandy silt w/ some gravel	NE
		25 - 54	Tshirege Member, Unit 1g, ash flow tuff, light pinkish brown, medium to coarse grained matrix, quartz and sanidine phenocrysts up to 1mm, glassy but partially crystalline grey pumice up to 2 cm, non-welded, very few lithics. Grades to light pinkish grey,	
		54 - 67	Cerro Toledo Interval, volcaniclastic sediments consisting of silty sand matrix with medium to coarse grains of quartz and sanidine, pumice fragments up to 5 mm, glassy. Red-brown to brown, wet, extremely weak, crudely bedded, occasional pumice-rich layer	Qct wet
		67 - 148.5	Otowi Member of the Bandelier Tuff, ash flow tuff, light reddish to pinkish brown, fine to medium grained, ashy matrix w/ phenocrysts of quartz and sanidine, up to 2 mm; light grey (some oxidized, orange), glassy pumice up to 1.5 cm, chocolate brown lithi	
SC-3	~6702	0 - 51.5	Alluvium; poorly graded sand, clayey sand, lean clay, silty sand	Init: 35
		51.5 - 63	Tshirege Member, Unit 1g, ash flow tuff, reddish orange-ish brown, medium-grained ashy, pyroclastic matrix, quartz and sanidine phenocrysts up to 1mm, glassy, grey and yellowish-orange pumice up to 1 cm, non-welded to partially welded, trace lithics.	Final: none
		63 - 97.1	Cerro Toledo Interval, volcaniclastic sediments consisting of silty sand matrix with medium to coarse grains of quartz and sanidine, glassy pumice fragments. Grey to red-brown, crudely bedded, gravelly layers w/ basalt clasts up to 1.5", medium to coarse	Qct wet
		97.1 - 123.7	Otowi Member of the Bandelier Tuff, ash flow tuff, pinkish brown, fine grained, ashy groundmass w/ phenocrysts of quartz and sanidine, up to 1 mm; up to ~3% dark brown lithics up to 3 mm, light grey (some oxidized, orange), glassy pumice up to 3 cm, non-	
SC-4	6682	0 - 50	Alluvium; silty sand to poorly graded sand, clay, clayey sand	NE
		50 - 104	Otowi Member of the Bandelier Tuff, ash flow tuff, light reddish to pinkish brown, fine to medium grained, ashy matrix w/ medium to coarse grained phenocrysts of quartz and sanidine, up to 2 mm; oxidized (orange) glassy pumice up to 8 cm, 1-2% dark grey l	
SC-5	~6682	0 - 49.5	Alluvium; silty sand to poorly graded sand	NE
		49.5 - 84	Otowi Member of the Bandelier Tuff, ash flow tuff, pinkish orange, fine grained, ashy matrix w/ phenocrysts of quartz and sanidine, up to 1 mm; oxidized (orange) glassy pumice up to 3 cm, trace lithics up to 1/2", non- to partially welded, extremely to ve	
MC-1	~6765	0 - 12	Alluvium; silty sand with lean clay layers	NE
		12 - 55	Tshirege Member, Unit 1g, ash flow tuff, light brown, ashy matrix, quartz and sanidine phenocrysts up to 1mm, glassy but partially crystalline grey pumice up to 1 cm, non-welded, fresh to slightly weathered, extremely weak, non-indurated, trace lithics up	
		55 - 82.1	Cerro Toledo Interval, volcaniclastic sediments consisting of silty sand interlayered with medium to coarse sand, trace silt, white, glassy pumice fragments up to 1 cm, reddish brown, poorly bedded, extremely weak, pumice-rich to 50 with occasional pumic	
		82.1 - 179.2	Otowi Member of the Bandelier Tuff, ash flow tuff, light grey brown, fine to medium grained, ashy matrix w/ phenocrysts of quartz and sanidine, up to 2 mm; light grey to pinkish, glassy pumice up to 5 cm, lithics up to 1/2", non- to partially welded, sig	
MC-2	~6752	0 - 79.5	Alluvium; silty sand to sandy silt, sandy lean clay to clayey sand, poorly graded sand with silt	NE
		79.5 - 116	Cerro Toledo Interval, volcaniclastic sediments consisting of sand with silt to silty sand, ash and pumice, medium to coarse sand, light grey to light yellow glassy pumice fragments up to 1.5 cm, trace obsidian up to 3/4", poorly bedded, 5-15% lithics (ba	
		116 - 171.5	Otowi Member of the Bandelier Tuff, ash flow tuff, pinkish orange, fine to medium grained, ashy matrix w/ phenocrysts of quartz and sanidine up to 2mm, oxidized (orange), glassy pumice up to 9+ cm (3.5"), lithics up to 1-1/2", ~5%, non welded, slightly we	
MC-3	~6727	0 - 55.5	Alluvium; silty sand to sand with silt, silty clay with sand	NE
		55.5 - 64	Colluvium boulders, gravel- to cobble-sized clasts of ash-flow tuff from above vapor-phase notch	
		64 - 104.2	Cerro Toledo Interval, volcaniclastic sediments consisting of various proportions of sand, silt, lithics (basalt gravel), ash and pumice, medium to coarse sand, light brownish grey, trace obsidian, poorly bedded, 5-15% lithics (basalt), increases up to ~3	
		104.2 - 143.7	Otowi Member of the Bandelier Tuff, ash flow tuff, light pinkish orange, fine to medium grained, ashy matrix w/ sparse phenocrysts of quartz and sanidine, oxidized (orange), glassy pumice up to 5 cm (2"), up to 10% lithics up to ~2", non-welded, slightly	

NE Not encountered

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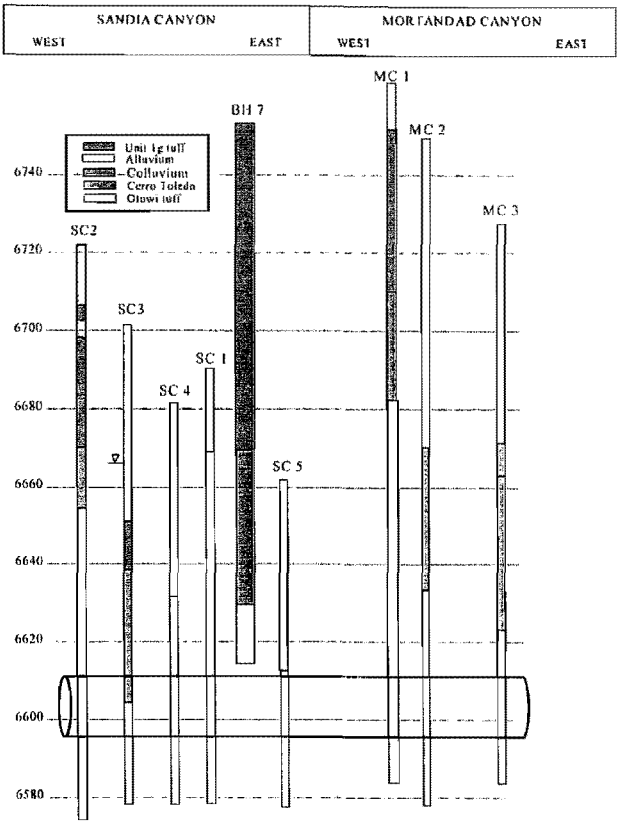

FIGURE 2. Graphic Summary of Test Boring Logs

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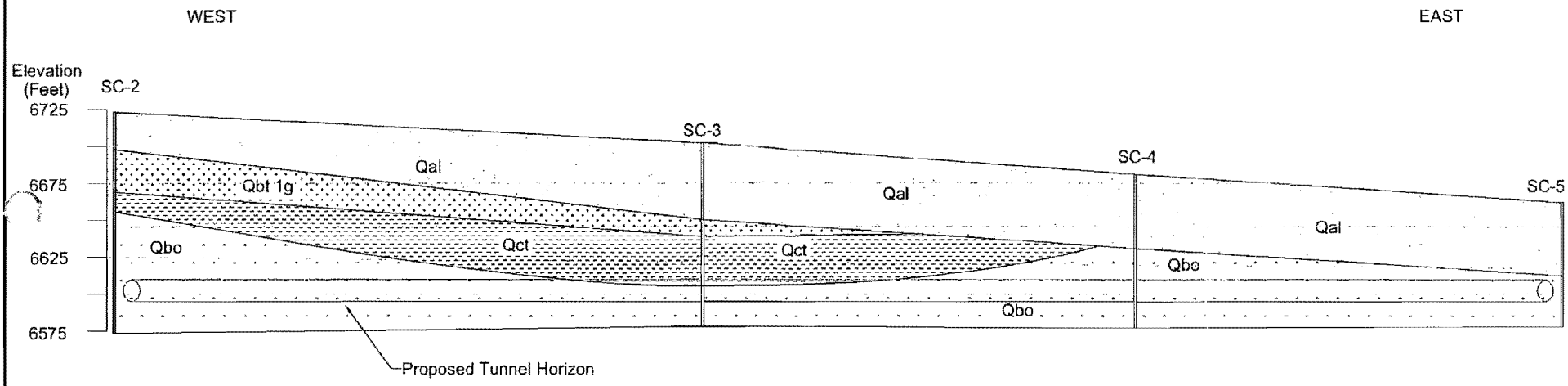

LEGEND:

- Quaternary Alluvium (Qal)
- Quaternary Tshirege Member, Unit 1g (Qbt 1g)
- Quaternary Cerro Toledo Interval (Qct)
- Quaternary Otowi Member (Qbo)

Horizontal Scale:

200 0 100 200

SCALE: 1 inch = 200 ft.

