Site Characterization Data from the U3ax/bl Exploratory Boreholes at the Nevada Test Site

Prepared by

Bechtel Nevada
Geotechnical Sciences
Las Vegas, Nevada

Prepared for

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Las Vegas, Nevada

August 2005

DISCLAIMER STATEMENT

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof

AVAILABILITY STATEMENT

Available for sale to the public from—

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA, 22161-0002
Telephone: 800.553.6847
Fax: 703.605.6900
E-mail: orders@ntis.gov
Online ordering: <http://www.ntis.gov/ordering.htm>

Available electronically at <http://www.osti.gov/bridge>.

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from—

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Telephone: 865.576.8401
Fax: 865.576.5728
E-mail: reports@adonis.osti.gov

Site Characterization Data from the U3ax/bl Exploratory Boreholes at the Nevada Test Site

Prepared by
Bechtel Nevada
Geotechnical Sciences
Las Vegas, Nevada

Prepared for
U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Las Vegas, Nevada

August 2005

This manuscript was prepared by Bechtel Nevada under Contract No. DE-AC08-96NV11718
with the U.S. Department of Energy.

This page intentionally left blank.

Site Characterization Data from the U3ax/bl Exploratory Boreholes at the Nevada Test Site

DOE/NV/11718--003-REV.1

Preface

The Special Projects Section of Reynolds Electrical & Engineering Co., Inc. (REECo) and its successor, Bechtel Nevada (BN), were responsible for characterizing the subsurface hydrogeology of the Area 3 Radioactive Waste Management Site (RWMS) at the Nevada Test Site for the U.S. Department of Energy, Nevada Operations Office in the early and mid-1990s. This work was documented in a series of limited-distribution data reports. As part of BN's current scope for closure planning for the Area 3 RWMS, some of these REECo and older BN data reports are being updated and submitted for approval for public release so they will be accessible for public review and for citation in future documents.

This document was originally prepared under the same title in April 1996, by John S. Schmeltzer, Lawrence E. Barker, and Daniel O. Blout. The report has been updated by revising it to conform to current editorial standards of BN and of the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office.

Acknowledgments

In the acknowledge section of the original document, the authors expressed their thanks to Ken D. Donnelson of Raytheon Services Nevada, who was the field geologist during drilling of the U3ax/bl boreholes. Mr. Donnelson played a major role in the project. He collected most of the geologic samples, measured the water content of drill cuttings, and completed the borehole log sheets found in Appendix B. Without his assistance the original data report could not have been completed.

This page intentionally left blank.

Site Characterization Data from the U3ax/bl Exploratory Boreholes at the Nevada Test Site

DOE/NV/11718--003-REV.1

Abstract

This report provides qualitative analyses and preliminary interpretations of hydrogeologic data obtained from two 45-degree, slanted exploratory boreholes drilled within the Area 3 Radioactive Waste Management Site (RWMS) at the Nevada Test Site. Borehole UE-3bl-D1 was drilled beneath the U3ax/bl mixed waste disposal unit, and Borehole UE-3bl-U1 was drilled in undisturbed alluvium adjacent to the disposal unit. The U3ax/bl disposal unit is located within two conjoined subsidence craters, U3ax and U3bl, which were created by underground nuclear testing. Data from these boreholes were collected to support site characterization activities for the U3ax/bl disposal unit and the entire Area 3 RWMS. Site characterization at disposal units within the Area 3 RWMS must address the possibility that subsidence craters and associated disturbed alluvium of the chimneys beneath the craters might serve as pathways for contaminant migration.

The two boreholes were drilled and sampled to compare hydrogeologic properties of alluvium below the waste disposal unit with those of adjacent undisturbed alluvium. Whether Borehole UE-3bl-D1 actually penetrated the chimney of the U3bl crater is uncertain. Analyses of core samples showed little difference in hydrogeologic properties between the two boreholes.

Important findings of this study include the following:

- No hazardous or radioactive constituents of waste disposal concern were found in the samples obtained from either borehole.
- No significant differences in physical and hydrogeologic properties between boreholes is evident, and no evidence of significant trends with depth for any of these properties was observed. The values observed are typical of sandy materials.
- The alluvium is dry, with volumetric water content ranging from 5.6 to 16.2 percent. Both boreholes exhibit a slight increase in water content with depth, the only such trend observed.
- Water potential measurements on core samples from both boreholes show a large positive potential gradient (water moves upward, via evapotranspiration) for the entire vertical depth.
- Very little liquid flow occurs through the vadose zone. The direction of flow in the upper vadose zone (approximately the upper 35 meters) is upward, based on unsaturated hydraulic conductivity data, water potential data, and environmental tracer data.

This page intentionally left blank.

Table of Contents

Preface	iii
Acknowledgments	iii
Abstract	v
List of Figures	ix
List of Tables	xi
List of Appendices	xii
List of Acronyms and Abbreviations	xiv
1.0 Introduction	1-1
1.1 Project Description	1-1
1.2 Purpose and Justification	1-1
1.3 Data Objectives of the Drilling Project	1-4
1.4 Scope of Report	1-4
1.5 Site Description	1-4
1.6 Testing and Waste Management Activities	1-8
1.7 Drill Site Location	1-10
2.0 Drilling, Sampling, and Completion	2-1
2.1 Borehole Preparation	2-1
2.2 Dust Control System	2-2
2.3 Drilling and Casing	2-2
2.4 Sampling for Hydrogeologic and Environmental Tracer Data	2-3
2.4.1 Collection of Samples	2-3
2.4.2 Geologic Description and Storage of Samples	2-6
2.4.3 Radiological Surveys of Geologic Samples	2-8
2.4.4 Characterization of Drill Cuttings	2-9
2.5 Borehole Completion	2-10
3.0 Laboratory Testing Methods and Results	3-1
3.1 Testing Laboratories	3-1
3.2 Laboratory Test Results	3-1

Table of Contents *(Continued)*

3.3	General Geologic Description, Lithology, and Stratigraphy	3-9
3.3.1	General Geologic, Lithologic, and Stratigraphic Data for Alluvium	3-9
3.3.2	Inorganic Carbon	3-10
3.4	Physical and Chemical Properties	3-10
3.4.1	Particle Size Distribution	3-10
3.4.2	Bulk Density, Particle Density, and Porosity	3-12
3.4.3	Cation-Exchange Capacity	3-17
3.5	Hydrogeologic Properties	3-22
3.5.1	Saturated Hydraulic Conductivity	3-22
3.5.2	Moisture Retention Relations	3-25
3.5.3	Unsaturated Hydraulic Conductivity	3-26
3.6	Hydrogeologic Conditions	3-29
3.6.1	Water Content	3-29
3.6.2	Total Hydraulic Potential	3-30
3.7	Pneumatic Properties	3-34
3.8	Environmental Tracers	3-34
3.8.1	Chloride-Bromide Profiles	3-37
3.8.2	Stable Isotope Profiles	3-40
3.8.3	Tritium Profiles	3-42
4.0	Directional Survey Results	4-1
5.0	Recommendations and Future Work	5-1
6.0	References	6-1

Distribution List

List of Figures

<i>Number</i>	<i>Title</i>	<i>Page</i>
1-1	Location of the Area 3 Radioactive Waste Management Site at the Nevada Test Site	1-2
1-2	Location of the Area 3 Radioactive Waste Management Site in Yucca Flat	1-5
1-3	Location of the U3ax/bl Exploratory Boreholes Within the Area 3 Radioactive Waste Management Site	1-9
3-1	Slant Depth Profiles of Inorganic Carbon for Core Samples from the U3ax/bl Exploratory Boreholes	3-11
3-2	Slant-Depth Profiles of Dry Sieve Analyses for Core Samples from UE-3bl-D1 ..	3-13
3-3	Slant-Depth Profiles of Dry Sieve Analyses for Core Samples from UE-3bl-U1 ..	3-14
3-4	Slant-Depth Profiles of Dry Bulk Density for Core Samples from UE-3bl-D1	3-15
3-5	Slant-Depth Profiles of Dry Bulk Density for Core Samples from UE-3bl-U1	3-16
3-6	Slant-Depth Profiles of Dry Bulk Density for DB1 Core Samples from the U3ax/3bl Exploratory Boreholes	3-18
3-7	Slant-Depth Profiles of Particle Density for Core Samples from UE-3bl-D1	3-19
3-8	Slant-Depth Profiles of Calculated (c) and Water-Saturated (s) Porosity for Core Samples from UE-3bl-D1	3-20
3-9	Slant-Depth Profiles of Calculated (c) and Water-Saturated (s) Porosity for Core Samples from UE-3bl-U1	3-21
3-10	Slant-Depth Profiles of Cation-Exchange Capacity for Core Samples from the U3ax/3bl Exploratory Boreholes	3-23
3-11	Slant-Depth Profiles of Saturated Hydraulic Conductivity for Core Samples from the U3ax/3bl Exploratory Boreholes	3-24
3-12	Composite Moisture Retention Curve Data for Core Samples from UE-3bl-D1 ...	3-27
3-13	Composite Moisture Retention Curve Data for Core Samples from UE-3bl-U1 ...	3-27
3-14	Fitted Unsaturated Hydraulic Conductivity Functions For Core Samples from UE-3bl-D1	3-28
3-15	Fitted Unsaturated Hydraulic Conductivity Functions For Core Samples from UE-3bl-U1	3-28
3-16	Slant Depth Profiles of Water Content for Core Samples from UE-3bl-D1	3-31
3-17	Slant Depth Profiles of Water Content for Core Samples from UE-3bl-U1	3-32
3-18	Slant Depth Profiles of Volumetric Water Content for DB1 Core Samples from the U3ax/bl Exploratory Boreholes	3-33
3-19	Vertical Depth Profiles of Total Hydraulic Potential for Core Samples from the U3ax/3bl Exploratory Boreholes	3-35

List of Figures (Continued)

<i>Number</i>	<i>Title</i>	<i>Page</i>
3-20	Slant Depth Profiles of Air Permeability for UE-3bl-D1 and Calculated (c) Permeability for Core Samples from the U3ax/3bl Exploratory Boreholes	3-36
3-21	Slant Depth Profiles of Dry Soil Chloride Concentrations for Core Samples from the U3ax/bl Exploratory Boreholes	3-38
3-22	Slant Depth Profiles of Dry Soil Bromide Concentrations for Core Samples from the U3ax/bl Exploratory Boreholes	3-39
3-23	Slant Depth Profiles of Dry Soil Chloride-Bromide Ratios for Core Samples from the U3ax/bl Exploratory Boreholes	3-41
3-24	Slant Depth Profiles of Stable Isotopes for Core Samples from the U3ax/bl Exploratory Boreholes	3-43
3-25	Comparison of Measured Stable Isotopes for Core Samples from UE-3bl-D1 with Stable Isotope Data for the Global Meteoric Water Line (MWL)	3-43
3-26	Comparison of Measured Stable Isotopes for Core Samples from UE-3bl-U1 with Stable Isotope Data for the Global Meteoric Water Line (MWL)	3-45
3-27	Slant Depth Profiles of Unenriched Tritium Concentrations for Geologic Samples from the U3ax/bl Exploratory Boreholes	3-47
4-1	Cross Section Showing UE-3bl-D1 Relative to the Estimated Positions of the U3bl Crater/Chimney/Cavity	4-2

List of Tables

<i>Number</i>	<i>Title</i>	<i>Page</i>
1-1	Drilling and Location Data for the U3ax/bl Exploratory Boreholes	1-10
2-1	REECo Standard Operating Procedures Applicable to the U3ax/bl Exploratory Boreholes	2-1
2-2	Core Record for Borehole UE-3bl-D1	2-4
2-3	Core Record for Borehole UE-3bl-U1	2-5
2-4	Definitions of Core and Drill Cuttings Sample Labels for the U3ax/bl Exploratory Boreholes	2-7
3-1	Summary of Laboratory Methods	3-2
3-2	Summary of the Numbers of Tests Performed on Samples from the U3ax/bl Exploratory Boreholes	3-4
3-3	Summary of Descriptive Statistics for Physical and Pneumatic Properties for Core Samples from the U3ax/bl Exploratory Boreholes	3-5
3-4	Summary of Descriptive Statistics for Hydrologic Properties for Core and Drill Cuttings Samples from the U3ax/bl Exploratory Boreholes	3-6
3-5	Summary of Descriptive Statistics for Chemical Properties and Environmental Tracer Data for Core Samples and Drill Cuttings Samples from the U3ax/bl Exploratory Boreholes	3-7
3-6	Summary of Unified Soil Classification System Assignments for Core Samples from the U3ax/bl Exploratory Boreholes	3-8
3-7	Summary of Descriptive Statistics of Moisture Retention Curves for Core Samples from the U3ax/bl Exploratory Boreholes	3-8
A-1	Chronological Drilling Summary for Borehole UE-3bl-D1	A-1

List of Appendices

A Drilling Information

A.1 Chronological Drilling Summary for UE-3bl-D1

B Core and Drill Cuttings Sample Description Data

B.1 Borehole Log Sheets for UE-3bl-D1

B.2 Borehole Log Sheets for UE-3bl-U1

B.3 Drill Cuttings Log Data for UE-3bl-D1

B.4 Drill Cuttings Log Data for UE-3bl-U1

C Laboratory Testing Data of Geologic Samples

C.1 Results of Laboratory Tests for Hydrogeologic Properties for Core Samples from UE-3bl-D1

C.2 Results of Laboratory Tests for Physical and Pneumatic Properties for Core Samples from UE-3bl-D1

C.3 Results of Laboratory Tests for Chemical Properties and Environmental Tracer Data for Core Samples from UE-3bl-D1

C.4 Results of Gravimetric Water Content Measurements for Drill Cuttings Samples from UE-3bl-D1

C.5 Results of Unenriched Tritium Analysis for Drill Cuttings and Core Samples from UE-3bl-D1

C.6 Results of Laboratory Tests for Hydrogeologic Properties for Core Samples from UE-3bl-U1

C.7 Results of Laboratory Tests for Physical and Pneumatic Properties for Core Samples from UE-3bl-U1

C.8 Results of Laboratory Tests for Chemical Properties and Environmental Tracer Data for Core Samples from UE-3bl-U1

C.9 Results of Gravimetric Water Content Measurements for Drill Cuttings Samples from UE-3bl-U1

C.10 Moisture Retention Data for Core Samples from UE-3bl-D1

C.11 Moisture Retention Data for Core Samples from UE-3bl-U1

C.12 Parameters Required to Calculate Unsaturated Hydraulic Conductivities for Core Samples from the U3ax/bl Exploratory Boreholes

C.13 Results of Unenriched Tritium Analysis for Core Samples from UE-3bl-U1

List of Appendices (Continued)

D Directional Survey Data

- D.1 Gyroscopic Directional Survey by Minimum Curvature for UE-3bl-D1 on August 23, 1994
- D.1 Gyroscopic Directional Survey by Minimum Curvature for UE-3bl-U1 on August 23, 1994

List of Acronyms and Abbreviations

$^{\circ}\text{C}$	degrees Celsius
$^{\circ}\text{F}$	degrees Fahrenheit
^{16}O	oxygen-16
^{18}O	oxygen-18
ASD	Analytical Services Department
BN	Bechtel Nevada
CAU	casing-advance under-reaming
CEC	cation-exchange capacity
CFR	Code of Federal Regulations
cm	centimeter
D	deuterium
DBS&A	Daniel B. Stevens & Associates, Inc.
DOE	U.S. Department of Energy
DRI	Desert Research Institute
ft	foot (feet)
gal	gallon(s)
HGC	Hydro Geo Chem, Inc.
I.D.	inner diameter
in.	inch(es)
L	liter(s)
m/hr	meters per hour
m/s	meters per second
m^2	square meter(s)
m^3	cubic meter(s)
mi/hr	miles per hour
mm	millimeter(s)
MWL	meteoric water line
NNSA/NSO	National Nuclear Security Administration Nevada Site Office
NTS	Nevada Test Site
O.D.	outside diameter
pCi/L	picoCuries per liter
$^{239+240}\text{Pu}$	plutonium-239 and plutonium-240
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
RCT	Radiological Control Technician
REEC _o	Reynolds Electrical and Engineering Co., Inc.
RWMS	Radioactive Waste Management Site
SPS	Special Projects Section
USCS	Unified Soil Classification System
VOCs	volatile organic compounds
yd^3	cubic yard(s)

1.0 Introduction

The work described in this document was conducted by personnel of the Special Projects Section (SPS) of Reynolds Electrical and Engineering Co., Inc. (REECo) and Bechtel Nevada (BN) at the Nevada Test Site (NTS). The work was conducted for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO; formerly U.S. Department of Energy [DOE], Nevada Operations Office) Waste Management Division. This report was originally prepared under the same title by John S. Schmeltzer, Lawrence E. Barker, and Daniel O. Blout in April 1996. The original report has been updated to conform to current editorial standards of BN and the NNSA/NSO, and to facilitate public distribution of the data contained herein. The data appendices are included unchanged from the original report. No new data have been added to this report, though additional relevant studies of the area have been conducted in the intervening years.

1.1 Project Description

This report provides qualitative analyses and preliminary interpretations of hydrogeologic data obtained from two boreholes drilled at a 45-degree angle from vertical within the NTS Area 3 Radioactive Waste Management Site (RWMS). Borehole UE-3bl-D1 was drilled beneath the U3ax/bl mixed waste (low level radioactive waste containing hazardous constituents) disposal unit to a slant depth of 74 meters (m) (242 feet [ft]). Borehole UE-3bl-U1 was drilled adjacent to the disposal unit to a slant depth of 76 m (250 ft). The vertically corrected depth for both boreholes is approximately 50 m (165 ft). Data from these boreholes were collected to support site characterization activities for the U3ax/bl disposal unit and the entire Area 3 RWMS. Figure 1-1 shows the location of the Area 3 RWMS within the NTS. Throughout this report, boreholes UE-3bl-D1 and UE-3bl-U1 will be referred to as boreholes D1 and U1, respectively.

1.2 Purpose and Justification

The U3ax/bl disposal unit is regulated under the Resource Conservation and Recovery Act (RCRA), according to Title 40 Code of Federal Regulations (CFR) §265. The disposal unit is located within two conjoined subsidence craters, U3ax and U3bl, which were created by underground nuclear testing. The NNSA/NSO has slated the U3ax/bl disposal unit for permanent closure without groundwater monitoring. Under Title 40 CFR §265, site characterization is required to support the final closure design and groundwater monitoring

Figure 1-1
Location of the Area 3 Radioactive Waste Management Site
at the Nevada Test Site

waiver for a disposal unit, such as U3ax/bl. Also, DOE Order 5820.2A requires site characterization of RWMSs.

Site characterization at disposal units within the Area 3 RWMS must address the possibility that subsidence craters and their respective alluvial chimneys (regions of alluvium lying between the collapsed subsurface cavity created by the detonation of a nuclear device and the corresponding subsidence crater; also termed “collapse zone”) act as pathways for contaminant migration. Researchers have suggested that chimneys might provide enhanced pathways for the migration of water into the uppermost aquifer (Borg et al., 1976; Tyler et al., 1992).

Tyler et al. (1992) compared the hydrogeologic conditions, using water content and water potential data, inside and outside an alluvial chimney. They found evidence of enhanced infiltration and wetter soil conditions within an alluvial chimney than in the alluvium outside the chimney. They posited that this enhanced infiltration resulted from ephemeral ponding of water in the crater. However, no significant differences in physical properties, as indicated by bulk density data, or hydrogeologic properties, as indicated by saturated hydraulic conductivity data, were discernable between the alluvium inside and outside the chimney. These results suggest that once a crater is filled with material, thereby preventing ponding, enhanced infiltration might no longer occur.

REECo (1994a) developed a conceptual model describing the potential for migration of liquids from the disposal unit to the uppermost aquifer. This conceptual model was based on data obtained from a U3ax/bl waste inventory report (REECo, 1994b) and an archival literature search for existing site characterization data pertinent to U3ax/bl and the Area 3 RWMS (REECo, 1994a). The model suggests that the potential for leachate formation is small for two reasons: (1) the craters are filled with waste and soil, and (2) an engineered cover, designed to prevent water from contacting the waste, will be placed over the unit. As leachate is unlikely to exist, alluvial chimneys beneath the disposal unit are unlikely to act as enhanced contaminant pathways.

Boreholes D1 and U1 were drilled and sampled to compare hydrogeologic conditions of alluvium within the chimney (disturbed) below the waste disposal crater with those of alluvium outside the chimney (undisturbed), respectively. Whether Borehole D1 actually penetrated the chimney is uncertain, because technical problems (Section 2.3) ended drilling of this borehole before the target slant depth was reached.

Throughout this report, the term “disturbed alluvium” is used to mean alluvium contained in or bordering the chimney resulting from an underground nuclear test. While chimney formation has subjected such alluvium to collapse, it does not necessarily follow that any of the physical, hydrogeologic, or pneumatic properties were altered.

1.3 Data Objectives of the Drilling Project

The data objectives listed below were identified to ensure that the appropriate data were collected to support site characterization and to test the initial conceptual model.

- Obtain core and drill cuttings samples to characterize physical, hydrogeologic, and pneumatic properties of disturbed and undisturbed alluvium in the upper vadose zone.
- Measure concentrations of environmental tracers and hydrogeologic parameters in the core samples to estimate soil water fluxes in the upper vadose zone of the disturbed and undisturbed alluvium.
- Determine if contaminants, whether from the disposal unit itself or from nuclear testing, are present below the U3ax/bl disposal unit.
- Obtain access for geophysical logging of the boreholes, which will make periodic measurement of in-situ water content possible.

1.4 Scope of Report

This report includes the following information:

- Descriptions of the drilling, sampling, and laboratory testing methods
- Documentation for the data collected from the drilling and sampling activities (appendices)
- Preliminary interpretations of the data

1.5 Site Description

The NTS is located in southern Nevada, approximately 105 kilometers (km) (65 miles [mi]) northwest of Las Vegas. The NTS encompasses 3,561 square kilometers (1,375 square miles) of arid basin-and-range lands in southern Nye County. The NTS is surrounded on the east, north, and west by the Nellis Air Force Test and Training Range, a government-owned, restricted-access area.

The Area 3 RWMS is located within the south-central part of Yucca Flat, an alluvium-filled, topographically closed basin (Figure 1-2). The U3ax/bl disposal unit, located within the Area 3

Figure 1-2
Location of the Area 3 Radioactive Waste Management Site in Yucca Flat

This page intentionally left blank.

RWMS, is situated at an elevation of approximately 1,225 m (4,020 ft), which is 32 m (106 ft) above the Yucca playa, an ephemeral lake at the southern end of Yucca Flat. The ground surface at the Area 3 RWMS slopes primarily from north to south at 0.5-percent grade.

Alluvium beneath U3ax/bl is composed primarily of unconsolidated to partially consolidated gravelly sand, eolian sand, and colluvium eroded from the surrounding mountains during the main period of basin development, and deposited on alluvial fans by debris flow and sheet-flood processes. The alluvial fans coalesce to form discontinuous, gradational, and poorly sorted deposits of detritus derived from volcanic and Paleozoic-age sedimentary rocks. The thickness of the alluvium beneath U3ax/bl is estimated to be 370 m (1,200 ft) according to Drellack (1994), and to be 460 m (1,500 ft) according to Fernald (1974). The uppermost aquifer is at a depth of approximately 490 m (1,600 ft), and is located in the Tertiary-age volcanic rocks (Doty and Thordarson, 1983). Existing hydrogeologic data pertinent to U3ax/bl (REECo, 1994a) suggest that the undisturbed alluvium beneath the Area 3 RWMS is hydrogeologically homogeneous and that no barriers to flow, such as carbonate horizons, are present.

The climate and meteorology of the region are typical of the upper Mojave desert province. Annual precipitation in Yucca Flat averages less than 180 millimeters (mm) (7 inches [in.]), and the annual potential evaporation typically exceeds 1,525 mm (60 in.) (REECo, 1994a). Most precipitation falls during two peak seasons, with a greater peak in the winter and a lesser in the summer.

Precipitation during the winter months is governed by the formation of a high pressure ridge in the Pacific and an accompanying low pressure cell in the Gulf of Alaska, known as the Aleutian Low. This combination often forces cold, wet air masses from the Pacific Northwest over the Great Basin and the Rocky Mountains, typically resulting in low-intensity rainfall and occasional snowfall at the Area 3 RWMS. Summer precipitation usually develops during convective storms caused by moisture moving up from the Gulf of California and the Gulf of Mexico. Convective storms are generally localized, of high intensity, and typically have a duration of six hours or less (Christiansen and Spahr, 1980). Although winter storms are often less intense than summer storms, they account for most of the annual moisture at the NTS, due to their longer duration.

The temperature range in Yucca Flat varies widely both with seasons and during a single day. During December, on average the coolest month, the average daily maximum and minimum temperatures are 11 degrees Celsius ($^{\circ}\text{C}$) (52 degrees Fahrenheit [$^{\circ}\text{F}$]) and -7°C (20°F), respectively. During July, on average the warmest month, the average daily maximum and

minimum temperatures are 36°C (96°F) and 14°C (57°F), respectively. Wind direction is primarily from either the north or the south. Wind speed ranges from calm to over 27 meters per second (m/s) (60 miles per hour [mi/hr]). The annual average wind speed for January 1962 through April 1978 was 3.2 m/s (7.2 m/hr). January and November are the calmest months, with wind speeds averaging 2.7 m/s (6.0 mi/hr). April is the windiest month, with an average wind speed of 4.0 m/s (9.0 mi/hr).

1.6 Testing and Waste Management Activities

Nuclear tests were conducted at Yucca Flat from 1951 to 1992, and included both surface and underground tests (DOE, 2000). Within Area 3, underground nuclear tests were sponsored primarily by Los Alamos National Laboratory.

Underground nuclear tests within Yucca Flat have created hundreds of subsidence craters. Seven subsidence craters are located within the Area 3 RWMS: U3ah, U3at, U3ax, U3az, U3bg, U3bh, and U3bl (Figure 1-3). Four of these craters, U3ah, U3at, U3ax, and U3bl, have been used as disposal units. The remaining craters, U3az, U3bg, and U3bh, have not been used as waste disposal units, and may or may not eventually be so used. The area between the U3ax and U3bl craters was excavated to form the U3ax/bl disposal unit, where mixed waste was disposed between the late 1960s and 1987. Similarly, the U3ah and U3at craters were combined to form the U3ah/at disposal unit. The U3ah/at disposal unit, which has been in operation since 1988, is and has been used exclusively for the disposal of low-level radioactive waste.

The underground nuclear tests that created the U3ax and U3bl craters were named PACA (detonated on May 7, 1962) and BOBAC (detonated on August 24, 1962) (DOE, 2000). The PACA and BOBAC detonations occurred in alluvium above the water table, at depths of 258 and 195 m (846 and 640 ft), respectively. Each had a yield of less than 20 kilotons (DOE, 2000). The U3ax subsidence crater measured approximately 19 m (62 ft) deep and 138 m (453 ft) in diameter, with an approximate volume of 88,000 cubic meters (m³) 115,000 cubic yards [yd³]. The U3bl subsidence crater measured approximately 14 m (46 ft) deep and 122 m (400 ft) in diameter, with an approximate volume of 50,000 m³ (65,000 yd³). The volume of the conjoined U3ax/bl disposal unit is approximately 228,400 m³ (298,800 yd³).

During the operational life of the U3ax/bl disposal unit, 80 to 90 percent of the waste placed there originated from the NTS Waste Consolidation Project (REECo, 1994b). This project

Figure 1-3
Location of the U3ax/bl Exploratory Boreholes Within the Area 3 Radioactive Waste Management Site

consolidated debris contaminated by atmospheric nuclear testing. The remaining waste originated from offsite activities or from weapons tests conducted in the NTS Area 12 tunnels. Further description of waste sources, characteristics, and quantity disposed in U3ax/bl can be found in REEC Co (1994b).

An engineered dirt cover was installed on the U3ax/bl waste disposal unit in 2000. Moisture sensors were installed at various depths in the cover to monitor the stability of soil moisture conditions within the upper 2.4 m (8 ft) of the cover (BN, 2000).

1.7 Drill Site Location

The drill site for boreholes D1 and U1 is located adjacent to the U3ax/bl disposal unit within the Area 3 RWMS (Figure 1-3). Table 1-1 provides the drilling depths and location data for the two exploratory boreholes.

Table 1-1
Drilling and Location Data for the U3ax/bl Exploratory Boreholes

Borehole	Drilling Dates		Approximate Bearing and Inclination	Ground Surface Location ^a meters (feet)			Total Borehole Depth ^b meters (feet)	Vertical Depth of Borehole meters (feet)
	Start	End		North	East	Elevation		
UE-3bl-D1	06/27/1994	08/02/1994	N26°E -45°	254,869 (836,183)	209,536 (687,455)	1,223 (4,013)	74 (242)	50 (163)
UE-3bl-U1	08/05/1994	09/06/1994	S25°E -45°	254,862 (836,161)	209,527 (687,423)	1,223 (4,103)	76 (250)	50 (164)

a Nevada State Central Zone Coordinates, 1927 North American Datum. 1929 National Geodetic Vertical Datum.

b Slant depth, as measured along the borehole path.

2.0 Drilling, Sampling, and Completion

This section provides an overview of the drilling, sampling, and completion methods. For details of these methods, see REEC Co (1993) and BN (2005a). Additional procedures and plans applicable to these activities are listed in Table 2-1.

Table 2-1
REEC Co Standard Operating Procedures Applicable to the
U3ax/bl Exploratory Boreholes

Title	Procedure Number	Date
Quality Assurance Plan for Site Characterization and Monitoring Tasks	ER&TDD-SP.01.28	02/28/1994
Handling and Transport of Characterization Samples	ER&TDD-SP.01.04	06/23/1994
Geologic Logging of Alluvium (Draft)	ER&TDD-SP.01.23	02/16/1994
Gravimetric Moisture Content Determination (Draft)	ER&TDD-SP.01.05	02/16/1994
Stemming Well Screen, Casing, and Instruments (Draft)	ER&TDD-SP.01.16	02/16/1994
Borehole Abandonment (Draft)	ER&TDD-SP.01.17	02/16/1994

2.1 Borehole Preparation

Two 3-m (10-ft) lengths of directional casing were placed in the ground at 45-degree angles before boreholes U1 and D1 were drilled. Each casing required the excavation of a 0.5-m (1.5-ft) wide trench, approximately 2 m (6 ft) deep and 2 m (6 ft) long. After the casings were set at the desired angle and direction, they were secured by filling each trench with concrete.

Directional casing was used for two reasons: (1) to ensure that the boreholes were drilled, at least initially, at the proposed angle and direction, and (2) to reduce the amount of airborne dust released during drilling. Dust control was an item of high priority, as areas within the Area 3 RWMS are potentially contaminated by radioactive fallout from past atmospheric nuclear testing.

The outside diameter (O.D.) of the directional casing was 193 mm (7.6 in.), slightly larger than the casing used in the casing-advance under-reaming (CAU) drilling system (Section 2.3). This size casing was chosen so that the drilling tools and casing could pass through, yet the directional casing would still guide the borehole direction and angle.

The REECo Analytical Services Department (ASD) analyzed excavated soil from both trenches for radiological materials, RCRA-regulated metals, volatile organic compounds (VOCs), and semi-VOCs. Based on these analyses, the REECo Waste Management Department classified the excavated soil as non-RCRA and non-radioactive waste.

2.2 Dust Control System

Drilling can disperse airborne particulates, so a dust control system was used to limit the spread of particulates into the atmosphere. In this system, drill cuttings are directed through a return line into the Newsom[®] Model 110 dust control system, consisting of a main cyclone separator, which captures and separates about 98 percent of the drill cuttings, and an electric-powered, vacuum-operated, high efficiency dust filter unit, which traps over 99.9 percent of the remaining dust particles. This combination of cyclone separator and high efficiency dust filter prevents dust particles with a diameter greater than 0.3 micrometers from escaping. Drill cuttings captured by the cyclone separator were directed into a 0.21-m³ (55-gallon [gal]) metal drum.

2.3 Drilling and Casing

The subcontractor, Boyles Brothers Drilling Company, drilled boreholes U1 and D1 using a CAU drilling system. The drill rig was a Schramm[®] T685H rig with an angle package. The CAU drilling system used a Tubex[®] 140 system with a Mission[®] D-5 down-hole hammer and dual-wall reverse circulation. The diameter of the borehole was approximately 188 mm (7.4 in.). The casing was carbon steel Christiansen Drive-Ex[®] System 140. The O.D. of the casing was 168 mm (6.6 in.), and the inner diameter (I.D.) was approximately 152 mm (6.0 in.). During drilling, cuttings were transported up the borehole by compressed air and directed into the dust control system.

In the CAU drilling system, the borehole is lined with casing as the hole is drilled. This system uses compressed air as the drilling fluid. Compressed air is less disruptive to the hydrogeologic conditions of the drill cuttings, core samples, and formation than other drilling fluids.

The major advantage of a CAU system is that it prevents the borehole from collapsing during drilling. Therefore, CAU systems are well suited for use in unconsolidated alluvium, where borehole collapse is a constant risk. The major disadvantage of a CAU system is that the casing can detach, breaking into two parts. When the casing detaches, the break usually occurs near the bottom of the borehole, where stress on the casing is greatest. If the casing detaches, it can no longer advance and must be removed from the borehole before drilling with a new casing can

resume. However, removal of the casing might be impossible, since the forces that caused the casing to detach might also prevent removal.

The casing in both exploratory boreholes detached at slant depths of approximately 75 m (245 ft), 17 m (55 ft) short of the proposed depths for both boreholes. When the casing detached in Borehole D1, drilling was stopped and no attempt was made to remove the casing. This decision was influenced by deadlines, budget constraints, and engineering judgement, which indicated that the casing could probably not be removed. Because drilling ended prematurely, it is not certain that the borehole entered the U3bl chimney. Borehole U1, drilled next to U3ax/bl into undisturbed alluvium, also failed to reach its target depth. However, detachment of the casing of Borehole U1 was of lesser consequence than that of Borehole D1. The data objective for Borehole U1, to obtain hydrogeologic data from the undisturbed, near-surface alluvium, was achieved. Chronological drilling summaries for both boreholes are provided in Appendix A.

2.4 Sampling for Hydrogeologic and Environmental Tracer Data

Geologic samples, both cores and drill cuttings, were collected, described, and handled as described in REECo (1993, 1995) and BN (2005a). Drill cuttings samples were collected at 0.76-m (2.5-ft) intervals, and core samples were collected at 3-m (10-ft) intervals. The sample collection and handling procedures used (Table 2-1) were developed to reduce the loss of water by evaporation and to reduce disturbance of the physical integrity of the core samples.

2.4.1 Collection of Samples

Core samples were collected from the alluvium at selected intervals (Tables 2-2 and 2-3) employing a drive core sampler. An air-percussion hammer was used to drive a 0.76-m (2.5-ft) long by 114-mm (4.5-in.) O.D. solid-tube core barrel, containing clear Lexan[®] segments (76-mm [3.0-in.] long by 81-mm [3.2-in.] I.D.) to contain the sample material. The method was chosen because it provides good core recovery and reduces the disturbance of hydrogeologic conditions and properties of relatively dry, coarse-grained, unconsolidated alluvial samples (Hammermeister et al., 1986). The possible effects of coring on the values of parameters sensitive to pore-size distribution are discussed in BN (2005a). Always, core barrels were transported to a temperature-controlled field laboratory for geologic description and disposition as soon as possible after removal from the borehole.