Vertical Scale is 3:1 to Horizontal Scale
All Locations are Approximate
All Contacts are Interpreted

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Drawn By: B. Bockisch
Project No: c59010120
Date: September 2002
Filename: SonCanSec.dwg

Cross Section Parallel to Sandia Canyon
Advanced Hydrotest Facility
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure 3

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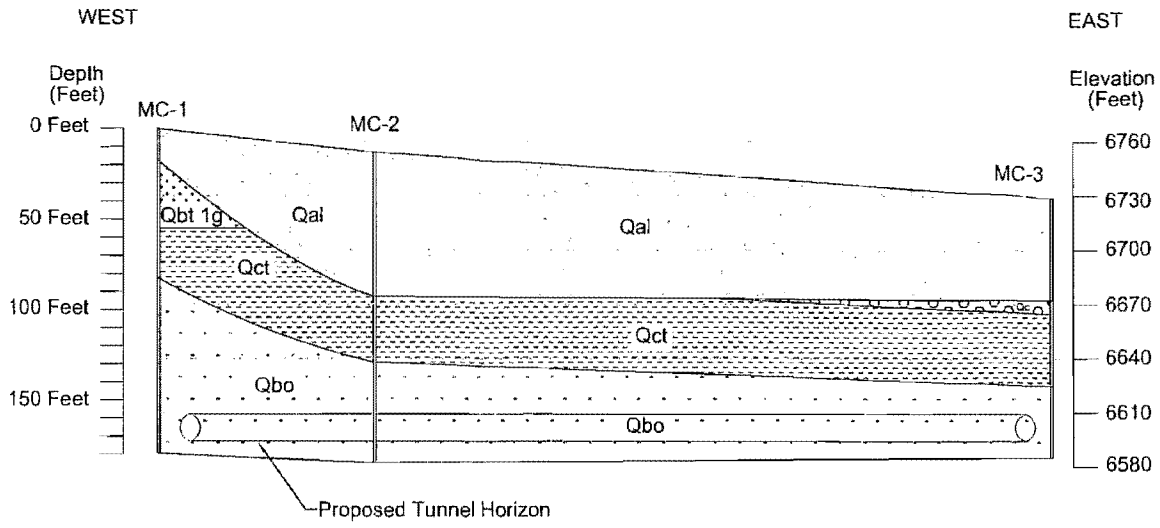

LEGEND:

- Quaternary Alluvium (Qal)
- Quaternary Colluvium (Qc)
- Quaternary Tshirege Member, Unit 1 (Qbt 1g)
- Quaternary Cerro Toledo Interval (Qct)
- Quaternary Otowi Member (Qbo)

Horizontal Scale:

200 0 100 200

SCALE: 1 inch = 200 ft.

Vertical Scale is 3:1 to Horizontal Scale
All Locations are Approximate
All Contacts are Interpreted

KLEINFELDER

Drawn By: B Backisch
Project No: c59010120
Date: September 2002
Filename: MortConSec.dwg

Section Through Mortandad Canyon
Advanced Hydrotest Facility
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure 4

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Mortandad Canyon (MC) Borings

The three test borings drilled in Mortandad Canyon all encountered the Otowi Member, the Cerro Toledo, and the alluvium, all of which had essentially the same physical properties as in Sandia Canyon. The 1g Unit occurred in MC1 but not in the other two MC borings. Both the absence of the 1g Unit and the much lower position (about 50-60 feet lower) of the Cerro Toledo interval in MC2 and MC3, compared to MC1, implies that there is either a paleocanyon wall or a structural offset (fault) between MC1 and MC2.

No water was encountered in the MC test borings.

The geologic profile along Mortandad Canyon that can be interpreted from the MC borings is shown in Figure 4.

3.2.2 Results of Laboratory Testing Program

Based on the test boring logs and visual examination of samples, a limited number of samples were selected for testing in Kleinfelder's Albuquerque and Pleasanton (CA) material testing laboratories. All sampled materials, including the tuffs, were tested using soil mechanics methods. These tests provide some initial insight into the physical properties of the geologic units in the canyons; although too limited to support design, the test results indicate the range of properties that should be considered when evaluating facility layout and depth, design and excavation approaches, and later site investigation plans.

Laboratory test results are included in Appendix B and summarized in Table 2. The results can be evaluated by geologic unit as follows:

Alluvium – general sandy soil with up to 50% minus #200 sieve (fines) consisting of silt (SM soil) or clay (SC soil), low plasticity to non-plastic. This material should be suitable for excavation of stable cut slopes and for use as engineered fill.

Tshirege Unit 1g – generally silty sand with enough bonding of particles (from cohesion, welding or cementation) to give the tuff relatively good strength (95.8 psi in unconfined compression) considering its low density (71.9 pcf).

Cerro Toledo – variably graded silty sand and silt, moderate to low density (96.2 to 70.9 pcf), low strength in unconfined compression (4.8 to 14.5 psi) but good strength parameters (ϕ =28-31, cohesion = 2-3 ksf) in direct shear. This material should be suitable for excavation of stable cut slopes and for use as engineered fill.

Otowi tuff – generally silty sand with enough bonding of particles (from cohesion, welding or cementation) to give the tuff some unconfined strength (6.0 to 53.0 psi) and good strength parameters (ϕ =38, cohesion = 1.1 ksf) in direct shear. Five triaxial unconsolidated-undrained (U-U) tests, run of samples from five different borings, produced a wide range of results, from a deviator stress of 16.91 ksf at 1.0 ksf confining pressure to 7.19 ksf deviator

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Table 2
Tabulation of Laboratory Test Results