Table 2-2
Core Record for Borehole UE-3bl-D1

Date	Run Number	Core Interval (meters)		Core Recovery		Penetration Rate (minutes per meter)	Laboratory Tests
		From	To	Meters	Percent		
06/27/1994	1	3.81	4.06	0.00	0	11.54	None
06/28/1994	2	6.10	6.86	0.61	80	8.14	A,B,C,D,E,F,G
06/29/1994	3	9.14	9.91	0.30	40	4.27	A,C,F,G
06/29/1994	4	12.19	12.95	0.76	100	8.40	A,B,C,D,E,F,G
06/30/1994	5	15.24	16.00	0.53	70	2.76	A,B,C,E,F,G
07/11/1994	6	18.29	18.90	0.61	100	21.33	A,B,D,F,G
07/11/1994	7	21.34	22.10	0.76	100	19.68	A,B,C,D,E,F,G
07/12/1994	8	24.38	25.15	0.76	100	7.87	A,B,C,D,E,F,G
07/12/1994	9	27.43	28.19	0.00	0	9.19	None
07/13/1994	10	30.48	31.09	0.61	100	25.75	A,B,C,D,E,F
07/13/1994	11	33.53	34.29	0.76	100	8.27	A,B,C,E,F,G
07/15/1994	12	36.58	37.34	0.76	100	3.67	A,B,C,D,E,F,G
07/18/1994	13	39.62	40.39	0.76	100	4.59	A,B,C,E,F,G
07/19/1994	14	42.67	43.43	0.38	50	1.97	D,G
07/21/1994	15	45.72	46.48	0.46	60	3.54	B,D,G
07/25/1994	16	48.77	49.53	0.23	30	6.82	B,D,G
07/25/1994	17	51.82	52.58	0.76	100	8.14	A,B,C,D,E,F,G
07/26/1994	18	54.86	55.63	0.76	100	3.41	A,B,C,D,E,F,G
07/26/1994	19	57.91	58.67	0.00	0	3.94	None
07/27/1994	20	60.96	61.72	0.76	100	2.49	A,B,C,D,E,F,G
07/28/1994	21	64.01	64.77	0.76	100	3.02	A,B,C,D,E,F,G
07/29/1994	22	67.06	67.82	0.76	100	5.25	A,B,C,D,E,F,G
07/29/1994	23	70.10	70.87	0.69	90	1.71	A,B,C,D,E,F,G
08/01/1994	24	73.15	73.91	0.69	90	3.15	A,B,C,D,E,F,G

A: Physical and hydraulic properties
B: Inorganic carbon and cation exchange capacity
C: Water Potential, water content, density
D: Stable isotopes
E: Chloride-bromide, water content
F: Air permeability
G: Archive

Table 2-3
Core Record for Borehole UE-3bl-U1

Date	Run Number	Core Interval (meters)		Core Recovery		Penetration Rate (minutes per meter)	Laboratory Tests
		From	To	meters	percent		
08/04/1994	1	3.81	4.57	0.61	80	2.62	A,B,C,D,E,G
08/05/1994	2	6.10	6.86	0.69	90	3.28	A,B,C,D,E,F,G
08/05/1994	3	9.14	9.91	0.61	80	2.10	A,B,C,D,E,F,G
08/05/1994	4	12.19	12.95	0.61	80	6.96	A,B,C,D,E,F,G
08/05/1994	5	15.24	16.00	0.76	100	10.63	A,B,C,D,E,F,G
08/08/1994	6	18.29	19.05	0.76	100	3.54	A,B,C,D,E,F,G
08/09/1994	7	21.34	22.10	0.15	20	10.89	B,G
08/09/1994	8	24.38	25.15	0.76	100	1.57	A,B,C,D,E,F,G
08/09/1994	9	27.43	28.19	0.76	100	9.58	A,B,C,E,F,G
08/11/1994	10	30.48	31.24	0.61	80	7.09	A,B,C,D,E,F,G
08/11/1994	11	33.53	34.29	0.61	80	4.46	A,B,C,E,F,G
08/12/1994	12	36.58	37.34	0.00	0	8.66	None
08/17/1994	13	39.62	40.39	0.76	100	4.86	A,B,C,D,E,F,G
08/17/1994	14	42.67	42.95	0.76	278	20.68	A,B,C,D,E,G
08/17/1994	15	45.72	46.48	0.76	100	6.96	A,B,C,E,F,G
08/18/1994	16	48.77	49.53	0.76	100	6.04	A,B,C,D,E,F,G
08/18/1994	17	51.82	52.43	0.00	0	11.48	None
08/19/1994	18	54.86	55.37	0.61	120	16.50	B,D,G
08/19/1994	19	57.91	58.37	0.23	50	7.35	B,G
08/22/1994	20	60.96	61.72	0.76	100	11.68	A,B,C,D,E,F,G
08/22/1994	21	64.01	64.77	0.69	90	7.09	A,B,C,E,F,G
08/23/1994	22	67.06	67.82	0.76	100	4.99	A,B,C,D,E,F,G
08/23/1994	23	70.10	70.87	0.76	100	7.61	A,B,C,E,F,G
08/24/1994	24	73.15	73.76	0.00	0	8.86	None
09/06/1994	25	75.44	76.20	0.76	100	3.94	A,B,C,D,E,F,G

A: Physical and hydraulic properties
 B: Inorganic carbon and cation exchange capacity
 C: Water Potential, water content, density
 D: Stable isotopes
 E: Chloride-bromide, water content
 F: Air permeability
 G: Archive

Drill cuttings, which were only collected during initial drilling of any particular interval, were collected at 0.76-m (2.5-ft) intervals. Drill cuttings were never collected during hole cleaning or related activities, to ensure that the collected drill cuttings represented the specified interval. Immediately after drilling each 0.76-m (2.5-ft) interval, the valve on the cyclone separator's hopper was opened. As drill cuttings dropped into a 0.21-m³ (55-gal) metal barrel, samples were collected in plastic bottles, moisture tins, and 3.8-liter (L) (1-gal) cans for selected intervals. Samples were then delivered immediately to a temperature-controlled field laboratory.

Samples in the moisture tins were used to measure the cuttings' gravimetric water content, and the samples in the 3.8-L (1-gal) cans were analyzed for tritium. The samples in the plastic bottles were designated as archive samples, however, those not used for tests reported in this document have since been discarded.

2.4.2 Geologic Description and Storage of Samples

To ensure that the water content of each sample represented in-situ hydrogeologic conditions, both core and drill cuttings samples were handled, in the field laboratory and during storage and transport, in a way that minimized evaporative water loss, according to procedures listed in Table 2-1.

The labeling system used in the field to assign core segments and drill cuttings samples for different laboratory tests is summarized in Table 2-4. Each sample label identifies the following: (1) the laboratory testing required, (2) the priority of the test(s), and (3) the testing laboratory responsible for conducting the analyses. These labels (e.g., DB1, DRI1) are used when referring to specific core and/or drill cuttings samples in various tables, figures, and appendices in this report.

Liner segments containing core samples were removed from the solid-tube drive core sampler by a hydraulic core extruder. A geologic description of the core was made by examining the open ends of each segment. This geologic description was recorded on field data sheets (Appendix B).

Following geologic description and measurement of magnetic susceptibility, each core segment was capped, taped, and labeled with the appropriate sample identification and intended laboratory test(s). Core segments were further sealed in Protec-Core[®], a tubular aluminized Mylar[®] laminate that protects the core from damage, tampering, and moisture loss when sealed.

Table 2-4
Definitions of Core and Drill Cuttings Sample Labels for the
U3ax/bl Exploratory Boreholes

Sample Type	Sample Priority	Sample Condition	Sample ID	Laboratory Tests	Laboratory ^a
Core	1	Intact	DB1	<ul style="list-style-type: none"> Saturated Hydraulic Conductivity Moisture Retention Curves Water Content Dry Bulk Density Porosity Particle Size Distribution Hydrometer Particle Density 	DBS&A
	2	Intact	DRI1	<ul style="list-style-type: none"> Water Content Water Potential Dry Bulk Density 	DRI
	3	Intact	AIR1	<ul style="list-style-type: none"> Air Permeability 	REECo/SPS
	4	Intact	HGC	<ul style="list-style-type: none"> Chloride-Bromide Water Content 	HGC
	5	Intact or Disturbed	DB2	<ul style="list-style-type: none"> Inorganic Carbon Cation Exchange Capacity 	DBS&A
	6	Intact or Disturbed	DRI3	<ul style="list-style-type: none"> Stable Isotopes 	DRI
	7 - 10	Intact or Disturbed	ARCH	<ul style="list-style-type: none"> Archive ^b 	REECo/SPS
Drill Cuttings	--	N/A ^c	ARCH	<ul style="list-style-type: none"> None ^d 	N/A
	--	N/A	Depth	<ul style="list-style-type: none"> Water Content 	REECo/SPS
	--	N/A	DRI2	<ul style="list-style-type: none"> Tritium 	DRI

a DBS&A = Daniel B. Stevens and Associates
DRI = Desert Research Institute
REECo/SPS = Reynolds Electrical & Engineering Co., Inc. Special Projects Section
HGC = Hydro Geo Chem, Inc.

b Water content measurements were made on 3 archive core segments from Borehole D1 and 2 from Borehole U1, and reported as DB1 samples (see Section 3.6.1 and Appendix C). The remainder of the archive samples have been discarded.

c N/A = not applicable

d All archived drill cuttings samples have been discarded.

An additional label containing the same information was then affixed. Most of the core segments were specified for various types of laboratory tests, while the remainder was stored for future use. Tables 2-2 and 2-3, and Appendix B summarize the specific laboratory tests designated for each core run.

The assignment of core segments for various tests was based on a priority system. This was done because core recovery was not always 100 percent, and the degree of disturbance to water content, porosity, and aggregation was not uniform among core segments. The assignment of core segments to tests was made with awareness of the relative importance of each laboratory tests, and the degree of sample disturbance acceptable for each test. This priority system is described in procedures listed in Table 2-1.

A brief geologic description of the drill cuttings samples (Appendix B) was made after the samples were transported to the temperature-controlled field laboratory. Sample bottles containing drill cuttings were opened briefly, and the same procedures for geologic description and magnetic survey, referred to previously for core samples, were followed. Sample bottles were capped, taped, sealed in Protec-Core[®], and labeled with appropriate sample identification information and intended tests. These drill cuttings samples were collected primarily for storage.

The samples collected in the moisture tins were designated for gravimetric water content measurements done by the field geologist. The moisture tins were labeled, capped, and taped to prevent water loss until they could be measured. The drill cuttings collected in the 3.8-L (1-gal) containers were capped and labeled, then sealed with bees' wax and tape. The application of bees' wax, although not included in the procedure for handling and transporting characterization samples (ER&TDD-SP.01.04), was made to ensure that the seals of the containers were airtight. These samples were collected at selected intervals for tritium analysis.

2.4.3 Radiological Surveys of Geologic Samples

Gamma radiation levels from drill cuttings were monitored continuously with an energy-compensated Geiger-Muller detector mounted directly onto the cyclone separator. A Radiological Control Technician (RCT) from the REEC Co Health Protection Department monitored the drill cuttings as they entered the 0.21-m³ (55-gal) barrels, and when sediment samples were removed from the barrels. The RCT monitored core samples as they were removed from the core barrel. As a further precaution, the RCT daily collected many swipe samples from drilling and coring equipment, which were analyzed for removable alpha and beta contamination.

Additionally, air particulate samples were collected weekly and analyzed for plutonium-239 and plutonium 240 ($^{239+240}\text{Pu}$) by REECO ASD personnel. No radiation above background levels was encountered during drilling.

2.4.4 Characterization of Drill Cuttings

Drill cuttings samples from both boreholes were analyzed for radiological and RCRA-regulated constituents. Besides protecting the health and safety of personnel working on the drill site or with the samples, analyses of drill cuttings aided in testing the conceptual hydrogeologic model. If contamination had been found in samples from Borehole D1, it would have provided evidence against the conceptual model, which predicts that contaminants will not migrate from the disposal unit. However, if contamination had been found, it would have been difficult to determine if it indicated migration from the disposal unit or if it was a result of earlier underground nuclear testing. As none was found, this issue is moot.

From each borehole, thirteen 0.21-m^3 (55-gal) barrels, a total of 26 barrels, were filled with drill cuttings. Each barrel contained drill cuttings from a 6-m (20-ft) slant-depth interval. Samples from 2 barrels representing adjacent 6-m (20-ft) intervals were combined, and the combined samples were analyzed for $^{239+240}\text{Pu}$, gamma emitters, tritium, RCRA-regulated metals, and semi-VOCs. Volatile organic compounds were not considered, because the pressurized air which transported the cuttings up the borehole would have volatilized any VOCs before the drill cuttings entered the dust control system.

Since the drill cuttings from Borehole D1 could be used to test the conceptual model, samples were taken from Borehole D1 throughout the borehole depth. Fewer samples were taken from Borehole U1 because it was not drilled beneath the disposal unit. Atmospheric nuclear testing is the only credible source of contamination for drill cuttings from Borehole U1. Since this contamination, if present, would primarily occur in the near-surface, samples were taken only from the upper 18 m (60 ft) of this borehole.

Other than small concentrations of tritium, no RCRA-regulated materials or radioactive materials were found in any of the samples. The tritium concentrations were less than 1 percent of the Nuclear Regulatory Commission's concentration limit of 1×10^6 picoCuries per liter (pCi/L) for effluent released to an unrestricted area (Title 10 CFR §20). A discussion of the results from the tritium analysis is presented in Section 3.6.3.

2.5 *Borehole Completion*

After drilling was completed, a weather-proof cover was placed on the surface casing of each borehole. The concrete poured into each trench sets the surface casings at 45-degree angles and prevents precipitation or runoff from entering the borehole annulus. The two boreholes were monitored periodically with neutron loggers to evaluate moisture conditions of the alluvium surrounding the boreholes until the year 2000. To date, no instrumentation has been installed and the boreholes remain open.

3.0 Laboratory Testing Methods and Results

A summary of laboratory tests and testing methods is given in Table 3-1. The cited references contain specific details. A description of all laboratory testing methods used to obtain cation exchange capacity (CEC), pneumatic properties (i.e., air permeability), and tritium concentrations appear in REEC_o (1993). These three methods are described in their respective sections: Cation-Exchange Capacity (Section 3.4.3); Pneumatic Properties (Section 3.7); and Tritium Profiles (Section 3.8.3).

3.1 Testing Laboratories

Core and drill cuttings samples were sent to the following testing laboratories where physical, hydrogeologic, and chemical properties were measured. REEC_o audited and approved the Quality Assurance (QA) programs of the following testing laboratories: Daniel B. Stevens & Associates, Inc. (DBS&A), Albuquerque, NM, and Hydro Geo Chem, Inc., (HGC), Tucson, AZ. DBS&A was responsible for the review and approval of the QA program for the subcontracting laboratories that DBS&A used (Dr. B. Branvold, New Mexico Institute of Mining and Technology, Socorro, NM, and Soil and Water West, Inc., Rio Rancho, NM). The QA program for the Desert Research Institute (DRI) laboratory was reviewed and approved by the predecessor to NNSA/NSO.

3.2 Laboratory Test Results

In most cases, testing laboratories conducted several related tests on a single core segment. For example, initial water content, bulk density, porosity, hydraulic conductivity, moisture retention, and particle size distribution measurements were conducted on the same 7.6-centimeter (cm) (3-in.) core segment.

The types and numbers of tests conducted on core samples and drill cuttings for each borehole are summarized in Table 3-2. Results from all laboratory tests for both core and drill cuttings samples are given in tabular form in Appendix C. Summary statistics for laboratory measurements, where appropriate, are presented in Tables 3-3, 3-4, 3-5, and 3-6. Descriptive statistics for moisture retention curves appear in Table 3-7. Statistical calculations were done without outlier omission. Plots of laboratory results for specific tests, along with brief discussions of the data, are presented in the following sections.

Table 3-1
Summary of Laboratory Methods

Method Description	Reference
Geologic Description of Unconsolidated Alluvium	ASTM D 2488-84, 1990. Standard Practice for Description and Identification of Soils - Visual Manual Procedure. <u>In:</u> 1987 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Material. Philadelphia, PA.
Moisture Content	ASTM D 2216-90, 1990. Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures. <u>In:</u> 1990 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Material. Philadelphia, PA.
Bulk Density <ul style="list-style-type: none"> • Dry Bulk • Particle 	Blake, G. R., and K. H. Hartge, 1986. Bulk Density. <u>In:</u> Klute, A. L. (ed.), Methods of Soil Analysis, Part I, Physical and Mineralogical Methods, 2 nd Edition, American Society of Agronomy, Madison, WI. Chapter 13, pages 363-367. ASTM D 954-91. 1990. Standard Test Method for Specific Gravity of Soils. <u>In:</u> 1990 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Material. Philadelphia, PA.
Porosity	Danielson, R. E., and P. L. Sutherland, 1986. Total Porosity. <u>In:</u> Klute, A. L. (ed.), Methods of Soil Analysis, Part I, Physical and Mineralogical Methods, 2 nd Edition, American Society of Agronomy, Madison, WI. Chapter 18, pages 444-445.
Saturated Hydraulic Conductivity <ul style="list-style-type: none"> • Constant Head • Falling Head 	ASTM D 2434-68(74), 1974. Test Method for Permeability of Granular Soils (Constant Head). <u>In:</u> 1987 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Material. Philadelphia, PA. Klute, A. L., and C. Dirksen, 1986. Hydraulic Conductivity and Diffusivity: Laboratory Methods - Falling Head Method. <u>In:</u> Klute, A. L. (ed.), Methods of Soil Analysis, Part I, Physical and Mineralogical Methods, 2 nd Edition, American Society of Agronomy, Madison, WI. Chapter 28, pages 700-703.
Moisture Retention Curves <ul style="list-style-type: none"> • Pressure Plate Extractor • Hanging Column • Thermocouple Psychrometer 	ASTM D 2325-68(81), 1981. Test Method for Capillary- Moisture Relationships for Coarse- and Medium-Textured Soils by Pressure-Plate Apparatus. <u>In:</u> 1987 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Material. Philadelphia, PA. Klute, A. L., 1986. Water Retention: Laboratory methods - Falling Head Method. <u>In:</u> Klute, A. L. (ed.), Methods of Soil Analysis, Part I, Physical and Mineralogical Methods, 2 nd Edition, American Society of Agronomy, Madison, WI. Chapter 26, pages 635-641. Operator's Manual for the SC-10A Thermocouple Psychrometer Sample Chamber (manufactured by Decagon Devices, Inc., Pullman, WA)
Particle Size Characteristics - Wet and Dry Sieve	ASTM D 422-63(90), 1990. Standard Method for Particle- Size analysis of soils. <u>In:</u> 1990 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Material. Philadelphia, PA.
Water Potential	Gee, G. W., M. D. Campbell, G. S. Campbell, and J. H. Campbell, 1992. Rapid Measurement of Low Soil Water Potential Using a Water Activity Meter. Soil Science Society of America Journal, Vol. 56, Pages 1,068-1,071.

Table 3-1
Summary of Laboratory Methods (continued)

Method Description	Reference
Air Permeability	ER&TDD-SP.01.25. Laboratory Air Permeability Measurements for Geologic Core Samples. Reynolds Electrical & Engineering Co., Inc. Las Vegas, NV
Chloride and Bromide <ul style="list-style-type: none"> • Sample Leaching • Ion Chromatography 	<p>Los Alamos National Laboratory - Internal Document, 1992. Sample Leaching to Extract Soluble Chloride and Bromide. LANL-INC-DP-92.R0. Pages 9-15.</p> <p>Los Alamos National Laboratory - Internal Document, 1991. Draft Procedure for Using Ion Chromatography to Determine Chloride and Bromide Concentrations. LANL-INC-DP-94.R0. Pages 3-25.</p>
Tritium <ul style="list-style-type: none"> • Soil Water Extraction • Analysis 	<p>Ingraham, N. L. and C. Shadel, 1992. A Comparison of the Toluene Distillation and Vacuum/Heat Methods for Extracting Soil Water for Stable Isotope Analysis. Journal of Hydrology, Vol. 140, pages 371-387.</p> <p>Packard, 1990. Operations Manual for Tri-Carb Liquid Scintillation 2500TR.</p>
Inorganic Carbon	Nelson, R. E., 1982. Carbonate and Gypsum: Pressure-Calculator Method. In: Page, A. L., R. H. Miller, and D. R. Keeney (eds.), Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, 2 nd Edition, American Society of Agronomy, Madison, WI, Chapter 11, pages 188-192.
Stable Isotopes <ul style="list-style-type: none"> • Soil Water Extraction • Oxygen Isotope Analysis • Hydrogen Isotope Analysis • Mass Spectrometry Analysis 	<p>Ingraham, N. L. and C. Shadel, 1992. A Comparison of the Toluene Distillation and Vacuum/Heat Methods for Extracting Soil Water for Stable Isotope Analysis. Journal of Hydrology, Vol. 140, pages 371-387.</p> <p>Revezs, K., and dP. H. Woods, 1990. A Method to Extract Soil Water for Stable Isotope Analysis. Journal of Hydrology, Vol. 115, pages 397-406</p> <p>Dugan, J. P., J. Borthwich, R. S. Harmon, M. A. Gagnier, J. E. Glahn, E. P. Kinsel, S. MacLeod, J. A. Viglino, and J. W. Hess, 1985. Guanidine Hydrochloride Method for Determination of Water Oxygen Isotope Ratios and the Oxygen-18 Fractionation Between Carbon Dioxide and Water at 25°. Analytical Chemistry, Vol. 57, pages 1,734-1,736.</p> <p>Kendall, C., and T. B. Coplen, 1985. Multisample Conversion of Water to Hydrogen by Zinc for Stable Isotope Determination. Analytical Chemistry, Vol. 57, pages 1,437-1,440.</p> <p>Gonfiantini, R., 1981. The Del-Notation and the Mass Spectrographic Measurements Techniques. International Atomic Energy Agency, Technical Report Series No. 210, Chapter 4, pages 35-84.</p>
Cation-Exchange Capacity	U.S. Environmental Protection Agency, September 1986. Cation-Exchange Capacity of Soils (Sodium Acetate), Method 9081. In: Test Methods for Evaluating Solid Waste (SW-486), Chapter 5, Miscellaneous Test Methods, RO, 4 pages.

Table 3-2
Summary of the Numbers of Tests Performed on Samples from the
U3ax/bl Exploratory Boreholes

Test		UE-3bl-D1		UE-3bl-U1	
		Core	Drill Cuttings	Core	Drill Cuttings
Hydrologic Properties and Conditions	Saturated Hydraulic Conductivity	18	--	19	--
	Moisture Retention Curves	18	--	19	--
	Gravimetric Water Content	55	93	59	95
	Volumetric Water Content	55	--	59	--
	Total Water Potential	16	--	19	--
Physical, Pneumatic, and Chemical Properties	Particle Size Distribution Dry Sieve	18	--	19	--
	Hydrometer	8	--	6	--
	Dry Bulk Density	34	--	38	--
	Particle Density	18	--	19	--
	Porosity, Calculated	34	--	38	--
	Porosity, Saturated	18	--	19	--
	Air Permeability	5	--	--	--
	Calculated Permeability	18	--	19	--
	Cation Exchange Capacity	21	--	23	--
Environmental Tracers	Inorganic Carbon	21	--	23	--
	Chloride-Bromide	18	--	19	--
	Stable Isotopes	17	--	15	--
	Tritium	--	4	--	--

Note: -- indicates test not performed.

Table 3-3
Summary of Descriptive Statistics for Physical and Pneumatic Properties for
Core Samples from the U3ax/bl Exploratory Boreholes

	Sample ID	Number of Samples	Range		Mean	Standard Deviation	Coefficient of Variation (percent)
			Minimum	Maximum			
Sieve Analysis (percent passing Number 4 mesh screen)							
UE-3bl-D1	DB1	18	51.6	98.8	87.9	11.5	13.1
UE-3bl-U1		19	53.0	97.8	83.5	14.8	17.7
Sieve Analysis (percent passing Number 200 mesh screen)							
UE-3bl-D1	DB1	18	1.8	35.3	13.8	11.3	81.7
UE-3bl-U1		19	1.9	14.5	7.5	4.6	60.7
Dry Bulk Density (grams per cubic centimeter)							
UE-3bl-D1	DB1	18	1.25	1.64	1.44	0.11	8.0
	DRI1	16	1.16	1.75	1.46	0.14	9.3
	TOTAL	34	1.16	1.75	1.45	0.12	8.5
UE-3bl-U1	DB1	19	1.25	1.75	1.47	0.11	7.3
	DRI1	19	1.27	1.69	1.51	0.12	8.1
	TOTAL	38	1.25	1.75	1.49	0.12	7.7
Particle Density (grams per cubic centimeter)							
UE-3bl-D1	DB1	18	2.50	2.60	2.55	0.03	1.0
UE-3bl-U1		19	2.44	2.58	2.53	0.04	1.5
Porosity, calculated (percent)							
UE-3bl-D1	DB1	18	36.3	51.2	43.7	4.3	9.9
	DRI1	16	31.3	54.5	42.6	5.3	12.5
	TOTAL	34	31.3	54.5	43.1	4.8	11.1
UE-3bl-U1	DB1	19	31.7	49.7	41.8	4.1	9.8
	DRI1	19	33.1	49.7	40.1	4.8	12.1
	TOTAL	38	31.7	49.7	41.0	4.5	11.0
Porosity, saturated (percent)							
UE-3bl-D1	DB1	18	29.2	48.2	39.9	5.3	13.4
UE-3bl-U1		19	29.3	44.1	37.9	4.0	10.5
Air Permeability (square meters)							
UE-3bl-D1	AIR	5	5.9 x 10 ⁻¹³	1.1 x 10 ⁻¹¹	3.9 x 10 ⁻¹²	4.2 x 10 ⁻¹²	107.6
UE-3bl-U1		18	8.4 x 10 ⁻¹⁴	2.6 x 10 ⁻¹¹	5.4 x 10 ⁻¹²	8.2 x 10 ⁻¹²	150.1

Table 3-4
Summary of Descriptive Statistics for Hydrologic Properties for Core and Drill
Cuttings Samples from the U3ax/bl Exploratory Boreholes

	Sample ID	Number of Samples	Range		Mean	Standard Deviation	Coefficient of Variation (percent)
			Minimum	Maximum			
Saturated Hydraulic Conductivity (centimeters per second)							
UE-3bl-D1	DB1	18	8.2×10^{-5}	2.5×10^{-2}	5.4×10^{-3}	8.0×10^{-3}	149.3
UE-3bl-U1		19	1.2×10^{-4}	1.9×10^{-2}	3.4×10^{-3}	4.6×10^{-3}	134.6
Gravimetric Water Content (percent)							
UE-3bl-D1	DB1	21	4.2	11.6	7.6	1.8	23.6
	DRI1	16	4.4	11.1	7.7	1.6	20.5
	HGC	18	3.8	11.2	7.7	1.8	24.1
	TOTAL	55	3.8	11.6	7.6	1.7	22.5
UE-3bl-U1	DB1	21	4.1	9.2	6.4	1.8	28.1
	DRI1	19	3.6	11.3	7.1	2.1	29.3
	HGC	19	4.0	10.6	6.9	2.0	29.1
	TOTAL	59	3.6	11.3	6.8	1.9	28.7
UE-3bl-D1	Drill Cuttings Samples	93	2.7	8.1	5.2	1.1	22.0
UE-3bl-U1		95	2.9	10.2	5.1	1.2	22.7
Volumetric Water Content (percent)							
UE-3bl-D1	DB1	21	6.8	14.5	10.7	2.0	19.0
	DRI1	16	7.3	13.7	11.2	1.6	14.2
	HGC	18	5.6	16.2	11.1	2.7	24.1
	TOTAL	55	5.6	16.2	11.0	2.1	19.4
UE-3bl-U1	DB1	21	6.7	13.7	9.3	2.3	24.9
	DRI1	19	6.1	14.4	10.6	2.6	24.6
	HGC	19	5.9	15.8	10.3	3.0	29.1
	TOTAL	59	5.9	15.8	10.0	2.6	26.4
Water Potential (bars)							
UE-3bl-D1	DRI1	16	-51.0	-10.2	-24.7	14.4	58.2
UE-3bl-U1		19	-61.6	-9.5	-27.8	16.9	60.6
Total Hydraulic Potential (bars) ^a							
UE-3bl-D1	DRI1	16	-51.6	-14.7	-27.4	13.0	47.3
UE-3bl-U1		19	-61.9	-14.4	-29.7	15.6	52.3

a Water potential and gravimetric potential (assuming 0 datum at ground surface)

Table 3-5
Summary of Descriptive Statistics for Chemical Properties and
Environmental Tracer Data for Core Samples and Drill Cuttings Samples from the
U3ax/bl Exploratory Boreholes

	Sample ID	Number of Samples	Range		Mean	Standard Deviation	Coefficient of Variation (percent)	
			Minimum	Maximum				
Inorganic Carbon (percent)								
UE-3bl-D1	DB2	21	0.01	1.63	0.64	0.42	66.5	
UE-3bl-U1		23	0.02	1.17	0.41	0.35	87.1	
Cation Exchange Capacity (milliequivalents per 100 grams)								
UE-3bl-D1	DB2	21	15.8	29.4	20.2	3.1	15.5	
UE-3bl-U1		23	11.5	23.4	15.1	3.2	21.5	
Chloride in Dry Soil (parts per million)								
UE-3bl-D1	HGC	18	0.53	5.22	1.33	1.19	89.7	
UE-3bl-U1		19	0.55	29.63	3.47	6.94	199.9	
Bromide in Dry Soil (parts per million)								
UE-3bl-D1	HGC	18	0.007	0.037	0.019	0.008	42.5	
UE-3bl-U1		19	0.006	0.818	0.099	0.244	244.9	
Chloride-Bromide Ratio								
UE-3bl-D1	HGC	18	47.0	141.0	66.0	26.8	40.6	
UE-3bl-U1		19	7.0	152.0	95.5	33.1	34.7	
Stable Isotopes (per mil)								
UE-3bl-D1	δ D	DRI3	17	-117.0	-92.0	-107.8	8.2	7.6
	- δ ¹⁸ O		17	-15.5	-9.2	-13.6	1.9	13.9
UE-3bl-U1	δ D		15	-113.0	-92.0	-102.7	7.2	7.0
	- δ ¹⁸ O		15	-15.4	-9.4	-12.7	2.0	15.9
Tritium (unenriched) (picoCuries per Liter)								
UE-3bl-D1 (drill cuttings samples)	DRI2	8	760	9,240	3,843.9	2,630.4	68	
UE-3bl-D1 (core samples)	ARCH	10	471	7,300	3,465.0	2,346.8	65	
UE-3bl-U1 (core samples)		10	350 ^a	849	469.0	172.1	37	

a This value is the detection limit for the unenriched tritium analyses.

Table 3-6
Summary of Unified Soil Classification System Assignments for Core Samples from the U3ax/bl
Exploratory Boreholes

Borehole	Number and Percent () of Samples with Given USCS Group Names ^a					Total
	SW	SP	SW-SM	SP-SM	SM	
UE-3bl-D1	3 (17%)	1 (6%)	6 (33%)	1 (6%)	7 (39%)	18
UE-3bl-U1	6 (32%)	1 (5%)	7 (37%)	-- --	5 (26%)	519
TOTAL	9 (24%)	2 (5%)	13 (35%)	1 (3%)	12 (32%)	37 (99%) ^b

- a USCS = Unified Soil Classification System
SW: Well graded sand (<5 % silt) SP: Poorly graded sand (<5 % silt)
SW-SM: Well graded sand with silt (5 to 12 %silt) SP-SM: Poorly graded sand with silt (5 to 12 % silt)
SM: Silty sand (>12 %silt)
-- No samples in this USCS group

- b Total does not equal 100 percent due to rounding.

Table 3-7
Summary of Descriptive Statistics of Moisture Retention Curves for Core Samples from the U3ax/bl
Exploratory Boreholes

Borehole	Statistic	θ_r (percent)	θ_s (percent)	α (cm ⁻¹)	n
Ue-3bl-D1 (s = 18)	Minimum	0.0	29.2	0.009	1.15
	Maximum	10.2	48.2	0.457	1.90
	Mean	7.6	39.9	0.065	1.47
	Standard Deviation	2.9	5.3	0.10	0.21
	Coefficient of Variation (percent)	38.2	13.3	153.8	14.3
UE-3bl-U1 (s = 10)	Minimum	0.5	29.3	0.016	1.13
	Maximum	4.4	44.1	0.776	1.61
	Mean	2.0	37.9	0.159	1.29
	Standard Deviation	1.3	4.0	0.21	0.14
	Coefficient of Variation (percent)	65.0	10.6	132.1	10.9

Where: θ_r is the residual volumetric water content (cm³/cm³)
 θ_s is the saturated volumetric water content (cm³/cm³)
 α (cm⁻¹) and n (dimensionless) are curve-fitting parameters
s is the number of samples

Since each borehole was drilled at an approximate 45-degree angle, the borehole slant depth does not correspond to vertical depth below the ground surface. Unless specifically stated otherwise, borehole slant depths, rather than vertical depths, are presented in this report. The corresponding vertical depths for given borehole slant depths are given in Appendix D.

3.3 General Geologic Description, Lithology, and Stratigraphy

General geologic descriptions and qualitative lithologic and stratigraphic information are useful in describing the hydrogeologic conditions of the alluvium beneath the U3ax/bl disposal unit. The lithology of the alluvium can influence soil water movement. For example, the presence of a carbonate horizon would impede soil water movement.

3.3.1 General Geologic, Lithologic, and Stratigraphic Data for Alluvium

Visual geologic descriptions were made on both core and drill cuttings samples. These were recorded on borehole log sheets and drill cuttings log data sheets (Appendix B). These data sheets include a field description of lithology, cementation, particle shape, color, and texture. Preliminary soil texture classifications were determined via visual inspection in the field; final soil texture classifications were determined from sieve analyses (Section 3.4.1). Geologic descriptive information from both boreholes is summarized below.

The geologic samples from both boreholes consisted of unconsolidated alluvium. The field geologist, who examined all samples, estimated that the alluvial material consisted of 95 percent tuff fragments and 5 percent carbonate fragments. This estimate was based on visual inspection and is only an approximation. The degree of cementation in the samples ranged from weakly cemented to uncemented. This field assessment was based on visual inspection and the reaction of the samples to dilute hydrochloric acid, which ranged from no reaction to strong reaction. Thin layers (less than 5 cm [2 in.]) of secondary calcium carbonate were found in core samples from both boreholes. Gravel and coarse-grained sand particles were subangular to subrounded. Using the Munsell color chart, the most prevalent color was brown, ranging from very pale brown to yellowish brown.

The textural groups based on the Unified Soil Classification System (USCS) are summarized for alluvial core samples in Table 3-6. Laboratory results are presented in Appendix C. The textural group of all core samples ranged from a silty sand to a well-graded sand. The two most prevalent textural groups found in the samples from Borehole D1 were SW-SM (well-graded sand with silt) and SM (silty sand). In the samples from Borehole U1, the most prevalent groups

were SW (well-graded sand), SW-SM (well-graded sand with silt), and SM (silty sand). The textural data are consistent with the findings of the archival literature search (REECo, 1994a).

3.3.2 Inorganic Carbon

Carbon concentration in the geologic samples might suggest the presence of a carbonate horizon, which could create a barrier to soil water movement. Depth profiles of inorganic carbon in core samples from boreholes U1 and D1 are shown in Figure 3-1. Tabular values of inorganic carbon measurements, as percent inorganic carbon, are listed in Appendix D. Descriptive statistics are given in Table 3-5.

Inorganic carbon concentrations in the core samples were low, with mean values less than 1 percent by weight. Borehole D1 had 5 (out of 18) core samples with values equal to or greater than 1 percent, and Borehole U1 had 2 (out of 19) core samples with values equal to or greater than 1 percent. For Borehole D1, the highest carbon value (1.63 percent) was found at a slant depth of 6.4 m (21 ft). In Borehole D1, a thin (less than 35 mm [1 in.]) layer of carbonate was identified from field descriptions for the depth interval of 6.1 to 6.9 m (20.0 to 22.5 ft), which corresponds to the high inorganic carbon concentration for this interval. For Borehole U1, the highest carbon concentration was 1.17 percent, at a slant depth of approximately 13 m (42 ft); the gravel-sized particles at this depth were observed to be coated with carbonate. As is documented in Sections 3.5 and 3.6, no evidence was found that the thin carbonate layers or carbonate-coated particles influenced the hydrogeologic properties or conditions of the alluvium.

3.4 Physical and Chemical Properties

Core samples were analyzed for several physical properties (particle size distribution, dry bulk density, particle density, and porosity) and one chemical property, CEC. Bulk density and porosity measurements are dependent on the arrangement and packing of unconsolidated alluvial particles, and therefore were made only on intact core segments. Cation-exchange capacity tests were done on either intact or non-intact core segments, as CEC is much more dependent on soil texture than on soil structure (arrangement and packing). Particle size distribution analyses were done only after all other analyses had been completed, since particle size distribution analysis destroys the soil structure of the sample.

3.4.1 Particle Size Distribution

Particle size distribution analyses were completed on all DB1 core segments using a dry sieve method. DBS&A determined that 8 of the 18 core segments from Borehole D1, and 6 of 19 core

Figure 3-1
Slant Depth Profiles of Inorganic Carbon for Core Samples from the
U3ax/bl Exploratory Boreholes

segments from Borehole U1 required wet sieve analysis for the fine fraction (silt/clay size fraction) because of the large amount of fine material in these samples.

The results of particle size distribution analyses are presented in tabular form in Appendix C. Data from the Number (No.) 4 and No. 200 sieve screens (percent of material passing) for alluvial core samples are plotted versus depth in Figures 3-2 and 3-3. These two sieve screen sizes are chosen for plotting because material within these two screen sizes is designated as sand. Material that does not pass through the No. 4 sieve is classified as gravel, and material passing through the No. 200 sieve is designated as fines (i.e., the silt and clay size fraction).

Based on the USCS, all core samples collected from both boreholes are classified as sand. However, a comparison of Figures 3-2 and 3-3 reveals slight differences in the particle size distribution between the two boreholes. The core samples from Borehole D1 appear to have a higher silt/clay content and lower gravel content than samples from Borehole U1. For example, six sampled intervals from Borehole D1 had a silt/clay content greater than any interval from Borehole U1, and five sampled intervals from Borehole U1 had a gravel content greater than any interval from Borehole D1. Such variability is common in alluvial deposits.

No trend with depth in particle size distribution was evident in either borehole (in this report, the word “trend” refers to drift in mean, and not in standard deviation or other statistical properties). Descriptive statistics of the No. 4 and No. 200 sieve screen data for core samples from both boreholes are given in Table 3-3.

3.4.2 Bulk Density, Particle Density, and Porosity

For each borehole, dry bulk density was determined on the DB1 and DRI1 core segments from each core run. These data are listed in tabular form in Appendix C. Descriptive statistics for bulk density, as well as particle density and porosity, are presented in Table 3-3. Plots of bulk density versus depth for boreholes D1 and U1 are shown in Figures 3-4 and 3-5, respectively.