Bore Hole	Depth (ft)	Geologic Unit	USCS	Direct Shear	Sieve Analysis % Passing # 200	Atterberg Limits	Dry Density (pcf)	Moisture Content (%)	Unconfined Compression (psi)	Max Dry Density	Hydraulic Conductivity (k) cm/sec	Triaxial U-U (ksf)
SC-3	30	Alluvium	CL		65.0	LL=33, PI=13		23.0				
SC-3	35	Alluvium	SM		47.0	LL=35, PI=6		29.1				
SC-4	15	Alluvium	SP-SM		5.8	NP		4.3				
SC-4	25	Alluvium	SC-SM		15.0	LL=26, PI=5		6.9				
SC-5	46.5	Alluvium	SC		18.0	LL=31, PI=12		9.5		122pcf @ 10%		
MC-1	8	Alluvium	SM		36.0	NP		5.7				
MC-2	18	Alluvium	ML		55.0	NP		6.6				
MC-2	48	Alluvium	SC-SM		36.0	LL=32, PI=6		11.9				
MC-2	58	Alluvium	SM		24.0	NP		10.7				
MC-3	10	Alluvium	SW-SM		7.4			4.3				
MC-3	30	Alluvium	CL-ML		70.0	LL=27 PI=4		7.7				
MC-3	40	Alluvium	SW-SM		6.2			1.3				
MC-3	60	Colluvium	SM		25.0			6.0				
SC-2	50-51	Tshirege					71.9	31.5	95.8			
MC-1	23	Tshirege	SM		40.0	NP		4.5				
MC-1	43	Tshirege	SM		28.0	NP		5.5				
SC-2	65.5-66	Cerro Toledo				NP	76.7	29.1	7.6			
SC-3	72.2-73.7	Cerro Toledo		ϕ=31°, c=3.0ksf			96.2	14.7	6.0	114 pcf @ 14%		
MC-1	56-58	Cerro Toledo		ϕ=28°, c=2.0ksf			74.1	10.3	14.5			
MC-1	66	Cerro Toledo	SW-SM		8.6			7.9				
MC-1	74	Cerro Toledo	ML		50.0			10.6				
MC-2	80-81.5	Cerro Toledo					70.9	14.0	4.8			
SC-1	92.8-94	Otowi					75.0	15.0	9.7			
SC-2	135.7-136.5	Otowi					83.2	20.8	53.0			
SC-3	109	Otowi					70.2	22.8			2.70×10^{-7}	σ_D=16.91, σ_3=1.00
SC-3	110	Otowi					72.8	19.8				
SC-4	75	Otowi					57.1	16.3				σ_D=5.07, σ_3=1.00
SC-4	75.5	Otowi					61.7	14.7				
SC-4	91.5-92.6	Otowi					72.3	12.0	7.3			
SC-5	76.5-77.5	Otowi					78.4	10.0	6.7		4.1×10^{-7}	
MC-1	91	Otowi	SM		28.0	NP		8.1				
MC-1	127.5-129	Otowi						NA				
MC-1	152-153.2	Otowi						34.5			2.48×10^{-7}	
MC-1	152.8	Otowi					66.5	9.4				σ_D=7.98, σ_3=1.50
MC-2	138.4-140.3	Otowi					69.9	7.0	6.0			
MC-2	145.2	Otowi					65.9	12.9				σ_D=7.19, σ_3=2.00
MC-3	116.2-118.7	Otowi		ϕ=35°, c=1.1ksf			74.6	9.2	6.0			
MC-3	135	Otowi					68.7	8.3				σ_D=11.72, σ_3=1.50

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stress at 2.0 ksf confining pressure Although confinement appears to increase stress at failure, the results are not conclusive. Densities are consistently low, 69.9 to 83.2 pcf, over the six samples tested Hydraulic conductivity (permeability to water) also appears to be consistent, in the range of 10-7 cm/sec.

Alkali-silica reactivity (ASR) testing was performed on a selected set of samples from the several geologic units. These tests are time-dependent and could not be completed by the submittal date of this report. Laboratory testing started several weeks later than originally scheduled, the result of delays in the drilling and sample collection caused by fire hazard conditions and drill rig mechanical problems. The results of ASR tests will be submitted later as an addendum to this report

The tests show that all of the geologic units consist of soils or soil-like material – none of these units have typical rock density, hardness or strength properties.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 GROUND CONDITIONS AFFECTING TUNNELS AND SHAFTS

Both the test borings and the laboratory tests indicate that the geologic units in which tunnels and shafts will be constructed in the canyons will behave like soil rather than rock The low strength parameters of the Otowi will require a soft-ground approach to excavation and structural support. The Otowi should excavate easily but is likely to have short stand-up times, requiring substantial ground support installed close to the heading within a short time, perhaps minutes, of excavation. Consequently, if unshielded tunnel construction methods are used (e.g.; roadheader or NATM) the excavation cycle will be short, probably less than 10 feet. If a TBM is used, support immediately behind the shield will be needed. In shafts, shoring or other bracing will be required in each cycle as the shaft is sunk

4.2 GROUND CONDITIONS AFFECTING OPEN EXCAVATIONS

The geotechnical parameters that make tunnel and shaft excavation relatively easy should also make open excavation straightforward. The apparent absence of ground water and high-plasticity soils and the good frictional characteristics of all geologic units are favorable factors for open excavation. However, relatively low in-place densities and unconfined strengths might limit cut slope gradients and increase potential for settlement and slumping of ground adjacent to cuts Alternatively, these same properties could make retained excavation more feasible because support systems like soldier piles or soil nails should be comparatively quick to install.

4.3 IMPLICATIONS FOR FACILITIES LAYOUT AND DEPTH

The graphic logs in Figure 2 and the profiles in Figure 3 and 4 show that, if the beam line in the tunnel is at elevation 6600, a 15-foot diameter tunnel will break out of the Otowi into the Cerro Toledo in at least one location and come very close to breaking into alluvium in at least one other location in Sandia Canyon. In Mortandad Canyon the base of the Cerro Toledo will be less than one tunnel diameter above the crown of the tunnel in at least one location. Considering the number of trouble spots encountered in a limited number of test borings (three out of eight), it is

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reasonable to expect that these conditions would occur over a substantial portion of the tunnel alignments under the canyons. The variability of the vertical position and thickness of the Cerro Toledo shown by these test borings will almost certainly persist under the mesas, as well Consequently, with the tunnel elevation and layout that is currently baselined for the AHF project, zones of Cerro Toledo soils and possibly alluvium will be exposed in tunnels. Although the laboratory results from these investigations do not show a sharp contrast in geomechanical properties between the Otowi and the Cerro Toledo, it is possible that the stand-up time and stress-strain behaviors of the two units would be different enough to require different primary support and permanent lining designs. Such a mixed-face condition would add to construction costs and lead to a more complex design.

To avoid a mixed-face tunneling scenario and lessen the risk of instability in the tunnel above the crown, the tunnel level can be lowered to a depth that would provide at least one diameter (preferably two diameters) below the Otowi/Cerro Toledo or Otowi/ alluvium contact This can be achieved by either actually lowering the elevation of the tunnel level or by shifting the alignment to avoid the deepest horizons of those contacts, resulting in a new layout with respect to the site topography and geology. However, for either approach to be taken with confidence, additional site investigations would be needed to establish the form of the upper surface of the Otowi across the footprint of the tunnel system.

An alternative approach would be to assume the certainty of a mixed-face tunnel scenario and to design the tunnels and plan construction for those conditions.

4.4 DATA NEEDS

This investigation program has produced some initial insight into the geologic conditions and geomechanical properties that will impact the AHF subterranean facilities, but the results of this investigation have also identified additional questions and have shown how variable the geotechnical elements of the site are likely to be. Geotechnical uncertainties of primary importance are:

- Parameters related to facility layout and depth – the shape and position of the top of the Otowi and the thickness and continuity of the overlying geologic units. Data from this investigation shows that these parameters can vary substantially across the site and will have major effect on the layout, construction methods, and cost of the subterranean facilities.
- Primary geomechanical parameters – strength parameters (friction, cohesion, unconfined strength, triaxial maximum deviator stress). The values of these parameters determined in this investigation vary over a wide range. The number of tests performed is not sufficient to support a judgment about whether this variability is due to sample disturbance, test operator influence, or actual variation in the tested materials. Because the strength parameters are critical to design and construction of the tunnels and shafts, more strength testing is needed

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- Major geologic structures – the existence and location of any faults or erosional breaks that could impact the position and continuity of geologic units along the tunnel alignments.

4.5 SUBSEQUENT GEOTECHNICAL INVESTIGATIONS

The site investigations conducted for this pre-conceptual design phase of the project produced the data needed for determining the general geologic setting of the canyons within the AHF footprint and for initial assessments of geotechnical properties. These data needs can be addressed through a set of geotechnical investigations, starting with the "CD0" phase of the Site Characterization Master Plan (SCMP) described in detail in the TA-53 Integrated Design Studies Report, September, 2001.

The CD0 phase is not linked to any specific information needs of CD0; it would occur before the start of conceptual design. This phase would identify any site features that could force major realignment or repositioning of AHF facilities. For example, an active or capable fault underlying the location of FS2 could force that structure to be relocated. Such a feature affects project planning at a pre-conceptual level, so it must be addressed before conceptual design.