Figures 3-4 and 3-5 show little variability in the bulk density between the DB1 and DRI1 core segments from both boreholes, except Run No. 23 in Borehole D1 (Figure 3-4), taken at a slant depth of approximately 70 m (230 ft). In this core run, the DRI bulk density value was 1.16 grams per cubic centimeter (g/cm^3) and the DB1 value was 1.55 g/cm^3 . A bulk density of 1.16 g/cm^3 is significantly lower than the bulk density values associated with the other samples from both boreholes.

Figure 3-2
Slant-Depth Profiles of Dry Sieve Analyses for Core Samples from UE-3bl-D1
(percent passing No. 4 and No. 200 Mesh Screens)

Figure 3-3
Slant-Depth Profiles of Dry Sieve Analyses for Core Samples from UE-3bl-U1
(percent passing No. 4 and No. 200 Mesh Screens)

Figure 3-4
Slant-Depth Profiles of Dry Bulk Density for Core Samples from UE-3bl-D1
 (in grams per cubic centimeter)

Figure 3-5
Slant-Depth Profiles of Dry Bulk Density for Core Samples from UE-3bl-U1
 (in grams per cubic centimeter)

If the small value (1.16 g/cm^3) reflected in-situ conditions, it is likely that the value of the next sample would also have been small. However, the bulk density values for the DB1 and DRI1 core segments of the next core run, taken at a slant depth of approximately 73 m (240 ft) are 1.75 and 1.59 g/cm^3 , respectively; both are above the overall mean value of 1.45 g/cm^3 . The occurrence of an isolated unusual data point, with surrounding data points not reflecting the same conditions, is consistent with the hypothesis that something happened during sampling, handling, or shipping that affected the bulk density of that DRI core segment. Hence, the bulk density observed in Run No. 23 is thought to be an artifact, not representing in-situ conditions.

For both boreholes, no consistent trends with depth were found in bulk density. This is similar to the bulk density data obtained from nearby boreholes (REECo, 1994a). No significant differences in bulk density values were apparent between the two boreholes (Figure 3-6).

Particle density was determined on all DB1 core segments. These data are presented in tabular form in Appendix C. Plots of particle density versus depth are shown in Figure 3-7. Figure 3-7 illustrates the small variation of the particle density of the alluvial materials with depth, and the similarity of particle density values between the two boreholes. The observed particle densities are, as expected, consistent with values obtained from nearby boreholes (REECo, 1994a).

Estimates of porosity with depth were calculated (by definition) from the DB1 dry bulk density for a specific depth and the average particle density for each borehole. These data are presented in Appendix C. As with the bulk density values, outliers in the porosity values may reflect sampling disturbance rather than in-situ conditions. In addition, water-saturated porosity was measured on the DB1 core segments after the saturated hydraulic conductivity measurement was conducted on the same core segment (Section 3.5.1). Both calculated and water-saturated porosity values are plotted versus depth for boreholes U1 and D1 in Figures 3-8 and 3-9, respectively.

3.4.3 Cation-Exchange Capacity

Cation-exchange capacity is the amount of exchangeable cations that a soil can adsorb, expressed in milliequivalents per 100 grams of soil. Most cation exchange in soil occurs on the clay fraction because this size fraction has the largest surface area and the most reactive surfaces. Silt and sand particles can contribute to the CEC, but their contribution is generally insignificant when compared to that of the clay fraction. The CEC could influence the movement of contaminants (e.g., lead, cesium, and strontium) (Drever, 1988) disposed in the U3ax/bl disposal

Figure 3-6
 Slant-Depth Profiles of Dry Bulk Density for DB1 Core Samples from the
 U3ax/3bl Exploratory Boreholes (in grams per cubic centimeter)

Figure 3-7
Slant-Depth Profiles of Particle Density for Core Samples from UE-3bl-D1
(in grams per cubic centimeter)

Figure 3-8
Slant-Depth Profiles of Calculated (c) and Water-Saturated (s) Porosity for
Core Samples from UE-3bl-D1

Figure 3-9
Slant-Depth Profiles of Calculated (c) and Water-Saturated (s) Porosity for
Core Samples from UE-3bl-U1

unit, were any leachate generated. Inorganic hazardous and radiological contaminants are often present as cations. A soil with a high CEC will generally have a greater ability to retard these contaminants than that of a soil with a low CEC.

Cation-exchange capacity values were determined on the DB2 core segments using a sodium acetate method (Table 3-1). CEC data for both boreholes are presented in tabular form in Appendix C. Figure 3-10 contains a plot of CEC versus depth for both boreholes. Descriptive statistics for CEC are given in Table 3-5. The mean CEC value for the samples from Borehole D1 was about one-third greater than the mean value for the samples from Borehole U1. This suggests that the clay content is higher in the samples from Borehole D1. This result supports the conclusion, drawn from the particle size distribution data, that the silt/clay fraction is higher in samples from Borehole D1 than the samples from Borehole U1.

3.5 Hydrogeologic Properties

Hydrogeologic property measurements include saturated hydraulic conductivity and moisture retention curves. For this study, unsaturated hydraulic conductivity values were calculated from these properties. Direct methods of measuring unsaturated hydraulic conductivity were not used because these measurements are difficult to obtain, in either the laboratory or in situ, at the very low water content conditions (Section 3.6.1) found in the vadose zone beneath the Area 3 RWMS.

3.5.1 Saturated Hydraulic Conductivity

Saturated hydraulic conductivity measurements were conducted on all DB1 core segments. The measurements were made using a constant head permeameter. Saturated hydraulic conductivity profiles are presented in Figure 3-11, and descriptive statistics are summarized in Table 3-4. Data are provided in tabular form in Appendix C. No trends with depth in the values from either borehole are apparent (where “trend” indicates trend in mean and not in other statistical properties). Although slight differences in particle size distribution were noted, differences in saturated hydraulic conductivity between the two boreholes were minor to negligible, considering the large natural variability of saturated hydraulic conductivity. Hydraulic conductivity values observed are typical of the values Freeze and Cherry (1979) report for sand.

Figure 3-10
Slant-Depth Profiles of Cation-Exchange Capacity for Core Samples from the
U3ax/3bl Exploratory Boreholes (in milliequivalents per 100 grams of soil)

Figure 3-11
Slant-Depth Profiles of Saturated Hydraulic Conductivity for Core Samples from
the U3ax/3bl Exploratory Boreholes (in centimeters per second)

Saturated hydraulic conductivity depends on the porous medium and fluid. The parameter describing the porous medium is known as permeability. The relationship between saturated hydraulic conductivity and permeability is described by the following equation (Freeze and Cherry, 1979):

$$K = (k\rho g)/\mu \quad (1)$$

where K is the hydraulic conductivity, k is the intrinsic permeability of the porous medium, ρ is the density of the fluid, g is the acceleration due to gravity, and μ is the viscosity of the fluid. Since the density and viscosity of water are known, the permeability of the core can be calculated from the saturated hydraulic conductivity values. Descriptive statistics and tabular data for permeability are given in Table 3-3 and Appendix C, respectively. These calculated permeability values were compared to the effective permeability values determined from air permeability tests on selected core samples. This comparison is discussed in Section 3.7.

3.5.2 Moisture Retention Relations

Following saturated hydraulic conductivity measurements, moisture retention measurements were made on DB1 core segments from both boreholes. These measurements provide a relationship between water potential and water content at equilibrium (water potential and water content are constant with time) for a given soil water condition. The relationship between water potential and water content, as soil water conditions vary from near saturation to air-dried, can be described with a moisture retention relation. A minimum of eight points was measured for each core sample, so that a moisture retention curve could be developed. For each core segment, a moisture retention curve was fitted to the data using the method of van Genuchten (1978, 1980). The moisture retention relation is:

$$\theta = \theta_r + (\theta_s - \theta_r) [1 + (-\alpha h)^n]^{-m} \quad (2)$$

where θ is volumetric water content (cm^3/cm^3), θ_s is the saturated volumetric water content (cm^3/cm^3), θ_r is the residual volumetric water content (cm^3/cm^3), h is matric potential (cm), α (cm^{-1}) and n (dimensionless) are curve fitting parameters, and m equals $(1-1/n)$. A nonlinear least squares computer code was used to calculate the curve-fitting parameters α , n , and θ_r (van Genuchten, 1978, 1980). These parameters for core samples are tabulated in Appendix C, and summary descriptive statistics are given in Table 3-6. Observed values of α from both boreholes are consistent with values calculated for coarse-grained materials (REEC, 1995; BN, 2005a).

The moisture retention curves for core segments from each borehole are shown in Figures 3-12 and 3-13. Tabular data are listed in Appendix C. Core interval depths are not identified in Figures 3-12 and 3-13. The curves from Borehole D1 did not extend into drier soil water conditions, as did the curves from Borehole U1, because air-dried measurements were not performed on the samples from Borehole D1.

In the laboratory analysis reports, DBS&A stated that the moisture retention relations of the samples at low water potentials were typical of coarse-textured materials. However, the observed continued release of water at middle and high water potentials is not typical of a coarse-textured material. DBS&A suggest that this atypical relation results from the presence of porous tuff clasts, which provide more water storage than the particle size distribution alone would predict.

3.5.3 Unsaturated Hydraulic Conductivity

Unsaturated hydraulic conductivity was calculated from moisture retention data and saturated hydraulic conductivity values using a method described by van Genuchten (1978, 1980). Water content is the amount of liquid water in a specified mass or volume of soil, and total hydraulic potential is the total energy of the soil water at a specific point in the soil. In van Genuchten's method, water content is expressed as the effective saturation, S , which is a dimensionless water content defined by:

$$S = (\theta - \theta_r) (\theta_s - \theta_r)^{-1} \quad (3)$$

where θ , θ_s , and θ_r are as in Equation 2. Unsaturated hydraulic conductivity, $K(S)$, is derived by substituting the van Genuchten moisture retention curve-fitting parameters into the Mualem (1976) model for predicting $K(S)$ to obtain:

$$K(S) = K_s S^{1/2} [1 - (1 - S^{1/m})^m]^2 \quad (4)$$

where K_s is the saturated hydraulic conductivity and m is as in Equation 2.

The resulting $K(S)$ data, shown in Figures 3-14 and 3-15, is expressed as a function of θ and $K(\theta)$, using Equation 3. The parameters required to calculate unsaturated hydraulic conductivity values for core samples are summarized in Appendix C. The plots in Figures 3-14 and 3-15 show unsaturated hydraulic conductivity decreasing steeply with decreasing water content.

Figure 3-12
Composite Moisture Retention Curve Data for Core Samples from UE-3bl-D1

Figure 3-13
Composite Moisture Retention Curve Data for Core Samples from UE-3bl-U1

Figure 3-14
Fitted Unsaturated Hydraulic Conductivity Functions For Core Samples
from UE-3bl-D1

Figure 3-15
Fitted Unsaturated Hydraulic Conductivity Functions For
Core Samples from UE-3bl-U1

The vertical line on each plot represents the mean volumetric water content (Table 3-5) of all core segments from that borehole. The unsaturated hydraulic conductivity values at the mean water content of both boreholes are several orders of magnitude less than saturated hydraulic conductivity values.

3.6 Hydrogeologic Conditions

Hydrogeologic conditions are described using parameters, such as water content and total hydraulic potential, that can vary with time. The driving force for soil water movement is the difference in the total hydraulic potential between two points divided by the distance separating these points, which is called the total hydraulic gradient.

3.6.1 Water Content

The gravimetric water content, which is the ratio of the mass of water in a sample to the mass of the oven-dried soil sample, was determined for both drill cuttings and core samples. Volumetric water content, which is the ratio of the mass of water to the volume of soil, was determined for core samples. Volumetric water content was calculated by multiplying the gravimetric water content of a sample by its bulk density. Depending on core recovery, water content was measured in as many as three core segments (DB1, DRI1, and HGC) within a core run. The volumetric water content for each DB1 and DRI1 core segment was calculated using the bulk density value measured for each segment. The bulk density was not measured for the HGC core segments, so the volumetric water content for these core segments was calculated using the mean bulk density value of all DB1 and DRI1 core segments within the same borehole.

In addition, gravimetric water content was measured by REEC Co SPS personnel on archive core segments (3 from Borehole D1 and 2 from Borehole U1), and the data reported as DB1 samples. The archive core segments that were used to supplement the DB1 samples are identified in Appendix C. These samples were measured to fill data gaps resulting from poor core recovery at these depths. The volumetric water content values of the archive samples were calculated using the mean bulk density (including all core segments) for each borehole. The gravimetric and volumetric water content data from the two boreholes are listed in tabular form in Appendix C. Descriptive statistics for water content for drill cuttings and core samples are given in Table 3-5.

The mean gravimetric water content of drill cuttings samples from Borehole D1 was approximately 2.5 percent less than that for core samples. For Borehole U1, the mean gravimetric water content of drill cuttings samples was approximately 1.5 percent less than that

for core samples. This is thought to result from the drying of cuttings by the compressed air as it lifted the cuttings from the borehole.

Volumetric water content profiles for boreholes D1 and U1 are presented in Figures 3-16 and 3-17, respectively. In both boreholes, the means and standard deviations of volumetric water content values differ little among samples from the DB1, DRI1, and HGC core segments (Table 3-4). As expected, water content data were within the range of water content values found in nearby boreholes (REECo, 1994a). Volumetric water content profiles for the two boreholes, using only the DB1 and archive core segments, are shown in Figures 3-18. For both profiles, the only noticeable trend is a slight increase in water content with increasing depth. No significant differences were evident in water content between samples from boreholes D1 and U1. The mean volumetric water content for samples from Borehole D1 is slightly larger (approximately 1 percent) than that from Borehole U1 (Table 3-4). From the moisture retention curves (Figures 3-12 and 3-13), these mean water content values correspond to very low water potentials. This indicates that the alluvium, both beneath and adjacent to the disposal unit, is dry; therefore, water flux is small to nonexistent. Water potential data (Section 3.6.2) support this conclusion.

3.6.2 *Total Hydraulic Potential*

The two major components of total hydraulic potential are water potential and gravitational potential. Water potential is the energy required to pull a unit mass of water from the unsaturated soil, and gravitational potential is the energy required to move a unit mass of pure, free water from a reference elevation (Kirkham and Powers, 1972). The reference elevation for the gravitational potential was established as the ground surface; thus, gravitational potential at a given vertical depth will equal -1 times the depth. For example, gravitational potential of a soil sample taken from a vertical depth of 9 m (30 ft) will be -9 m (-30 ft). In arid areas such as Yucca Flat, the near-surface alluvium is typically dry. Under dry conditions, the water potential gradient is the dominant driving force affecting soil water movement.

Water potential measurements were made on the DRI1 core segment from each run. Water potential and total hydraulic potential data for geologic samples are listed in tabular form in Appendix C. Descriptive statistics for water potential and total hydraulic potential are given in Table 3-5. Because there is a vertical trend in the total hydraulic potential, profiles of the total

Figure 3-16
Slant Depth Profiles of Water Content for Core Samples from UE-3bl-D1

Figure 3-17
Slant Depth Profiles of Water Content for Core Samples from UE-3bl-U1

Figure 3-18
Slant Depth Profiles of Volumetric Water Content for DB1 Core Samples
from the U3ax/bl Exploratory Boreholes

hydraulic potential data represent vertical depth instead of slant depth (Figure 3-19). The profiles show an upward gradient for the entire depth (approximately 50 m [165 ft]) of both boreholes. Despite this upward gradient, upward flux is likely to be small because the unsaturated hydraulic conductivity (Figures 3-14 and 3-15) at in-situ water content is several orders of magnitude smaller than the saturated hydraulic conductivity.

3.7 *Pneumatic Properties*

REECo SPS personnel completed air permeability tests on five 15.3-cm (6-in.) core samples from Borehole D1. These tests were conducted to obtain the effective permeability (k) in units of square meters (m^2). This testing method measures the air pressure gradient required to move air through a core sample under steady-state conditions at a given flow rate. Pressure measurements under steady-state conditions were made at a minimum of nine different flow rates. Data from these measurements were used to calculate the effective permeability for a core sample using the extended Darcy's equation (Scheidegger, 1974), which adapts Darcy's equation so that it applies to air flow through a porous medium. The procedure for air permeability testing is listed in Table 3-1.

Results of the air permeability tests are given in Appendix C. Descriptive statistics for the effective permeability are listed in Table 3-3. A plot of effective permeability values versus depth for Borehole D1 is shown in Figure 3-20, along with a plot of calculated permeability values versus depth for both boreholes, derived from the saturated hydraulic conductivity data (Section 3.5). The air permeability results obtained by the two methods are similar. This is as expected, although the interaction between the soil matrix and water can reduce the permeability of the medium. However, in the sandy alluvium of the samples from Borehole D1, this interaction was expected to be small.

3.8 *Environmental Tracers*

Environmental tracers provide a method, independent of the hydraulic parameters, of estimating water movement in the vadose zone. In this study, two types of environmental tracers were used: dissolved ions, such as chloride and bromide, that travel in solution with the soil water through the vadose zone; and isotopes, stable and radioactive, which are part of the water molecule itself. The concentrations of these tracers are measured with depth. Analysis of the profile data yields information concerning the history of water movement through the unsaturated zone. In the following sections, only qualitative observations concerning tracer profiles are made.

Figure 3-19
Vertical Depth Profiles of Total Hydraulic Potential for Core Samples from the
U3ax/bl Exploratory Boreholes

Figure 3-20
Slant Depth Profiles of Air Permeability for UE-3bl-D1 and Calculated (c)
Permeability for Core Samples from the U3ax/3bl Exploratory Boreholes
 (in square meters)

3.8.1 Chloride-Bromide Profiles

Chloride and bromide ions can serve as tracers because their negative charge discourages sorption with negatively charged mineral surfaces in soils (Allison, 1988). Chloride and bromide ions primarily enter the soil as dissolved components of precipitation. These ions also enter the soil in lesser and more variable amounts, as salts contained in aeolian dust, which can dissolve in water infiltrating into the soil. As water evaporates, the concentration of these ions increases. Plots of the concentrations of these ions versus depth provide insight into the hydrogeologic condition of the vadose zone over time (Conrad, 1993). At depths where the ion concentrations are large, the hydrogeologic condition of the vadose zone at the time these ions were emplaced was such that the evaporation rate exceeded the infiltration rate. Conversely, at depths where ion concentrations are small, conditions were such that the infiltration rate exceeded the evaporation rate.

Chloride and bromide concentrations were measured on core samples. Descriptive statistics for the chloride-bromide ratios for the core samples are presented in Table 3-7. Tabular data are listed in Appendix C. Depth profiles of chloride and bromide concentrations, per unit dry weight of soil, for boreholes D1 and U1, are shown in Figures 3-21 and 3-22, respectively.

The depth profiles of the chloride and bromide concentrations for both boreholes indicate similar trends: namely, chloride and bromide concentrations in the upper part of each profile are greater than those in the remainder of the profile. The chloride and bromide depth profiles are similar to the profiles obtained from core samples at the NTS Area 5 RWMS within Frenchman Flat (REECo, 1995; BN, 2005a). Based on chloride data from Area 5, Conrad (1993) hypothesized that low chloride concentration at depth suggest that this water entered the subsurface under wetter climate conditions, when infiltration exceeded evaporation.

If water movement in the upper profile is upward, as described in Section 3.6.2, large chloride and bromide concentrations would be expected in the upper alluvium. This is what was observed.

Although trends in the chloride and bromide profiles for both boreholes were the same, the concentrations in the upper profile of Borehole U1 were at least two times greater than those of Borehole D1. The high ion concentrations in Borehole D1 occurred at a slant depth of approximately 9 m (30 ft), which is still in undisturbed alluvium (i.e., not yet beneath the crater).

Figure 3-21
Slant Depth Profiles of Dry Soil Chloride Concentrations for Core Samples
from the U3ax/bl Exploratory Boreholes (in parts per million)

Figure 3-22
Slant Depth Profiles of Dry Soil Bromide Concentrations for Core Samples
from the U3ax/bl Exploratory Boreholes (in parts per million)

The reason for the difference in concentrations between the two boreholes is uncertain. Even though the boreholes are only 12 m (40 ft) apart, the location of Borehole U1 may have received historically more runoff than the location of Borehole D1. The current topography does not suggest that the Borehole U1 location receives more water than the Borehole D1 location. However, both boreholes are located in an area that has been graded periodically over the last 30 years, potentially concealing washes and shallow drainage swales that might have existed under natural conditions. Also, during waste disposal operations for U3ax/bl, water trucks were used for dust control. The location of Borehole U1 may have received more water from these trucks or another artificial source than the location of Borehole D1.

Chloride-bromide ratios (Figure 3-23) are useful in evaluating precision in laboratory measurements. A constant ratio indicates good laboratory precision. The ratios for the samples from Borehole D1 are relatively constant, whereas the ratios for the samples from Borehole U1 vary widely throughout the profile. The variability in the ratios for samples from Borehole U1 raises questions about the validity of the measurements made on these samples. Because there is more variability in the bromide profiles than in the chloride profiles, the Borehole U1 bromide concentrations are more suspect.

For both boreholes U1 and D1, the chloride-bromide ratio is more variable at shallow depths than at greater depths, as can be seen in Figure 3-23. This is probably due to evaporation causing the variability in concentrations in both chloride and bromide to be greater at shallow depths than at greater depths (see Figures 3-21 and 3-22).

3.8.2 Stable Isotope Profiles

The stable isotopes of hydrogen (deuterium, D, and hydrogen, H) and oxygen (^{18}O and ^{16}O) are excellent tracers of water movement because these isotopes are components of the water molecule itself (Allison, 1988). Stable isotopes are used in unsaturated zone studies to infer the source of soil water and to determine if evaporation has occurred. Results are reported as ratios of heavy to light isotopes (D/H and $^{18}\text{O}/^{16}\text{O}$) in delta notation (δ) relative to standard mean ocean water (Craig, 1961).

Fractionation, or change in this ratio, occurs during phase change processes. Therefore, condensation and evaporation processes affect isotopic ratios. The condensation of precipitation occurs under near thermodynamic equilibrium conditions, resulting in a linear relationship between hydrogen and oxygen isotopes in worldwide precipitation known as the meteoric water

Figure 3-23
Slant Depth Profiles of Dry Soil Chloride-Bromide Ratios for Core Samples
from the U3ax/bl Exploratory Boreholes

line (MWL) (Craig, 1961). Evaporation of water generally occurs under non-equilibrium conditions. Under these conditions, fractionation of oxygen isotopes is greater than that of hydrogen isotopes. Thus, the water remaining behind in the evaporation process develops an isotopic composition that plots to the right of the MWL.

Stable isotope data from the boreholes is listed in Appendix C, descriptive statistics for core samples are given in Table 3-5, and depth profiles for the boreholes are presented in Figure 3-24. In general, the profiles from both boreholes show enrichment of heavy isotopes, indicating that evaporation is occurring.

A plot of oxygen isotope ratios from selected core sample from each borehole, with the MWL for reference, is shown in Figures 3-25 and 3-26. The data from both boreholes plot to the right of the MWL, on a line with a smaller slope. This slope is within the range of values found by Allison (1982) in experiments in which water was evaporated from sand columns; it strongly suggests that evaporation rates are high, relative to the downward rate of water movement in the upper vadose zone under the present climate (REECo, 1995; BN, 2005a). This provides further evidence of the conclusion drawn from the water potential data, that water movement in the near-surface alluvium is upward. Also, no recognizable difference in the isotope ratios was apparent between the two boreholes.

3.8.3 Tritium Profiles

Tritium, with a half-life of 12.3 years, is also effective tracer because it is part of the water molecule itself. Before extensive atmospheric nuclear weapons testing began in 1952, environmental tritium concentrations in meteoric waters were low and in many cases, non-detectable (Drever, 1988). However, tritium concentrations in precipitation and soil water began increasing in 1952 because of atmospheric testing. Consequently, if tritium concentrations in soil water exceed enrichment detection levels (approximately 16 pCi/L), the water must either have infiltrated into the soil after 1952 or the concentrations were enhanced from a source other than atmospheric testing, such as underground nuclear testing or the waste disposed in U3ax/bl (REECo, 1994b).

Tritium concentrations in precipitation reached a peak in the early 1960s, at concentrations of about 10,000 pCi/L (National Council on Radiation and Protection Measurements, 1975). Assuming the precipitation with a tritium concentration of 10,000 pCi/L infiltrated into the soil at the Area 3 RWMS in 1964, the tritium concentration after 30 years would be less than

Figure 3-24
Slant Depth Profiles of Stable Isotopes for Core Samples from the
U3ax/bl Exploratory Boreholes
 (Oxygen-18 and Deuterium [per mil] in standard delta [δ] notation)

Figure 3-25
Comparison of Measured Stable Isotopes for Core Samples from UE-3bl-D1 with
Stable Isotope Data for the Global Meteoric Water Line (MWL)
 (Oxygen-18 and Deuterium [per mil] in standard delta [δ] notation)

Figure 3-26
Comparison of Measured Stable Isotopes for Core Samples from UE-3bl-U1 with
Stable Isotope Data for the Global Meteoric Water Line (MWL)
 (Oxygen-18 and Deuterium [per mil] in standard delta [δ] notation)

2,500 pCi/L in soil water. If tritium concentrations in the soil water from the samples exceed 2,500 pCi/L, then the tritium is likely from sources other than atmospheric testing.

Eight drill cuttings samples and ten core sample were collected from Borehole D1 for unenriched tritium analyses. The drill cuttings samples were taken at slant depths of approximately 4, 18, 46, and 73 m (13, 60, 150, and 240 ft). The cuttings were placed in 3.8-L (1-gal) containers, one for each depth. Two samples were taken from each container, one sample from near the middle, and the other from near the top of the container. The ten core samples were added later to provide tritium concentration data at more intervals throughout the borehole. In addition, ten core samples were collected from Borehole U1 for unenriched tritium analyses. Descriptive statistics for the tritium concentrations are listed in Table 3-5. A plot of tritium versus depth is shown in Figure 3-27. Appendix C contains the data in tabular form.

The samples were analyzed by DRI using a vacuum distillation method to extract the water from the soil and a 2500TR Packard[®] Liquid Scintillation Counter to measure the tritium. The tritium concentrations in samples from Borehole U1 are all less than 850 pCi/L, decreasing with depth to levels near or below the detection limit of 350 pCi/L. The concentrations below the detection limit are plotted on Figure 3-27 at 350 pCi/L. On the other hand, tritium concentrations in samples from Borehole D1 were higher than those from Borehole U1, ranging from 471 to 9,240 pCi/L. In Borehole D1, the tritium concentrations generally increase with depth. These concentrations from Borehole D1 suggest sources other than past atmospheric testing, such as the waste from the U3ax/bl disposal unit or the materials associated with the underlying nuclear test BOBAC. Therefore tritium would not be appropriate as an environmental tracer beneath U3ax/bl.

These concentrations may be too large for tritium to serve as an environmental tracer, but they are still less than 1 percent of the Nuclear Regulatory Commission's concentration limit of 1,000,000 pCi/L for effluent released to an unrestricted area (Title 10 CFR §20). Also, the observed tritium concentrations were smaller than many concentrations observed in precipitation in the early 1960s (National Council on Radiation and Protection Measurements, 1975).

Figure 3-27
Slant Depth Profiles of Unenriched Tritium Concentrations for Geologic Samples
from the U3ax/bl Exploratory Boreholes
 (Vertical dashed line indicates the detection limit of 350 picoCuries per liter.)

This page intentionally left blank.

4.0 Directional Survey Results

The subcontractor, Christiansen Boyles Corporation-WELNAV, conducted directional surveys in boreholes U1 and D1 using a gyroscopic directional survey tool. Data were collected at points no more than 3 m (10 ft) apart. These data, in tabular form, are provided in Appendix D.

Figure 1-2 shows that Borehole D1 was drilled beneath the U3ax/bl disposal unit. Because the casing detached at the slant depth of approximately 74 m (242 ft), drilling of Borehole D1 stopped short of the target slant depth of 91 m (300 ft). Thus, it is not certain that Borehole D1 entered the U3bl chimney. The intended slant depth of 91 m (300 ft) would have placed the borehole directly above the U3bl cavity and clearly within the chimney.

Using the directional survey data, a profile view of Borehole D1 was plotted relative to the U3bl crater, the cavity, and the potential chimney boundaries (Figure 4-1). The horizontal coordinates and dimensions of the U3bl crater were obtained from a topographic map (Holmes & Narver, 1962). The location of the cavity center and its estimated radius were obtained from the Los Alamos National Laboratory database (Hawkins, 1993).

Two major models of chimney shape, cylindrical and inverted cone, have been proposed (Houser, 1970). Of the two models, the cylindrical model is the most widely accepted (Houser, 1970). In this model, the chimney extends vertically from the cavity; Houser (1970) notes that the radius of the chimney is about 10 percent larger than the cavity. In the inverted cone model, the radius of the chimney starts roughly the same as the cavity, expanding outward as the chimney grows upward. Chimney boundaries shown in Figure 4-1 reflect these models. The diagonal boundaries extending from the edge of the cavity to the outer edge of the crater represent the inverted cone model, and the vertical boundaries, maintaining roughly the same radius as the cavity, represent the cylindrical model. Figure 4-1 shows that the borehole is clearly within the chimney if the inverted cone model holds, but approximately 3 m (10 ft) outside the chimney if the cylindrical model applies and the chimney has, contrary to expectations, the same radius as the cavity. Because chimney boundaries in unconsolidated material are likely not distinctive, it would be possible to say with certainty that Borehole D1 penetrated the chimney only if the borehole was clearly above the cavity of BOBAC, which is not the case.

Figure 4-1
Cross Section Showing UE-3bl-D1 Relative to the Estimated Positions of the U3bl Crater/Chimney/Cavity

5.0 Recommendations and Future Work

The following are recommendations (from the 1996 version of this report) for future work to obtain a better understanding of the hydrogeologic system beneath the Area 3 RWMS, including the hydrogeologic conditions within chimneys:

- Future boreholes should be drilled deep enough to reach a zone where the soil water flux is no longer upward. Presently, that depth is unknown. Accordingly, it is recommended that the minimum depth of boreholes drilled in undisturbed alluvium be 122 m (400 ft), and boreholes that are proposed within the chimney should be drilled as deep as possible, without contacting radioactive contamination left by underground nuclear testing.
- A minimum of one borehole should be drilled into a chimney either within or near the Area 3 RWMS, with core samples taken every 3 m (10 ft). This borehole should start from the bottom of the crater to ensure that the samples collected are from within the chimney. Depth of penetration should be limited by safety considerations.

Several additional boreholes, including another hole beneath the U3ax/bl crater, have since been drilled at the Area 3 RWMS as a continuation of the effort to characterize the collapse zones beneath the U3ax/bl and U3ah/at waste disposal cells. See, for example, BN (2005b).

This page intentionally left blank.

6.0 References

- Allison, G. B., 1982. *The Relationship Between ^{18}O and Deuterium in Water and Sand Columns Undergoing Evaporation*. Journal of Hydrology, v. 55, pp. 163-169
- Allison, G. B., 1988. "A Review of Some of the Physical, Chemical, and Isotopic Techniques Available for Estimating Groundwater Recharge." In: Simmers, I., ed., Estimation of Natural Groundwater Recharge. Reidel Publishing, pp. 49-72.
- Bechtel Nevada, 2000. *Closure Plan for Corrective Action Unit 110: Area 3 RWMS U-3ax/bl Disposal Unit, Nevada Test Site, Nevada*. DOE/NV--647. Las Vegas, NV.
- Bechtel Nevada, 2005a. *Site Characterization and Monitoring Data from the Area 5 Pilot Wells*. DOE/NV/11718--1067. Las Vegas, NV.
- Bechtel Nevada, 2005b. *Hydrogeologic Characterization of U-3at Collapse Zone*. DOE/NV/11718--199-REV.1. Las Vegas, NV.
- BN, see Bechtel Nevada.
- Borg, I. Y., R. Stone, H. B. Levy, and L. D. Ramspott, 1976. *Information Pertinent to the Migration of Radionuclides in Ground Water, Part I: "Review and Analysis of Existing Information."* Lawrence Livermore National Laboratory Report UCRL-52078.
- Christensen, R. C., and N. E. Spahr, 1980. *Flood Potential of Topopah Wash and Tributaries, Eastern Part of Jackass Flats, Nevada Test Site, Southern Nevada*. U.S. Geological Survey Open File Report 80-963.
- Craig, H., 1961. *Standard for Reporting Concentrations of Deuterium and Oxygen-18 in Natural Waters*. Science, v. 133, pp. 1,833-1,934.
- Conrad, S. H., 1993. *Using Environmental Tracers to Estimate Recharge Through an Arid Basin*. 1993 International High-Level Radioactive Waste Management Conference, Las Vegas, NV. April 26-30, 1993.
- DOE, see U.S. Department of Energy.
- Doty, G. C., and W. Thordarson, 1983. *Water Table in Rocks of Cenozoic and Paleozoic Age, 1980, Yucca Flat, Nevada Test Site, Nevada*. U.S. Geological Survey Water Resources Investigations Report 83-4067 (map).
- Drellack, S. L., Jr., 1994. *Isopach Map of Alluvium in LANL-Use Areas, Yucca Flat, NTS*. Raytheon Services Nevada, LANL Geologic Support Group. Map ID: QTAISO, Rev. 4. Mercury, NV.

- Drever, J. I., 1988. The Geochemistry of Natural Waters, Second Edition. Prentice Hall, Inc., Englewood Cliffs, NJ.
- Fernald, A. T., 1974. *Geology and Material Properties of the Area 3 "Sand Pile," Southeastern Yucca Flat, Nevada Test Site, Part I: "Geology."* U.S. Geological Survey Special Projects Branch.
- Freeze, R. A., and J. A. Cherry, 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, NJ.
- Hammermeister, D. P., D. O. Blout, and J. C. McDaniel, 1986. "Drilling and Coring Methods that Minimize the Disturbance of Cuttings, Core, and Rock Formations in the Unsaturated Zone, Yucca Mountain, Nevada." In: Proceedings of the NWWA Conference on Characterization and Monitoring of the Vadose (Unsaturated) Zone, Denver, CO, 1985, pp. 506-541. National Water Well Association, Worthington, OH.
- Hawkins, W., Los Alamos National Laboratory, 1993. Personal communication. Subject: "Estimated Depth and Cavity Radius for U-3bl." Los Alamos, NM.
- Holmes & Narver, Inc., 1962. "Station U3bl: Portion of Area 3 Post Test Topography." Scale: 1:480, Contour Interval: 2 feet. Map currently held in the Bechtel Nevada Archive and Records Center, Mercury, NV.
- Houser, F. N., 1970. *A Summary of Information and Ideas Regarding Sinks and Collapse, Nevada Test Site*. U.S. Geological Survey Report USGS-474-41 (NTS-216).
- Kirkham, D., and W. L. Powers, 1972. Advanced Soil Physics. Robert E. Krieger Publishing, Malabar, FL.
- Mualem, Y., 1976. *A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media*. Water Resources Research, v. 12, pp. 513-522.
- National Council on Radiation and Protection Measurements, 1975. *Natural Background Radiation in the United States*. National Council on Radiation and Protection Measurements, Washington, DC.
- REEC Co, see Reynolds Electrical and Engineering Co.
- Reynolds Electrical and Engineering Co., Inc., 1993. *Hydrogeologic Data for Science Trench Boreholes at the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nye County, Nevada*. Special Projects Section, Environmental Management Division. Las Vegas, NV.
- Reynolds Electrical and Engineering Co., Inc., 1994a. Written communication. Subject: "Archival Literature Search and Conceptual Model for the U3ax/bl Disposal Unit." Las Vegas, NV.
- Reynolds Electrical and Engineering Co., Inc., 1994b. Written communication. Subject: "U3ax/bl Waste Inventory Report. Las Vegas, NV.

- Reynolds Electrical and Engineering Co., Inc. 1995. *Hydrogeologic Data for Science Trench Boreholes at the Area 5 RWMS, Nevada Test Site, Nye County, Nevada*. Reynolds Electrical and Engineering Co., Inc. Special Projects Section, Environmental Management Division. Las Vegas, NV. DOE/NV/11432--40.
- Scheidegger, A. E., 1974. The Physics of Flow Through Porous Media, Third Edition. University of Toronto Press, Toronto.
- Tyler, S. W., W. A. McKay, and T. M. Miheve, 1992. *Assessment of Soil Moisture Movement in Nuclear Subsidence Craters*. Journal of Hydrology, v. 139, pp. 159-181.
- U.S. Department of Energy, Nevada Operations Office, 2000. *United States Nuclear Tests, July 1945 through September 1992*. DOE/NV-209, Revision 15. Las Vegas, NV.
- van Genuchten, M. Th., 1978. *Calculating the Unsaturated Hydraulic Conductivity with a New Closed-Form Analytical Model*. Water Resources Program, Dept. of Civil Engineering, Princeton Univ., Princeton, NJ Res. Rpt. 78-WR-8, 63p.
- van Genuchten, M. Th., 1980. *A Closed-Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils*. Soil Science Society of America Journal, v. 45, pp. 892-898.

This page intentionally left blank.