The second SCMP phase is the conceptual design, or CD1, phase. It should be focused on the data requirements of conceptual design and on acquiring data needed to determine sizes and shapes of tunnels and shafts, on methods of excavation and ground support, and on identifying potential out-of-limits conditions including unstable slopes and excessive contaminant levels. This phase is intended to produce the additional data needed to support the conceptual design and to provide data required in the Environmental Impact Statement. The geotechnical characterization of SCMP CD1 should be directed toward establishing a geologic model of the entire site, including the mesas, and determining the range of geomechanical properties that affect facility layout, configurations, and constructability. Test borings should be drilled at the locations of the primary subterranean facilities to establish the thickness and vertical limits of rock units, to document in situ rock structure, and to extract additional samples for visual examination and testing. Geophysical surveys should be performed to assist in geologic correlation between test borings, to detect large subsurface discontinuities, and to provide data on rock mass properties. Specifically, these investigations should include:

- Continuous tube sampling and visual logging – to provide better characterization of site geology, to obtain core and other samples for testing, and to provide openings for video and downhole seismic logging.
- Video logging – to observe and record rock discontinuities in situ and in true spatial orientation
- Downhole seismic logging – to determine velocity characteristics of rock with depth, to complement seismic reflection and refraction surveys
- Seismic reflection and refraction surveys – to determine velocity characteristics of rock in three-dimensional space and to locate boundaries between geologic units, to complement downhole seismic logging and rock coring and visual logging

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- Laboratory testing
  - Direct shear – to quantify friction angle and cohesion of material
  - Compressive strength – to quantify strength in uniaxial compression
  - Grain size analyses – to classify soil and disaggregated tuff
  - Plasticity Indices– to classify soil and disaggregated tuff
  - Proctor moisture/ density – to quantify compaction characteristics of soil and disaggregated tuff
  - In-situ density and specific gravity – to quantify void ratio and unit weight of tuff
  - Alkali-silica reactivity – to evaluate chemical interaction of tuff with concrete

Data derived from these investigations should be added to the site database and terrain model. The terrain model will provide the primary platform for conceptual modeling of shafts and tunnels. Modeling will include AutoCAD simulation of excavations within the terrain model as well as representations of shaft and tunnel configurations for subsequent structural analysis during design

5 CLOSURE

5.1 LIMITATIONS

The recommendations contained in this report are based upon the field exploration, laboratory tests, and our understanding of the proposed facilities. It is the responsibility of the design team to determine the suitability of the information contained in this report and, at the discretion of the design team, to seek supplemental geotechnical information and recommendations. This supplemental information could include additional site-specific borings, laboratory testing, geotechnical engineering analysis, or geotechnical consultation.

The subsurface data used in the preparation of this report was obtained from the eight test borings. It is anticipated that variations in the subsurface soil and rock conditions may exist between the boring locations. The nature and extent of variations may not be evident until construction occurs.

This report was prepared in accordance with generally accepted standards of practice at the time the report was written. No warranty, express or implied, is made. It is the Client's responsibility to see that all parties to the project, including the Designer, Contractor, Subcontractors, etc., are made aware of this report in its entirety. The use of information contained in this report for design purposes; subsequent use of this information for construction should be done at the Contractor's option and risk.

Other standards or documents referenced in any given standard cited in this report, or otherwise relied upon by the authors of this report, are only mentioned in the given standard; they are not incorporated into it or "included by reference" as that latter term is used relative to contracts or other matters of law.

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APPENDIX A

Figure 1 – Location Plan of Pre-Conceptual Geotechnical Test Borings

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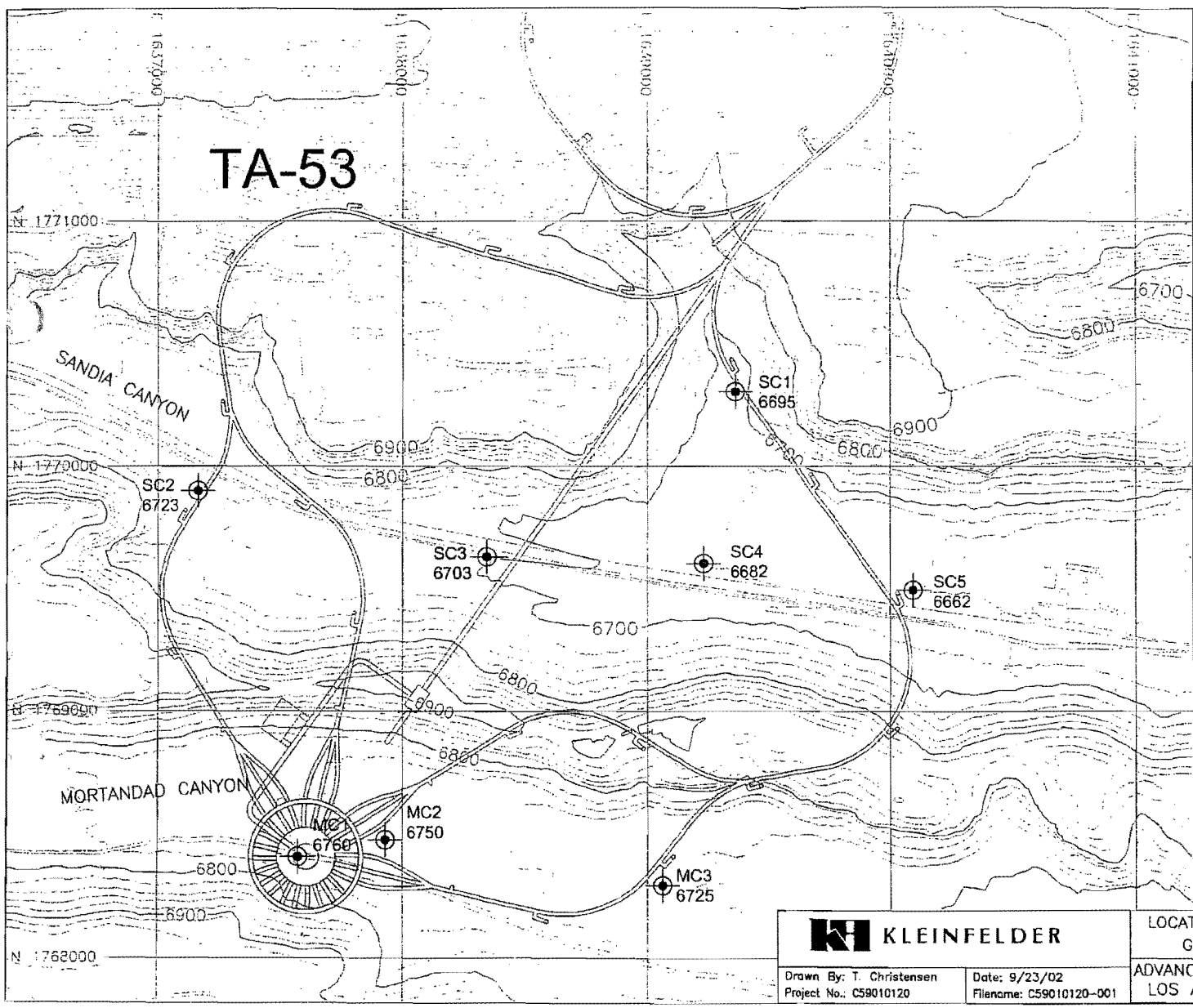

ID	NORTHING	EASTING	ELEV.	DEPTH
SC1	1770304	1639362	6695	115
SC2	1769900(1)	1637167(1)	6723	150
SC3	1769632	1638347	6703	123
SC4	1769606	1639232	6682	102
SC5	1769497	1640094	6662	82
MC1	1768409	1637573	6760	180
MC2	1768477	1637929	6750	170
MC3	1768294	1639063	6725	125

NOTES

1. LOCATION OF SC2 IS APPROXIMATE WITHIN 10 FT. OF LISTED COORDINATES.

400' 0 200' 400'

SCALE: 1 inch = 400 ft

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Drawn By: T. Christensen
Project No.: C59010120
Date: 9/23/02
Filename: C59010120-001

LOCATION PLAN OF PRE-CONCEPTUAL GEOTECHNICAL TEST BORINGS

ADVANCED HYDROTEST FACILITY, TA-53
LOS ALAMOS NATIONAL LABORATORY

FIGURE 1

APPENDIX B

Test Boring Logs
Laboratory Test Results

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Date Completed: 08/13/2002 Logged By: S. Merkley

Boring Location: Mortendad Canyon, 17' west of staked location

Driller: Chad Szpunar Drilling Method/Size: 8" HSA

Elev Top of Hole: 6765' Total Depth (ft): 179.2 Groundwater Depth: I ▽ not encountered

F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Silty SAND (SM), fine grained, brown, dry to slightly moist, loose to medium dense, non-plastic	
								Lean CLAY with sand (CL), fine grained sand, yellowish-brown, very moist, moderately firm to soft, low plasticity	
				4, 6				Silty SAND (SM), fine grained, brown, dry to slightly moist, loose to medium dense, non-plastic	
6760	5								
				12, 6					
6755	10							Light brown, with some GRAVEL to about 2"	
				10, 8				Bandelier Tuff (Qbt1g), ash flow TUFF, light brown, ashy matrix with phenocrysts to 1 mm, trace lithics to 2 mm (.1"), pumice to 1 cm (.4"), glassy, fresh to slightly weathered, extremely weak, non-indurated	
0	15							Light yellowish-brown at 15'	
				4, 12	NR				