U3ax/bl Exploratory Boreholes

Appendix A

Drilling Information

U3ax/bl Exploratory Boreholes

Appendix A Drilling Information

A-1 Chronological Drilling Summary for Borehole UE-3bl-D1

Table A-1
Chronological Drilling Summary for Borehole UE-3bl-D1

Date (1994)	Casing Borehole Depth (feet)	Core Run Number	Activity
06/09			Excavate 10-ft-deep cellars for boreholes D1 and U1. Place casing. Unload gravel.
06/13			Spread and prepare gravel pad for boreholes D1 and U1. Relocate corners.
06/14			Move equipment, logging, trailer, and transportainer onsite.
06/15			Steam-clean equipment.
06/20			Move drill rig on to the Borehole D1 site.
06/21			Move drill support equipment onsite. Install oil separator, stand, and accelerator cable on rig.
06/22			Unload casing. DOE inspection.
06/23			Gamma alarm installed. Inspection by Occupational Safety. Dust collection system onsite. Fabricate connections.
06/24			Place 6 $\frac{5}{8}$ -in. casing in hole. Connect fittings and hoses to dust control system.
06/27	12.5	1	Fabricate pack-off and guide.
06/28	22.5	2	Fabricate pack-off. Add mini-cyclone to cyclone.
06/29	50.0	3, 4	
06/30	60.0	5	Industrial Health inspects site. Rig down for repairs.
07/05			Down for repairs.
07/11	70.0	6, 7	
07/12	100.0	8, 9	
07/13	110.0	10, 11	Core barrel broke of in hole; retrieved with over-shot.
07/14			Fix rig pipe handler hydraulics. Environmental Compliance Office (ECO) inspection.
07/15	130.0	12	DOE and Nevada Division of Environmental Protection (NDEP) inspection.
07/18	132.5	13	
07/19	150.0	14	Wet core samples.
07/20			Environmental Protection Agency, DOE, NDEP, and ECO onsite. Rig hydraulic problems. WELNAV directional survey.
07/21	152.2	15	Broke rig hydraulic line.
07/25	170.0	16, 17	
07/26	190.0	18, 19	
07/27	200.0	20	
07/28	220.0	21	
07/29	230.0	22, 23	
08/01	240.0	24	
08/02	241.5		Casing separated.

This page intentionally left blank.

U3ax/bl Exploratory Boreholes

Appendix B

Core and Drill Cuttings Sample Description Data

U3ax/bl Exploratory Boreholes

Appendix B Core and Drill Cuttings Sample Description Data

- B.1 Borehole Log Sheets for UE-3bl-D1
- B.2 Borehole Log Sheets for UE-3bl-U1
- B.3 Drill Cuttings Log Data for UE-3bl-D1
- B.4 Drill Cuttings Log Data for UE-3bl-U1

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

1. BOREHOLE DATA		DESIGNATION: D1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 45 degrees				
2. CORE DATA		RUN No. 1	DATE & TIME: 6/27/94, 1612	INTERVAL: 12.5-13.33	ft	PENETRATION RATE: 3.52 min/ft	RECOVERY: 0	ft	0 %			
3. DEPTH (ft)	3a. CORRECTED DEPTH (ft)	4. COLOR (MUNSELL CHART)	5. MOISTURE		6. PARTICLE SIZE	7. MAJOR MINERALS (percent)	8. SORTING	9. GRAIN SHAPE	10. HCl REACTION	11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION
			DRY	MOIST								
1												1 DBI
2												2 DRII
3												3 AIRI
4												4 HGC
5												5 DBZ
6												6 ARCH
7												
8												
9												
10												
14. COMMENTS:												
3. 5" I.D. X 2.55 ft Solid Core Barrel & 0.45' Shoe; Air Pressure 210-260 psi; No core recovery;												
No radiation above background as determined by HPD personnel; Sampler out of Hole @ 1612, 6-27-94												
15. LOGGED BY:		Ken Donnelson, 1630, 6-27-94		16. REVIEWED BY & DATE:		D. Blout, 6-28-94						

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS08.XLS Page 8 of 24

1. BOREHOLE DATA										DESIGNATION: D1		RIG: Schramm T68SH		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
2. CORE DATA		RUN No. 8		DATE & TIME: 7/12/94, 1020		INTERVAL: 80.0-82.5		ft		PENETRATION RATE: 2.4 min/ft		RECOVERY: 2.5 ft		100 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE	6. CONTENT		7. PARTICLE SIZE		8. DISTRIBUTION		9. MINERALS (percent)		10. SORTING		11. GRAIN SHAPE			12. HCI REACTION				13. USCS GROUP SYMBOL	14. MAGNETIC SUSCEPTIBILITY	15. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
			DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	9. GRAIN SHAPE					10. HCI	12. HCI REACTION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
																	10. HCI	11. GRAIN SHAPE	12. HCI REACTION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
80.0-	55.45-	7.5YR6/4	X		0	5	85	10	95	5		X								SM	0.95																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

Very good core with every segment intact. No radioactivity above background detected by RCT.

14. COMMENTS:

15. LOGGED BY: D. O. Blout, 7-12-94

16. REVIEWED BY & DATE:

J. Schmeltzer, 7-12-94

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS09.XLS Page 9 of 24

1. BOREHOLE DATA		DESIGNATION: D1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 45 degrees		
2. CORE DATA		RUN No. 9	DATE & TIME: 7/12/94, 1418	INTERVAL: 90.0-92.5	ft	PENETRATION RATE: 2.8 min/ft	RECOVERY: 0 ft	0 %		
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE	6. PARTICLE SIZE	7. MAJOR MINERALS (percent)	8. SORTING	9. GRAIN SHAPE	10. REACTION	11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION
										1 DB1
1		DRY	COBBLES	SAND	WELL	ANGULAR	WEAK			1 DB1
2		MOIST	GRAVEL	SILT-CLAY	MODERATE	SUBANGULAR	MODERATE			2 DB1
3		WET		CARBONATES	POOR	ROUNDED	STRONG			3 AIR1
4				VOLCANICS		SUBROUNDED				4 HGC
5										5 DB2
6										6 ARCH
7										
8										
9										
10										
14. COMMENTS:										
No recovery. No radioactivity above background detected by RCT.										
15. LOGGED BY: D. O. Blout, 7-12-94										
16. REVIEWED BY & DATE: J. Schmeltzer, 7-12-94										

D. Blout, 7-14-94

FILE NAME: D1-BLS11.XLS Page 11 of 24

14. COMMENTS:

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS12.XLS Page 12 of 24

1. BOREHOLE DATA													
DESIGNATION: D1		RIG: Schramm T68SH		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 45 degrees							
2. CORE DATA		RUN No. 12		DATE & TIME: 7/15/94, 1100		INTERVAL: 120.0-122.0 ft		PENETRATION RATE: 1.12 min/ft		RECOVERY: 2.5 ft		100 %	
10	9	8	7	6	5	4	3	2	1	13. SAMPLE DESIGNATION			
										1 DB1	2 DB1	3 AIR1	4 HGC
120.00-	82.65-	10YR7/4	X										
120.25	82.82	10YR7/4	X										
120.50	82.99	10YR7/4	X										
120.75	83.16	10YR7/4	X										
121.00	83.33	10YR7/4	X										
121.25	83.50	10YR7/4	X										
121.50	83.67	10YR7/4	X										
121.75	83.84	10YR7/4	X										
122.00	84.01	10YR7/4	X										
122.25	84.18	10YR7/4	X										
122.50	84.35	10YR7/4	X										
14. COMMENTS:													
Solid tube core barrel used. Rig air pressure 260-360 PSI at 600-700 PSI downfeed. Core barrel out of hole at 1100, 7-15-94. No radioactivity detected above background by RCT. Good intact core. Predominantly uniform fine-grained sand with occasional subrounded pebbles.													
15. LOGGED BY: Ken Donnelson, 7-15-94, 1137													
16. REVIEWED BY & DATE: D. Blout, 7-16-94													

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS17.XLS Page 17 of 24

1. BOREHOLE DATA										DESIGNATION: D1										RIG: Schramm T685H										DRILL METHOD: Drive Core, SD-4 Hammer										DIRECTION & INCLINATION: N26E, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
2. CORE DATA										RUN No. 17										DATE & TIME: 7/25/94, 1502										INTERVAL: 170.0-172.5										ft										PENETRATION RATE: 2.48 min/ft										RECOVERY: 2.5 ft										100 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
3. DEPTH (ft)	3a. CORRECTED DEPTH (ft)	4. COLOR (MUNSELL CHART)	5. MOISTURE			6. PARTICLE SIZE			7. MAJOR MINERALS (percent)			8. SORTING			9. GRAIN SHAPE			10. HCI REACTION				11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
			DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE			STRONG	1 DB1	2 DRI1	3 AIR1	4 HGC	5 DB2	6 ARCH	7 DRI3	8	9	10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
1	170.00-116.31-170.25	10YR7/3	X			0	0	88	12	95	5		X									SM	3.50				X																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														</

14. COMMENTS:

Solid core barrel used. Rig air pressure 360-330 PSI at 500-700 PSI downfeed. Core barrel out of hole at 1502, 7-25-94. Good intact core. Fill? 170.0-170.25 ft.

Weakly to moderately cemented fine-grained sand. No radioactivity detected above background by RCT.

15. LOGGED BY:

Ken Donnelson, 7-25-94, 1350

16. REVIEWED BY & DATE:

D. Blout, 7-26-94

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS19.XLS Page 19 of 24

1. BOREHOLE DATA		DESIGNATION: D1		RIG: Schramm T68SH		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 45 degrees												
2. CORE DATA		RUN No. 19	DATE & TIME: 7/26/94, 1411	INTERVAL: 190.0-192.5 ft	PENETRATION RATE: 1.2 min/ft	RECOVERY: 0 ft	0 %													
10	9. CORRECTED DEPTH (ft)	4. COLOR (MUNSELL CHART)	5. MOISTURE CONTENT		6. PARTICLE SIZE		7. MAJOR MINERALS (percent)		8. SORTING		9. GRAIN SHAPE		10. REACTION				11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION	
			DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR				SUBANGULAR
1																			1 DB1	
2																			2 DRI1	
3																			3 AIR1	
4																			4 HGC	
5																			5 DB2	
6																			6 ARCH	
7																				
8																				
9																				
10																				
14. COMMENTS:																				
Solid core barrel used. Rig air pressure 250-330 PSI at 400-700 PSI downfeed. Core barrel out of hole at 1405, 7-26-94. No core recovery.																				
No radioactivity detected above background by RCT.																				
15. LOGGED BY: Ken Donnellson, 7-26-94, 1411																				
16. REVIEWED BY & DATE: D. Blout, 7-27-94																				

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS21.XLS Page 21 of 24

1. BOREHOLE DATA		DESIGNATION: D1		RIG: Schramm T68SH		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 4.5 degrees								
2. CORE DATA		RUN No. 21		DATE & TIME: 7/28/94, 1320		INTERVAL: 210.0-212.5 ft		PENETRATION RATE: 0.92 min/ft		RECOVERY: 2.5 ft 100 %						
13. SAMPLE DESIGNATION	12. MAGNETIC SUSCEPTIBILITY	11. USCS GROUP SYMBOL	10. HCI REACTION	9. GRAIN SHAPE	8. SORTING	7. MAJOR MINERALS (percent)		6. PARTICLE SIZE DISTRIBUTION		5. MOISTURE CONTENT		4. COLOR (MUNSELL CHART)	3. CORRECTED DEPTH (ft)	2. DEPTH (ft)	1. CORE NO.	
						CARBONATES	VOLCANICS	COBBLES	GRAVEL	SAND	SILT-CLAY					DRY
1 DB1	2.46	SP	WEAK	ANGULAR	WELL											
2 DB1	0.73	SP-SM	MODERATE	ANGULAR	MODERATE											
3 AIR1	1.08	SW	WEAK	ANGULAR	WELL											
4 HGC	0.78	SW	WEAK	ANGULAR	WELL											
5 DB2	1.25	SW	WEAK	ANGULAR	MODERATE											
6 ARCH	0.66	SW	WEAK	ANGULAR	MODERATE											
7 DR13	0.66	SW	WEAK	ANGULAR	MODERATE											
8	0.77	SP	WEAK	ANGULAR	WELL											
9	0.91	SW	WEAK	ANGULAR	MODERATE											
10	1.18	SW-SM	WEAK	ANGULAR	MODERATE											

14. COMMENTS: Solid tube core barrel used. Rig air pressure 200-240 PSI at 200-220 PSI downfeed. Core barrel out of hole at 1320, 7-28-94.

No radioactivity above background detected by RCT. Good intact core. Soils cleaner than previous run.

Coarse sand from 211.75-212.0 ft. Gravel size 0.25-0.375 in. and have slight caliche rind. Fine sand from 210.0-210.5 ft. may be aeolian.

15. LOGGED BY: Ken Donnellson, 7-28-94, 1414

16. REVIEWED BY & DATE: D. Blout, 8-1-94

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: D1-BLS22.XLS Page 22 of 24

1. BOREHOLE DATA										DESIGNATION: D1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: N26E, 45 degrees																				
2. CORE DATA		RUN No. 22		DATE & TIME: 7/29/1994, 0931		INTERVAL: 220.0-222.5 ft		PENETRATION RATE: 1.6 min/ft		RECOVERY: 2.5 ft		100 %																								
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE			6. PARTICLE SIZE			7. DISTRIBUTION (percent)			8. MAJOR MINERALS (percent)			9. SORTING			10. SHAPE			11. REACTION			12. USCS GROUP SYMBOL			13. SAMPLE DESIGNATION										
		DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE	STRONG	SW-SM	SP-SM	1 DB1	2 DB11	3 AIR1	4 HGC	5 DB2	6 ARCH	7 DB13	8	9	10		
220.00-	149.05-				0	30	64	9	95	5																										
220.25	149.21	X																																		
220.25-	149.21-				0	30	62	8	95	5																										
220.50	149.37-	X																																		
220.50-	149.37-				0	10	80	10	95	5																										
220.75	149.53																																			
220.75-	149.53-																																			
221.00	149.69				0	10	80	10	95	5																										
221.00-	149.69-				0	5	87	8	95	5																										
221.25	149.85																																			
221.25-	149.85-				0	5	87	8	95	5																										
221.50	150.01																																			
221.50-	150.01-				0	5	87	8	95	5																										
221.75	150.17																																			
221.75-	150.17-				0	5	87	8	95	5																										
222.00	150.33																																			
222.00-	150.33-				0	5	87	8	95	5																										
222.25	150.49																																			
222.25-	150.49-				0	5	87	8	95	5																										
222.50	150.65				0	10	80	10	95	5																										
222.50-	150.65-																																			

Solid tube core barrel used. Rig air pressure 250-300 PSI at 300-600 PSI downfeed. Core barrel out of hole at 0931, 7-29-94. No radioactivity above background detected by RCT.

Good intact core. Possible fill from 220.0-220.5 ft. Weakly to moderately cemented fine-grained sand from 220.5 to 222.25 ft. Possible bone cast fragment from 222.25 to 222.5 ft.

15. LOGGED BY:

Ken Donnelson, 7-29-94, 1020

16. REVIEWED BY & DATE:

D. Blout, 8-1-94

14. COMMENTS:

FILE NAME: D1-BLS23.XLS Page 23 of 24

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS01.XLS Page 1 of 25

1. BOREHOLE DATA										DESIGNATION: U1										RIG: Schramm T685H										DRILL METHOD: Drive Core, SD-4 Hammer										DIRECTION & INCLINATION: S26W, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
2. CORE DATA										RUN No. 1										DATE & TIME: 8/4/94, 1401										INTERVAL: 12.5-15.0 ft										PENETRATION RATE: 0.8 min/ft										RECOVERY: 2.0 ft										80 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
3. CORRECTED DEPTH (ft)										4. COLOR (MUNSELL CHART)										5. MOISTURE			6. PARTICLE SIZE			DISTRIBUTION			MINERALS			8. SORTING			9. GRAIN SHAPE			10. HCI REACTION				11. USCS GROUP SYMBOL										12. MAGNETIC SUSCEPTIBILITY										13. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
																				DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE	STRONG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
1	12.5-	8.84-9.01	7.5YR6/3	X			0	60	35	5	5	95	5	5																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							

14. COMMENTS:

Solid core barrel used. Rig air pressure 200-250 PSI at 0-500 PSI downfeed. Core barrel out of hole at 1401, 8-4-94. Fill from 12.5-12.75 ft. Poor intact core.

Considerable caliche on gravels. No radioactivity detected above background by RCT.

15. LOGGED BY: Ken Donnellson, 1439, 8-4-94**16. REVIEWED BY & DATE:**

D. Blout, 8-8-94

FILE NAME: U1-BLS05.XLS Page 5 of 25

1. BOREHOLE DATA				DESIGNATION: U1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
2. CORE DATA RUN No. 5				DATE & TIME: 8/5/94, 1457		INTERVAL: 50.0-52.5 ft		PENETRATION RATE: 3.24 min/ft		RECOVERY: 2.5 ft 100 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
3. DEPTH (ft)	9. CORRECTED DEPTH (ft)	5. MOISTURE CONTENT		6. PARTICLE SIZE DISTRIBUTION		7. MAJOR MINERALS (percent)		8. SORTING		9. GRAIN SHAPE			10. REACTION				11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
		DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR				ROUND	NONE	WEAK	Moderate	STRONG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
50.00-	35.35-	X			0	5	80	15	95	5	X				X																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

15. LOGGED BY: Ken Donnelson, 8-9-94, 0910

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS08.XLS Page 8 of 25

1. BOREHOLE DATA				DESIGNATION: U1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
2. CORE DATA				RUN No. 8		DATE & TIME: 8/9/1994, 1123		INTERVAL: 80.0-82.5 ft		PENETRATION RATE: 0.48 min/ft		RECOVERY: 2.5 ft		100 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE			6. PARTICLE SIZE DISTRIBUTION		7. MAJOR MINERALS (percent)		8. SORTING		9. GRAIN SHAPE			10. REACTION			11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
		DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR													ROUNDED	NONE	WEAK	MODERATE	STRONG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
1	80.00-80.25	X			0	2	86	12	95	5	X																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				</

14. COMMENTS:

Solid tube core barrel used. Rig air pressure 240-260 PSI at 500 PSI downfeed. Core barrel out of hole at 1123, 8-9-94. No radioactivity detected above background by RCT.

Good intact core. Uniform fine grained sand.