KA_RX-SOIL 010120.GPJ 9/27/02

KLEINFELDER

Drafted By: S. Merkley Project No: 59-010120

Date: 09/27/2002 File Number: 59-010120

LOG OF BORING MC-1
Advanced Hydrotest Facility - Preconceptual
Los Alamos National Laboratory
Los Alamos, New Mexico

PLATE 1 of 8

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				8, 12					
40	25							Light brown Glassy pumice up to 3 cm (1 2")	
				7, 12					
6735	30								
				29, 50					
6730	35								
				32, 48					
6725	40							Whitish-gray	

KA_RX-SOIL 010120.GPJ 9/27/02

KLEINFELDER

Drafted By: S Merkley
Date: 09/27/2002

Project No : 59-010120
File Number: 59-010120

LOG OF BORING MC-1
Advanced Hydrotest Facility - Preconceptual
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Los Alamos, New Mexico

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				35, 50/3"					
6720	45								
				55, 50/3"					
6715	50								
									Start continuous sampling at 53' Drilling adjustment set at 60 inches
								Possible Tsankawi pumice	
6710	55							Cerro Toledo Interval (Qct), reddish-brown, sandy unit with white, glassy pumice up to 1 cm, silty sand, fine grained matrix Pumice-rich to about 59', poorly bedded to crudely bedded	Drilling easier
					96				
								Sand increases, medium to coarse through 62', silt increases to trace to some	
6705	60								
								Pumice-rich bed observed at 61' to 62'	
								Silty sand, predominately fine grained at 63'	
								Pumice-rich bed observed at 64' to 66', up to 40% pumice	
5700	65								

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Drafted By: S. Merkley
Date: 09/27/2002
Project No.: 59-010120
File Number: 59-010120

LOG OF BORING MC-1
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PLATE 3 of 8

KA_RX-SOIL 010120.GPJ 9/27/02

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Grades from red-brown to light gray-brown, fine to medium SAND (about 80%), [about 5%] pumice up to 4 mm (16"). about 15% silt/ash	
6695	70							From 69' to 73.5' interlayered red brown, silty SAND with trace to some pumice, ash, lithics, fine to medium grained, layers of fine grained silty sand with 10 to 20% ash and pumice	
					85				
								From 73.5' to 78' silty SAND, red-brown, predominately fine to medium grained, approximately 30% pumice up to 1 cm (4"), weakly cemented	
6690	75								
6685	80							From 78' to 82.1' poorly graded, medium grained SAND with trace silt, some ash, light brown	
								Bandelier Tuff (Qbo), ash-flow TUFF, light gray brown. non-welded to partially welded, [15 to 20%] pumice to about 1.5 cm (8"), ashy matrix, pumice is glassy. pinkish-brown to white	
6680	85							Light pinkish/grayish-brown	
					95				

KA_RX-SOIL 010120.GPJ 9/27/02

KLEINFELDER

Drafted By: S Merkley
Date: 09/27/2002

Project No : 59-010120
File Number: 59-010120

LOG OF BORING MC-1
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PLATE
4 of 8

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6675	90							Pinkish-brown, lithics increase to about 5 to 7%, brown to red-brown, dacite, up to 1 2 cm (.5") Note: From 82 1' to about 89' may be re-worked Otowi	
6670	95								
6665	100				50			Unit grades to pinkish-orange, pumice is yellowish-orange. up to 5 cm (2"). glassy Percent pumice increases to about 30% Lithics angular to sub-angular, 5 to 10% light pinkish-brown, sparse phenocrysts up to about 5 to 10%	Sample tube was crushed - salvaged lower sample tube, 101 5' to 103 8'
6660	105								
6655	110				94				

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6650	115								
6645	120							Light pinkish-gray, percent lithics increases to about 10%, up to 5", pumice up to 5 cm (2")	
								Partially welded	
6640	125				94				
6635	130							Light gray	
								Basalt lithics to 2", sub-angular to sub-rounded	
6630	135								

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6625	140								
6620	145							Degree of welding increases slightly	
6615	150				95				
6610	155				100			Light pinkish-gray, pumice less abundant and smaller, up to about 2 cm (.8")	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Light gray	
6605	160							Basalt lithics to about .25". pumice is white, glassy. sparse phenocrysts	
					100				
								Lithics up to .5"	Drilling slower than last run - drill run stopped at 4.2' run so tubes didn't crush Very hard, slow drilling with sample tubes from approximately 165'
6600	165								
					100				
									3.9' run - tubes started to crush
6595	170								
					100				
								Degree of welding increases slightly, light gray, lithics increase slightly - 10%	
6590	175								
					95				
								Total depth to 179.2'	
6585	180								

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Date Completed: 08/09/2002 Logged By: S. Merkley

Boring Location: Mortendad Canyon, 8' south of staked location

Driller: Chad Szpunar Drilling Method/Size: 8" HSA

Elev Top of Hole: 6752' Total Depth (ft): 171.5 Groundwater Depth: I ▽ not encountered

F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Silty SAND (SM) with trace to some gravel, predominately fine grained, brown, slightly moist, medium dense, non-plastic, trace clay (low plasticity), roots to about 10' (trace)	
				4, 7, 8					
	5								
6745				4, 3, 7					
	10							Trace fine gravel	
6740				4, 6, 5					
	15								
6735								Sandy SILT (ML), trace clay, fine grained sand, slightly moist, brown, moderately firm, non-plastic	
				4, 6, 8					

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Date: 09/27/2002 File Number: 59-010120

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6730								Sandy silty CLAY (CL-ML) with trace fine gravel to .25", fine sand, brown, slightly moist, moderately firm, low plasticity to non-plastic, trace quartz/sanidine grains	
				6, 7, 8					
	25							Poorly graded SAND with trace to some silt (SP-SM), fine to medium sand, brown, slightly moist, medium dense, non-plastic, interbedded with 6" to 12" thick silty clay to sandy silt layers as above Note: Burnt wood at bottom of sample	
6725									
				5, 8, 10					
	30								
6720									
				16, 30				Sandy lean CLAY to clayey SAND (CL-SC), predominately fine sand, brown, slightly moist, very firm, low plasticity	
	35								
6715									
				12, 16				Sandy CLAY, same as above with traces of pumice, coarse quartz, sanidine grains	
	40							Sandy lean CLAY (CL), predominately fine sand, occasional layers of medium grained sand, brown, moist to slightly moist, very firm, low plasticity, epiclastic soil (fragments of phenocrysts, trace pumice, lithics)	
6710									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				26, 18					
	45								
6705									
				25, 46				Hard	Suspect blow counts - sampler may have been hung up
	50								
6700									
				12, 6				Firm	
	55							Clayey SAND (SC), fine to medium grained, yellowish-brown, slightly moist to moist, firm, low plasticity, layers of non-plastic silty sand, medium grained	
6695									
				10, 13					
	60							Interbedded with poorly graded SAND, predominately medium grained	
6690									
				11, 13					Blow counts suspect
								Poorly graded SAND with silt (SP-SM), some gravel up to about 4" (tuff, partially welded, purplish-pink), sand is predominately medium grained with some coarse and fine grained, brown, slightly moist, medium dense, non-plastic	
	65								

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6695									
	70								
6690								Grades to fine grained silty SAND with tuff gravel and cobbles, same as above	
				3, 5				Abrupt change to orange-brown ash flow TUFF, (possibly colluvial), moderately weathered, matrix is fine grained, some ash with sand, lithics less than 1 mm, pumice is sugary white to glassy white - variable, up to about 3 mm (12")	
	75								
6675									
									Start continuous sampling at 79'
	80				82			Cerro Toledo Interval (Qct) consisting of thin, interbedded SAND with silt, ash, occasional .2' thick pumice layer with sugary, grainy devitrified pumice and white vitrified pumice, sand is predominately medium grained, with trace obsidian fragments up to about 2 mm, pumice lense approximately 4' thick with pumice up to about 1 5 cm (6") from 86 6' to 87. glassy	
6670									
	85							Color varies from light yellow to white (sands) with tiny black flecks/grains	
6665									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	90							Unit is about 80% SAND, some sandy pumice layers with up to 50% pumice, light yellow	
6660					56				
	95							Obsidian pieces up to .75" in cuttings and sample Overall about 50% SAND, 25% PUMICE, 10% ASH, 5 to 15% LITHICS. basalt up to 1"	
6655									
	100							[Up to 50%] basalt gravels, angular to sub-angular, up to 2", pumice to about 5"(1 3 cm), non-bedded to slightly bedded	
6650					62				
	105							Gravel up to 70% in coarse grained layers. lose obsidian	
6645									
	110								
6640									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
					62				
	115								
6635					93			Bandelier Tuff (Qbo), ash-flow TUFF, pinkish-orange, ashy matrix with pumice, glassy, containing crystals of quartz and sanidine, lapilli to 3.5" (entire diameter of tube), pumice is orange/oxidized, glassy, lithics about 5%, up to 25", non-welded	
	120							Pumice about 20 to 30% of unit, up to 1 5" (about 4 cm), lithics up to 1 5" (averaging 25"), phenocrysts about 5%, up to 2 mm	
6630								Grades to light pinkish-gray Pumice is white and orange - not all is oxidized	
	125								
6625					90				
								Percent ash increases, about 20% pumice	
	130								
6620									
	135							Partially welded	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6615									
	140							Pumice is white, not oxidized, unit is light gray, partially welded	Harder drilling from 140' Slow drilling
6610					100				
	145								
					100				
6605								Cuttings white to light gray	
									Start NQ wireline coring
	150								
6600									
					0			Retrieved a few pieces of pumice/lithic fragments up to about 1"	
	155								
6595									
									Switched back to continuous sampling at 157.5'

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	160				100			Partially welded, light whitish-gray, about 20 to 30% pumice, glassy, white. up to 3 cm (1 2") Lithics about 5% up to about 25"	Drilled slow to obtain 100% recovery
6590									
	165				98			Pumice up to 4 cm (1 6"), some are yellowish-orange, oxidized	
6585									
	170				95				
6580								Total depth to 171 5'	
	175								
6575									
	180								

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Date Completed: 08/08/2002 Logged By: S. Merkley

Boring Location: Mortandad Canyon, North of road

Driller: Rob Helton/Chad Szpunar Drilling Method/Size: 8" HSA

Elev Top of Hole: 6727' Total Depth (ft): 143.7 Groundwater Depth: I ▽ not encountered F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Silty SAND (SM) with trace gravel, fine to medium sand, layers of coarse grained sand, light brown, slightly moist, loose to medium dense, non-plastic	
	5			5, 5, 6				Interbedded poorly graded SAND (SP) with silty sand, silty sand is fine grained, medium to coarse grained, light brown to brown, slightly moist, loose to medium dense, non-plastic, trace gravel to 1"	
6720									
	10			3, 4, 4					
6715									
	15			3, 5, 4					
6710									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				4, 4, 7					
6705									
	25			8, 13, 14				Silty CLAY with sand (CL-ML), fine grained sand, slightly moist, yellow brown, firm, low plasticity	
6700									
	30			9, 9, 10				At 30', grades to silty clay, some fine sand, yellow-brown, firm, slightly moist, low plasticity	
6695									
	35			5, 7, 9				Silty SAND with trace clay (SM), fine to some medium grained sand, yellow-brown, slightly moist, medium dense, non-plastic to low plasticity	
6690									
								Poorly graded SAND (SP), trace silt, predominately medium grained sand, brown, slightly moist, medium dense, non plastic	
	40			4, 6, 6					
6685									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	45			5, 11, 12				Percentage of SILT increases slightly, with gravel to cobble-sized tuff fragments, tuff fragments are friable, light grayish-purple, about 30 to 40% phenocrysts in ashy matrix	
6650									
	50			5, 5, 7				Silty SAND (SM), fine to medium grained, brown, slightly moist, medium dense, non-plastic, some tuff fragments, weakly cemented. trace to some gravel	
6575									
	55			3, 6, 9					
6670								Silty GRAVEL [GM], (Colluvium) with gravel and cobble-sized clasts of tuff, pinkish-orange, pumices up to about 1 cm, gray, devitrified, ashy matrix with altered phenocrysts, some are purplish-gray, sand is fine grained, trace clay Volcanic tuff boulders, very friable to friable, light gray to purplish-gray, pumice dark gray, up to 1 cm, devitrified, some phenocrysts of quartz, sanidine	Start continuous sampling at 58.7'
	60			5, 12, 20	64				
6665								Light gray, ashy matrix with [up to 20%] pumice up to 2 cm, dark gray, devitrified, some quartz and sanidine phenocrysts	
	65							Cerro Toledo Interval (Qct), horizontally bedded sand, ash and pumice, finely bedded, various proportions ash, lithics [basalt, dacite, up to .5", sub-rounded], trace obsidian nodules, pumice, sand Upper 1' of run is weathered, yellow-brown tuff with about 30% white, vitrified pumice, pumice is fine grained sugary white - devitrified	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Loose, layered sands may have been blown away	
6660									
	70				83				
6655									
	75								
6650									
								Obsidian fragments up to 1 mm	
	80								
6645									
								Light gray to beige, pumices are sugary white, about 30%, up to 4 mm (.25"), lithics are dark gray, up to about 1", phenocrysts of quartz, sanidine up to 2 mm	Drilling harder
	85								
					80			Predominately reworked material from ash-flow deposit, light brownish-gray to beige, fine grained ashy matrix with some phenocrysts (about 5%) of quartz, sanidine, up to 2 mm, about 10% lithics, dark gray to black specks up to 4 mm, pumice is white, glassy, up to 1 cm (4"), non-welded. friable texture, slightly porous	
6640								Poorly bedded to not bedded	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	90							Lithics increase to 15 to 20%	
6635									
	95				80			Percentage of lithics increases to about 30% dacite and basalt, percentage of pumice decreases to about 5%	
6630								Grades to light gray-brown	
	100							Moisture content increases slightly (still slightly moist) Unit is composed predominately of lithics, sub-angular Basalt clasts up to about 2", approximately 50% pumice From 100' to 100.5' is an ashy, fine grained layer with fewer lithics (5%) Partially cemented from 101'	
6625									
	105							Bandelier Tuff (Qbo), contact at 104.2' Ash-flow TUFF, fine grained, ashy matrix/groundmass, non-welded, light pinkish-orange (pumpkin colored), with pumice up to 1.8 cm (.75") oxidized (orange), with medium grained crystals in pumice, anhedral to sub-anhedral sparse phenocrysts up to about 5%, up to 1 mm, extremely weak to very weak, fresh, lithics up to 10%. to 5 mm (2")	
620									
	110							Color lightens to light pinkish-gray, partially welded	
5615									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	115				100				
6610									
	120				100				
6605								Increase in percentage lithics to about 15%, basalt, sub-angular to angular, up to .75", partially welded	
	125				100				
6600								Pumice up to 5 cm (2"), yellow-orange, with crystals, about 20%	
	130				100				
6595								Occasional layers with increased percentage lithics - up to 30%, basalt, sub-angular, up to 2" (average size .75")	
	135							Increase in percentage pumice to about 25%	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6590					100				
	140				100				
6585									Refusal encountered with sample tubes in barrel
								Total depth to 143 7'	
	145								
6580									
	150								
6575									
	155								
6570									

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Date Completed: 07/26/2002 Logged By: S. Merkley

Boring Location: Thumb canyon on north side of Sandia Canyon, TA-72

Driller: Rob Helton Drilling Method/Size: 8" HSA

Elev Top of Hole: 6691' Total Depth (ft): 114 Groundwater Depth: ▽ not encountered

F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6690								Silty SAND with gravel (SM), fine grained, light red-brown, slightly moist, loose, non-plastic, strong reaction to HCL, sub-rounded to round gravel up to about 2", consisting of miscellaneous foreign lithics, cemented/welded tuff, dacite	
	5			2, 2, 2					
6685								Occasional gravelly layers	
	10			12, 15, 16				Poorly graded SAND with trace to some gravel (SP), medium grained sand, light reddish-gray, slightly moist, dense, non-plastic	
6680								Interbedded clayey SAND with gravel and poorly graded sand from 13' to 17.5', clayey to silty sand is moist, red, medium dense, low plasticity to non-plastic	
	15			36, 15, 15				Poorly graded SAND predominately medium grained	
6675								From 17.5' to 20' is likely a colluvial block of ash-flow tuff, medium to coarse-grained matrix, highly weathered, moist, unweided, extremely weak, brown to red-brown, moisture content decreases with depth to slightly moist, phenocrysts of quartz and sanidine, devitrified pumice	Drilling harder

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LOG OF BORING SC-1

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
					95			Poorly graded SAND with silt (SP), fine to coarse, some bedding, gray brown, slightly moist, non plastic	
6670									
								Bandelier Tuff (Qbo), ash-flow TUFF, light red to reddish-orange, fine grained, ashy matrix, with phenocrysts of quartz and sanidine averaging 1 mm, up to 2 mm, glassy pumice up to about 1 cm (4"), very weak to extremely weak, very friable	
	25								
6665									
				50/3"				Light reddish-pink	
	30								
6660									
				50/3"					
	35								
6655									
				50/1"					
	40								
6650									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	45			20, 50, 45				Lapilli-sized pumice, vitreous but partially crystalized/sugary texture, chocolate brown dacite lithics up to 1 5". pumice is usually oxidized to orange-yellow	Start continuous sampling at 44'
6645					95				
	50								
6640									
	55								
6635									
	60								
6630					90				
	65								
6625									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Dark gray, dacitic to andecitic lithics 1" to 2" in size	
	70				95			Color darkens to reddish-orange, mottled with lighter red-pink. slightly more moist, percent lithics increases. pumices are yellowish-brown but glassy	Drilling slightly harder
	75								
6615									
	80				85			Slightly increased abundance of dark gray dacitic lithics	
6610									
	85								
6605									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	90							Light pinkish-brown	Drilling harder
6600					90				
								Pinkish-beige	
	95								
6595									
	100							Dacite lithics to 75" in size, unit grades to light gray	
6590					90				
								Sample is loose, broken up, similar color, composition except lithics sparse, up to about 2 mm	
	105								
6585								Pumice is slightly more abundant, larger clasts up to about 2"	
	110								
6580					95				

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Total depth to 114'	
	115								
6575									
	120								
6570									
	125								
6565									
	130								
6560									
	135								

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Date Completed: 08/01/2002 Logged By: S. Merkley

Boring Location: Sandia Canyon, south of road, 48' southwest of stream gauge

Driller: Rob Helton Drilling Method/Size: 8" HSA

Elev Top of Hole: 6723' Total Depth (ft): 149.5 Groundwater Depth: I ▽ perched : 53.7'
F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Sandy SILT to silty SAND (SM-ML), trace fine gravel, predominately fine grained sand, brown, slightly moist to moist, loose, non-plastic	
6720									
	5			3, 4, 4					
6715									
	10			2, 2, 3				Silty SAND with some gravel (SM), fine to medium sand, brown, slightly moist, loose to very dense, non-plastic, some gravels are devitrified pumice, up to 1 cm (4")	
6710									
	15			3, 2, 3				Percentage fines decreases, predominately fine grained sand	
6705									

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LOG OF BORING SC-2
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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				6, 4, 5				1.5" layer of light gray ash-flow, quartz and sanidine phenocrysts, ashy matrix - within brown silty sand, same as above	
6700				22, 25, 28					Start continuous sampling at 24'
	25				50			Bandelier Tuff (Qbt 1g), ash-flow TUFF, fine grained, ashy matrix with quartz and sanidine phenocrysts up to 1 mm, glassy but partially crystalline pumice, up to 2 cm (8"), light pinkish-brown to light pinkish-gray, non-welded Pumices are generally light gray, very few lithics	
6695								Tuff becomes partially welded	
	30								
6690									
	35				65				
	40								
6680									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	45								
6675									
	50								
6670									
	55							Moisture content increases to very moist to wet Cerro Toledo Interval (Qct), volcaniclastic sediments consisting of silty sand matrix with grains (medium to coarse) of quartz, sanidine; glassy pumice fragments up to about 5 mm, red-brown to brown. wet. extremely weak, crudely bedded	
6665									
	60							From 59.3' to 60.3' are 2 layers of pumice in a silty sand matrix, clast-supported pumice lapilli up to 2 cm (8"), vitreous, white to light brown to orange in color; unit is wet, soft Perched water encountered at 59 3'	
6660								At 63.5' unit grades to coarse SAND with silt, some fine gravel - pumice, lithics, fine to medium silty sand, wet, red-brown, dense, non-plastic	
	65							More uniform, basalt lithics up to 5 mm, very moist to moist, red-brown, with pumice lapilli up to about 1 cm (4")	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
					80				
6655								Bandelier Tuff (Qbo), ash-flow TUFF, reddish-brown to pinkish-brown, moist, fine to medium grained matrix in ash, lithics, phenocrysts of quartz, sanidine, coarse sand-sized, pumice up to 1.5 cm (.6"), whitish-tan to light gray, some orange, glassy, non- to partially welded, (predominately non-welded), uniform	
	70								
6650								Whitish-gray pumice lapilli, 3 cm (1.2")	
								Saturated at 73'	
								Unit is moist to slightly moist	
	75								
6645									
	80							Red-brown to orangish-brown	
6640									
	85							Cuttings very moist to moist	
					90				Drilling very hard
6635									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	90							Pumices predominately orange, up to 1 cm (4"), partially crystaline but some glassy Percentage lithics increases to about 5%, up to 5 mm, basalt	
6630									
	95							Color grades to pinkish-gray, slight increase in pumice, tuff is partially welded	Drilling got harder again
6625									
	100							Chocolate brown lithics, up to 2 mm, pumice mostly beige to light gray	
6620									
	105				90			Pumice block fragments up to 4 to 5 cm (1 6 to 2")	Drilling slightly easier
6615									
	110							Amount and size of pumice decreases, lithics consisting predominately of basalt and dacite	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6610									
	115								
								Light gray-brown, some pumices are oxidized - orange, up to 1 cm (.2") Unit is still partially welded, non-uniformly	
6605									
	120							Slightly moist	
6600									
	125								
6595									
	130							Increase in lithics, size up to 2", consisting mostly of basalt and dacite	Drilling difficulty increases
6590									
	135								

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6585									
	140							Medium gray-brown, about 15% oxidized pumice, fine grained matrix, trace lithics	Added 4 gallons of water in hole to help retrieve cuttings
6580									
	145								
6575									
	150							Total depth to 149.5' Cave to 140'	
6570									
	155								
6565									

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Date Completed: 08/05/2002 Logged By: S. Merkley

Boring Location: Sandia Canyon, south of road, 22' southwest of staked location

Driller: Rob Helton Drilling Method/Size: 8" HSA

Elev Top of Hole: 6702' Total Depth (ft): 123.7 Groundwater Depth: I ▽ perched: 35'

F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Poorly graded SAND (SP), with trace silt and gravel, medium to coarse sand, dark brown, moist, loose to medium dense. non-plastic	
	5			5, 5, 6					
6695									
	10			3, 2, 3				Loose. trace fine gravel to about 1", well rounded	
6690									
	15			3, 3, 3					
6685									

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Date: 09/27/2002 File Number: 59-010120

LOG OF BORING SC-3

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				2, 2, 4				Interbedded with silty SAND (fine to medium grained), very moist	
6680									
	25			6, 7, 3					
6675									
	30			3, 2, 4				Sandy lean CLAY (CL), with trace gravel, fine grained sand, brown, very moist, medium stiff, low to medium plasticity	
6670									
	35			3, 4, 3				Clayey SAND (SC) wih trace gravel, fine to medium grained sand, red brown, wet, medium stiff, low plasticity, interbedded poorly graded sand with silt layer	
6665									
	40			2, 4, 2				Percentage gravel increases, up to 1" in size, well rounded	
6660									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	45			3, 5, 6				Silty to clayey SAND (SM-SC), fine to coarse grained, brown to red-brown, wet, medium dense, non-plastic to low plasticity	
6655									
	50			2, 5, 10					
6650								Bandelier Tuff (Qbt 1g), ash-flow TUFF, reddish-orangish brown, fine to medium grained, ashy, pyroclastic matrix with grains of quartz and sanidine, pumices are light gray to yellowish-orange, grainy to glassy but mostly crystallized, up to about 1 cm (4") in size, unit is non-welded to partially welded	Start continuous sampling at 53 7'
	55								
6645								From 58.3' to 58.7' is light gray sandy layer, non-welded. slightly indurated, with black flecks, no pumice 58.7' red-brown, pumice to about 1.5 cm (6") up to 5 to 10%	
	60								
6640								Cerro Toledo Interval (Oct), poorly graded SAND. predominately medium grained, quartz, sanidine, black grains (possibly dacite and/or basalt), nonindurated, uncemented. very moist	No cuttings return since 53'
	65								

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6635								Gray to about 66.5' then grades to red-brown	
								At 68.5' grades to light gray, pumice to about 2 cm. concentrated between 68.5' and 68.7'	
	70								
					67				
6630								Interbedded sands from about 72'. very moist	Last foot of run drilled harder
	75							From about 75' to 75.5' is a gravelly sand layer with clasts up to 1.5", basalt predominately sub-rounded, about 25% gravel. medium to coarse sand	
6625									
								From 78' to 78.3' is a gravelly sand with pumice, dense, red-brown, gravel, pumice up to .25" Below 78.3' unit is bedded with 1" to 12" layers of coarse, poorly graded sand, pumice is glassy, light gray, with crystals up to 1 mm in size	
	80							Medium SAND with pumice up to .25", red-brown, many of the sand layers are loose to medium dense, very moist to wet	
6620									
								Well graded SAND. coarse to fine	
	85								
					92				
6615									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	90							Silty SAND with trace gravel, pumice up to 6 cm (2.4"), non-indurated, red-brown, fine grained, moist, interbedded with poorly graded sand, trace to no silt, medium to coarse grained, loose, very moist to wet	
6610									
	95				82				Drilling noticeably harder around 95' to 97', may be due to slough in hole
6605								Bandelier Tuff (Qbo), ash-flow TUFF, pinkish-brown, fine grained ashy groundmass with phenocrysts up to about 1 mm, lithics about 1 to 2%, dark brown, up to 3 mm, glassy pumice lapilli to 3 cm, light gray to orange (oxidized), pumice about 5 to 10% of unit	
	100				55			Fresh to slightly weathered, non-indurated, non-welded to partially welded, very weak, friable	
6600								Basalt lithics to 2 cm	
	105				100			Partially welded	
	110				100			Light gray-brown grades to light pinkish-gray	
6590									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	115				100				
6585									
	120				100				
6580									
								Total depth to 123.7' No water in hole when finished	
	125								
6575									
	130								
6570									
	135								

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Date Completed: 07/29/2002 Logged By: S. Merkley

Boring Location: Sandia Canyon, TA-72, 24' north of staked location

Driller: Rob Helton Drilling Method/Size: 8" HSA

Elev Top of Hole: 6682' Total Depth (ft): 104 Groundwater Depth: I ▽ perched: 40'
F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
								Silty SAND (SM) with some fine gravel, grades to poorly graded sand, fine to medium grained, brown, slightly moist, medium dense, non-plastic	
	5			10, 9, 5					
6675									
	10			10, 7, 7				Percentage silt decreases, trace gravel Poorly graded SAND with silt (SP-SM), fine to medium grained sand, brown, slightly moist, medium dense, non-plastic	
6670									
	15			8, 11, 12				Medium to coarse grained	
6665									

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LOG OF BORING SC-4
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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				20, 5, 7				Sandy CLAY (CL), fine grained sand, brown, slightly moist, medium firm to firm, low plasticity, interbedded with medium to coarse poorly graded sand	Blow counts suspect
6660									
	25			34, 35, 35				Sandy CLAY (CL) lenses (2" to 4" thick), interbedded with poorly graded sand as above, clay is slightly moist to moist, red-brown, hard, low plasticity, contains some 1 to 2 cm devitrified pumice, quartz, some sanidine (blue optical)	
6655									
	30			50/1.5"				Sand decreases, predominately clayey sand to sandy clay with coarse to medium sand	
6650									
	35			8, 5, 6				Poorly graded SAND (SP) with silt and trace gravel to .5", coarse sand, brown, slightly moist, medium dense, with occasional 1" to 2" clay lenses	Blow counts incorrect
6645									
	40			4, 5, 3				Wet	
6640								Sandy lean CLAY (CL), medium to fine, some coarse sand, red-brown, wet, medium stiff, low to medium plasticity, probably .5" to 1' thick beds interbedded with sand lenses Cuttings predominately sand, coarse grained	

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	45			4, 9, 12				Clayey SAND (SC) with trace gravel, color varies from brown to red-orange, includes clasts of Qbt2 up to about 6" in sampler, devitrified glass in pumice up to about 2 cm, moist to very moist, low plasticity	Start continuous sampling at 44'
6635									
	50							Bandelier Tuff (Qbo) ash-flow TUFF, red-orange mottled with pink, predominately very fine grained matrix with medium to coarse grained phenocrysts of quartz and sanidine, up to about 2 mm, highly weathered, very friable, vitreous pumice up to 1.5 cm (.6"), 1% to 2% dark gray lithics up to about 2 mm, pumices oxidized, ashy matrix	
6630									
	55				50				No cuttings return
6625									
								Moist	
	60								
								Color grades to light red-brown, pumices sparse, less oxidized to no oxidation from about 63'	
6620									
								Dacite lithics about 5%, up to 1" in size Unit is light gray-brown	
	65								

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6615									
								Pumices more abundant, oxidized, unit grades to light red-gray	
	70								
6610									
								Vitreous pumice lapilli up to 6 cm (2 4"), partially welded from 75' to approximately 90'	
	75								
6605									
	80							Lithics decrease in size to about 25" (6 mm) Unit grades to light gray-brown Phenocrysts up to 1 mm average, max 2 mm in size	
6600									
	85								
6595									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	90							Light gray-brown to light gray	
6590									
	95								
6585									
	100								
6580									
								Total depth to 104' Cave to 95'	
	105								
5									
	110								
6570									

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Date Completed: 07/30/2002 Logged By: S. Merkley

Boring Location: Sandia Canyon, TA-72, 31' southeast of staked location

Driller: Rob Helton Drilling Method/Size: 8" HSA

Elev Top of Hole: 6662' Total Depth (ft): 84 Groundwater Depth: I ▽ not encountered F ▼

ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6660								Poorly graded SAND with silt (SP), trace fine gravel, fine to medium sand, brown, slightly moist, loose to medium dense, non-plastic, pumice up to 1 cm in size	
	5			3, 6, 7					
6655								Silty SAND (SM), trace fine gravel, predominately fine sand, occasional poorly graded sand layers with medium to coarse sand, brown, slightly moist, non-plastic, medium dense. Interlayered with sandy silt layers	
	10			2, 4, 4				Grades to silty SAND to SILT (SM-ML)	
6650									
	15			3, 4, 4				Poorly graded SAND with silt (SP-SM), fine to medium sand, yellow-brown, loose, slightly moist, non-plastic	
6645									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
				8, 8, 13				Silty SAND with gravel (SM), brown to red-brown, slightly moist, medium dense, non-plastic, gravel/lithics up to about .5", appears to be material from tuff slopes/cliffs that has fallen into wash and interbedded with poorly graded coarse sand and fine grained silty sand, pumices are altered, devitrified	
6640									
	25			6, 9, 8					
6635									
	30								Drilling harder Start continuous sampling at 29'
6630									
	35							Silty SAND (SM), fine grained, trace coarse grains quartz, lithics, medium dense to dense, reddish-brown, slightly moist, non-plastic	
6625									
								Pumice lapilli and fragments up to 7 cm (2.75") long Light yellow-brown	
	40								
6620									

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
	45								
6015								Poorly graded SAND with silt (SP-SM), trace gravel, medium to coarse grained, interbedded silty sand, fine grained, some sandy silt lenses, brown to red-brown, slightly moist to moist, dense, non-plastic, some pumice to 1 cm (4"), crystallized, devitrified	
	50							Bandelier Tuff (Qbo), ash-flow TUFF, partially to non-welded, pinkish-orange, fine grained, ashy matrix with quartz and sanidine phenocrysts up to 1 mm, no bedding, oxidized pumice up to about 3 cm (1 2"), vitreous, extrememly weak to very weak, trace lithics	
6010									
								Grades to light pinkish-gray	
	55								
6005									
	60							Trace dacite and basalt lithics up to about 5"	
6000									
	65								

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ELEVATION	DEPTH	SAMPLE TYPE	SAMPLE/BOX NUMBER	BLOWS PER FOOT	% RECOVERY	RQD	Graphic Log	DESCRIPTION	DRILLING NOTES
6595									
	70							Light pinkish-orange	
6590									
	75							Light pinkish-gray, slight increase in percentage lithics near 75'	
6585									
	80								
6580									
								Total depth to 84'	
	85								
6575									

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APPENDIX C

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APPENDIX D

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APPENDIX E

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