15. LOGGED BY: Ken Donnelson, 8-9-94, 1203**16. REVIEWED BY & DATE:** D. Blout, 8/10/94

[illegible]

1. BOREHOLE DATA				DESIGNATION: U1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
2. CORE DATA				RUN No. 13		DATE & TIME: 8/17/94, 0904		INTERVAL: 130.0-132.5 ft		PENETRATION RATE: 1.48 min/ft		RECOVERY: 2.5 ft		100 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE CONTENT			6. PARTICLE SIZE DISTRIBUTION (percent)	7. MAJOR MINERALS (percent)		8. SORTING	9. GRAIN SHAPE			10. REACTION			11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
		DRY	MOIST	WET		COBBLES	GRAVEL		SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL				MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE	STRONG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
130.0-130.25	88.01-88.17	X			0	20	72	8	95	5																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS14.XLS Page 14 of 25

1. BOREHOLE DATA		DESIGNATION: U1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees																	
2. CORE DATA		RUN No. 14		DATE & TIME: 8/17/1994, 1132		INTERVAL: 140.0-142.5 ft		PENETRATION RATE: 6.3 min/ft		RECOVERY: 2.5 ft 100 %															
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE			6. PARTICLE SIZE			7. DISTRIBUTION			8. MAJOR MINERALS			9. SORTING			10. SHAPE			11. REACTION				12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION
		DRY	MOIST	WET	COBBLES	GRAVEL	SAND	SILT-CLAY	(percent)	(percent)	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE	STRONG		
1 140.0-140.25	94.47-94.63	X			0	10	87	3	95	5		X				X								1 DB1	
2 140.25-140.5	94.63-94.79	X			0	20	77	3	95	5		X				X								2 DR1	
3 140.5-140.75	94.79-94.95	X			0	20	77	3	95	5		X				X								3 AIR1	
4 140.75-141.0	94.95-95.12	X			0	30	67	3	95	5		X				X								4 HGC	
5 141.0-141.25	95.12-95.28	X			0	20	70	10	95	5		X				X								5 DB2	
6 141.25-141.5	95.28-95.44	X			0	10	78	12	95	5		X				X								6 ARCH	
7 141.5-141.75	95.44-95.60	X			0	20	77	3	95	5		X				X								7 DR3	
8 141.75-142.0	95.60-95.76	X			0	10	87	3	95	5		X				X								8 HGC2	
9 142.0-142.25	95.76-95.92	X			0	5	83	12	95	5		X				X								9	
10 142.25-142.5	95.92-96.08	X			0	15	77	8	95	5					X									10	

14. COMMENTS: Solid core barrel used. Rig air pressure 220-280 PSI at 500-700 PSI downfeed. Core barrel out of hole at 8-17-94, 1132. Pulled core barrel out of hole due to hammer not firing properly or refusal on cobble. No radioactivity detected above background by RCT. Excessive core recovery -top 15 inches- may be slough in hole, but it appears to be intact. Coarse grained sand from 140.0-141.0 ft. and 141.5-142.0 ft. Fine grained sand from 141.25-141.5 ft. and 142.0-142.25 ft. Moderately intact core.

15. LOGGED BY: Ken Donnellson, 1240, 8-17-94 **16. REVIEWED BY & DATE:** D. Blout, 8-18-94

FILE NAME: U1-BLS15.XLS Page 15 of 25

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS17.XLS Page 17 of 25

1. BOREHOLE DATA		DESIGNATION: U1		RIG: Schramm T68SH		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees													
2. CORE DATA		RUN No. 17		DATE & TIME: 8/18/94, 1355		INTERVAL: 170.0-172.0 ft		PENETRATION RATE: 3.5 min/ft		RECOVERY: 0 ft 0 %											
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE CONTENT	6. PARTICLE SIZE DISTRIBUTION	7. MAJOR MINERALS (percent)	8. SORTING	9. GRAIN SHAPE	10. REACTION	11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION											
										1 DB1	2 DB1	3 AIR1	4 HGC	5 DB2	6 ARCH	7	8	9	10		
1		DRY	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE	STRONG	
2		WET																			
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
14. COMMENTS:																					
Solid core barrel used. Rig air pressure 200-290 PSI at 500-650 PSI downfeed. Core barrel out of hole at 1355, 8-18-94. No radioactivity detected above background by RCT.																					
No recovery. Only able to drill 2 ft. due to possible slough in hole.																					
15. LOGGED BY: Ken Donnellson, 8-18-94, 1420				16. REVIEWED BY & DATE: D. Blout, 8-22-94																	

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

1. BOREHOLE DATA

RIG: Schramm T685H
DRILL METHOD: Drive Core, SD-4 Hammer

DIRECTION & INCLINATION: S26W, 45 degrees

1. BOREHOLE DATA		DESIGNATION: UI	RIG: Schramm T68SH	DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees	
2. CORE DATA		RUN No. 18	DATE & TIME: 8/19/94, 0938	INTERVAL:	180.0-181.7 ft	PENETRATION RATE: 5.03 min/ft	RECOVERY: 2.0 ft 120 %

[illegible]

Solid core barrel used. Rig air pressure 200-260 PSI at 1000-500 PSI downfeed. Core barrel out of hole at 0938, 8-19-94. No intact core-all loose. (May be 6" slough in hole

from 180.0-180.5 ft). No radioactivity detected above background by RCT. Fine grained sand from 181.0-181.5 ft.

15. LOGGED BY: Ken Donnelson, 8-19-94, 1015

16. REVIEWED BY & DATE:

D. Blout, 8-22-94

[illegible]

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS21.XLS Page 21 of 25

[illegible]

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS23.XLS Page 23 of 25

1. BOREHOLE DATA										DESIGNATION: U1										RIG: Schramm T68SH										DRILL METHOD: Drive Core, SD-4 Hammer										DIRECTION & INCLINATION: S26W, 45 degrees																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
2. CORE DATA										RUN No. 23										DATE & TIME: 8/23/94, 1455										INTERVAL: 230.0-232.5 ft										PENETRATION RATE: 2.32 min/ft										RECOVERY: 2.5 ft 100 %																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
3. DEPTH (ft)										4. COLOR (MUNSELL CHART)										5. MOISTURE			6. PARTICLE SIZE			7. MAJOR MINERALS (percent)			8. SORTING			9. GRAIN SHAPE			10. REACTION				11. USCS GROUP SYMBOL										12. MAGNETIC SUSCEPTIBILITY										13. SAMPLE DESIGNATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
																				DRY			COBBLES			GRAVEL			SAND			SILT-CLAY			VOLCANICS			CARBONATES			OTHER			WELL			MODERATE			POOR			ANGULAR			SUBANGULAR			SUBROUNDED			ROUNDED			NONE				WEAK				MODERATE				STRONG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS24.XLS Page 24 of 25

1. BOREHOLE DATA		DESIGNATION: U1		RIG: Schramm T685H		DRILL METHOD: Drive Core, SD-4 Hammer		DIRECTION & INCLINATION: S26W, 45 degrees															
2. CORE DATA		RUN No. 24		DATE & TIME: 8/24/94, 1057		INTERVAL: 240.0-242.5 ft		PENETRATION RATE: 2.7 min/ft		RECOVERY: 0.0 ft 0 %													
3. DEPTH (ft)	4. CORRECTED DEPTH (ft)	5. MOISTURE	6. PARTICLE SIZE	7. MAJOR MINERALS (percent)	8. SORTING	9. GRAIN SHAPE	10. REACTION	11. USCS GROUP SYMBOL	12. MAGNETIC SUSCEPTIBILITY	13. SAMPLE DESIGNATION													
										1 DBI	2 DRI	3 ALR	4 HCC	5 DBZ	6 ARCH	7	8	9	10				
1		DRY	COBBLES	GRAVEL	SAND	SILT-CLAY	VOLCANICS	CARBONATES	OTHER	WELL	MODERATE	POOR	ANGULAR	SUBANGULAR	SUBROUNDED	ROUNDED	NONE	WEAK	MODERATE	STRONG			
2		WET																					
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							
14. COMMENTS:																							
Solid core barrel used. Rig air pressure 240-250 PSI at 600 PSI downfeed. Core barrel out of hole at 1057, 8-24-94. No core recovery.																							
No radioactivity detected above background by RCT.																							
15. LOGGED BY:		Ken Donnelson, 8-24-94, 1100		16. REVIEWED BY & DATE:		D. Blout, 8-25-94																	

BOREHOLE LOG SHEET FOR ALLUVIAL CORE SAMPLES

FILE NAME: U1-BLS25.XLS Page 25 of 25

[illegible]

Appendix B.3 Drill cuttings log data for UE-3b1-D1.

Borehole Depth Interval			Drill Rate (min/ft)	Composition ¹					Gravel Size (in) ¹	USCS Group Symbol ¹	10% HCl Reaction ²	Apparent Magnetic Susceptibility	Comments
from	to	Gravel		Sand	Silt								
(ft)				(percent)									
10.0	12.5	0.40	10	78	12	¼	SM	M	1.53				
12.5	15.0	0.40	10	78	12	¼	SM	S	1.21				
15.0	17.5	0.40	10	78	12	¼	SM	M	1.40				
17.5	20.0	0.40	5	80	15	¼	SM	M	0.92				
20.0	22.5	0.40	5	80	15	¼	SM	M	1.18				
22.5	25.0	0.40	10	75	15	¼	SM	N	0.90				
25.0	27.5	0.40	5	80	15	¼	SM	M	0.99				
27.5	30.0	0.40	5	75	20	¼	SM	M	1.08				
30.0	32.5	0.40	10	80	10	¾	SM-SW	W-M	1.12				
32.5	35.0	0.40	10	80	10	¾	SM-SW	M	0.81				
35.0	37.5	0.40	5	83	12	¼	SM	S	0.87				
37.5	40.0	0.40	10	78	12	¾	SM	W	2.12				
40.0	42.5	0.40	5	80	15	¼	SM	M	1.26	Very fine sand			
42.5	45.0	0.40	0	80	20	-	SM	M	1.12	Very fine sand			
45.0	47.5	1.20	5	83	12	¼	SM-SW	N	0.76				
47.5	50.0	0.32	1	84	15	¼	SM	N	1.01	Very fine sand			
50.0	52.5	0.40	10	75	15	¾	SM	N	1.38				

Appendix B.3 Drill cuttings log data for UE-3bl-D1 (Continued).

52.5	55.0	0.48	5	80	15	¼	SM	W	1.04	
55.0	57.5	0.32	5	75	20	¼	SM	S	1.22	
57.5	60.0	0.60	15	70	15	¾	SM	M	1.15	
60.0	62.5	0.80	10	80	10	¼	SM	W	1.28	Slightly moist
62.5	65.0	0.80	10	80	10	¼	SM	W	0.97	
65.0	67.5	0.80	10	80	10	¼	SM	W	1.04	
67.5	70.0	0.40	10	80	10	¼	SM	W	1.10	
70.0	72.5	0.40	10	80	10	¼	SM	W	1.04	
72.5	75.0	0.40	10	80	10	¼	SM	W	0.97	
75.0	77.5	0.40	10	80	10	¼	SM	W	1.15	
77.5	80.0	0.40	10	80	10	¼	SM	W	0.95	
80.0	82.5	0.40	10	80	10	¼	SM	W	0.86	Drier
82.5	85.0	0.40	10	80	10	¼	SM	W	0.98	
85.0	87.5	0.40	10	80	10	¼	SM	W	0.47	
87.5	90.0	0.40	10	80	10	¼	SM	W	0.83	
90.0	92.5	0.40	10	80	10	¼	SM	W	0.82	
92.5	95.0	0.40	10	80	10	¼	SM	W	0.89	
95.0	97.5	0.40	10	80	10	¼	SM	W	1.46	
97.5	100.0	0.40	10	80	10	¾	SM	W	0.44	
100.0	102.5	0.80	5	80	15	¼	SM	W-N	1.16	Fine

Appendix B.3 Drill cuttings log data for UE-3bl-D1 (Continued).

102.5	105.0	1.32	0	85	15	¼	SM	N	0.93	Fine
105.0	107.5	0.80	0	90	10	¼	SM-SP	N	1.61	Fine
107.5	110.0	1.00	0	85	15	¼	SM	S	0.88	Fine
110.0	112.5	0.80	0	88	12	-	SM	S	1.03	
112.5	115.0	0.80	0	88	12	-	SM	S	0.91	
115.0	117.5	0.60	0	88	12	-	SM	S	1.18	
117.5	120.0	0.60	0	88	12	-	SM	S	1.41	
120.0	122.5	0.40	0	90	10	-	SM-SP	M-S	1.18	Sloughing sands
122.5	125.0	0.60	0	90	10	-	SM-SP	M	0.97	Sloughing sands
125.0	127.5	0.60	0	90	10	-	SM-SP	M-W	1.09	Sloughing sands
127.5	130.0	0.60	0	90	10	-	SM-SP	M	1.15	Sloughing sands
130.0	132.5	0.60	10	78	12	¼	SM	M-S	1.43	Poor recovery
132.5	135.0	0.48	20	70	10	¼	SM-SW	S	1.06	Poor recovery
135.0	137.5	0.72	5	80	15	¼	SM	S	0.90	Poor recovery
137.5	140.0	1.12	5	80	15	¼	SM	M	1.08	Poor recovery
140.0	142.5	0.40	20	68	12	¾	SM	M	0.93	
142.5	145.0	0.44	15	73	12	¼	SM	S	1.14	
145.0	147.5	0.16	15	80	5	¼	SW	W-M	0.95	
147.5	150.0	0.48	15	75	10	¼	SW-SM	M-S	0.97	
150.0	152.5	0.80	10	75	15	¼	SM	S	0.96	

Appendix B.3 Drill cuttings log data for UE-3bl-D1 (Continued).

152.5	155.0	0.60	10	75	15	¼	SM	M-S	1.27	
155.0	157.5	0.80	25	65	10	¼	SM-SW	S	1.00	
157.5	160.0	1.12	25	65	10	¼	SM-SW	S	1.08	
160.0	162.5	0.64	10	78	12	¾	SM	M	1.17	
162.5	165.0	0.60	15	73	12	¾	SM	W	1.21	
165.0	167.5	1.00	20	68	12	¾	SM	S	1.25	
167.5	170.0	0.80	5	83	12	¾	SM	S	1.17	
170.0	172.5	0.64	5	83	12	¼	SM	S	1.44	Copious cuttings
172.5	175.0	0.60	5	83	12	¼	SM	S	0.89	Copious cuttings
175.0	177.5	0.80	0	88	12	-	SM	S	0.74	Copious cuttings
177.5	180.0	0.68	0	88	12	-	SM	S	0.82	
180.0	182.5	0.80	5	83	12	¾	SM	S	1.14	
182.5	185.0	0.72	30	58	12	¾	SM	S	1.17	
185.0	187.5	0.80	20	68	12	¼	SM	S	1.12	
187.5	190.0	1.00	25	65	10	¾	SM-SW	S	1.03	
190.0	192.5	0.84	25	65	10	¾	SM-SW	W	1.06	
192.5	195.0	0.92	20	70	10	¾	SM-SW	S	0.87	
195.0	197.5	0.92	10	78	12	¼	SM	S	1.19	
197.5	200.0	0.88	15	73	12	¾	SM	S	1.50	
200.0	202.5	0.96	5	83	12	¼	SM	M	1.24	

Appendix B.3 Drill cuttings log data for UE-3bl-D1 (Continued).

202.5	205.0	0.96	5	83	12	1/4	SM	M	1.29	
205.0	207.5	0.92	5	83	12	1/4	SM	S	1.39	
207.5	210.0	0.92	20	68	12	3/8	SM	S	0.99	
210.0	212.5	0.88	10	80	10	3/8	SM-SW	M	1.15	
212.5	215.0	0.92	15	73	12	3/8	SM	S	0.89	
215.0	217.5	1.00	20	72	8	3/8	SM-SW	W	0.70	
217.5	220.0	1.36	20	72	8	3/8	SM-SW	W-M	0.95	Poor recovery
220.0	222.5	0.92	10	78	12	1/4	SM	M	1.61	
222.5	225.0	0.88	20	70	10	3/8	SM-SW	W	1.73	Poor recovery
225.0	227.5	1.04	50	40	10	3/8	GM-GW ³	W	1.03	
227.5	230.0	1.12	30	60	10	3/8	SM-SW	M-S	1.03	Poor recovery
230.0	232.5	0.96	10	78	12	3/8	SM	W	1.63	Poor recovery
232.5	235.0	1.24	15	73	12	3/8	SM	S	1.48	Poor recovery
235.0	237.5	1.24	50	38	12	3/8	GM ⁴	M	0.96	Poor recovery
237.5	240.0	1.36	30	60	10	3/8	SM-SW	M	1.12	Poor recovery
240.0	242.5	1.96	50	45	5	1/4	GW ⁵	N	2.26	Casing parted

¹Visual estimate by field geologist

²Visual estimate (N-none, W-weak, M-moderate, S-strong)

³GM-GW represents a poorly graded gravel with silt or with silt and clay

⁴GM represents a silty gravel with or without sand

⁵GW represents a well-graded gravel with or without gravel

Appendix B.4 Drill cuttings log data for UE-3bI-U1.

Borehole Depth Interval		Drill Rate (min/ft)	Composition ¹			Gravel Size (in) ¹	USCS Group Symbol ¹	10% HCl Reaction ²	Apparent Magnetic Susceptibility	Comments
from	to		Gravel	Sand	Silt					
(ft)										
10.0	12.5	0.24	30	55	15	1/2	SM	M-W	1.11	
12.5	15.0	0.16	20	65	15	3/4	SM	M-S	1.65	
15.0	17.5	0.28	20	65	15	3/4	SM	W	1.31	
17.5	20.0	0.52	15	70	15	3/4	SM	W-M	1.43	
20.0	22.5	0.24	5	83	12	1/4	SM	N	1.17	
22.5	25.0	0.24	5	83	12	1/4	SM	M	1.57	
25.0	27.5	0.32	10	78	12	1/4	SM	M	1.27	
27.5	30.0	0.36	10	78	12	1/4	SM	S	1.27	
30.0	32.5	0.36	10	78	15	1/4	SM	S	1.17	
32.5	35.0	0.28	10	75	15	3/4	SM	S	1.24	
35.0	37.5	0.36	20	68	12	3/4	SM	S	1.20	
37.5	40.0	0.32	20	68	12	3/4	SM	M	1.71	
40.0	42.5	0.36	15	73	12	3/4	SM	S	1.32	
42.5	45.0	0.48	10	78	12	1/4	SM	S	0.96	
45.0	47.5	0.48	10	78	12	1/4	SM	W	1.62	
47.5	50.0	0.48	20	68	12	1/4	SM	N	0.95	
50.0	52.5	0.44	0	85	15	-	SM	N	1.72	Fine sand

Appendix B.4 Drill cuttings log data for UE-3bl-U1 (Continued).

52.5	55.0	0.56	0	85	15	-	SM	N	1.08	Fine sand
55.0	57.5	0.32	20	68	12	%	SM	S	1.08	
57.5	60.0	0.36	40	75	10	%	SM-SW	M-S	0.95	
60.0	62.5	0.36	15	75	10	¼	SM-SW	M	0.98	
62.5	65.0	0.40	5	80	15	¼	SM	M	1.09	
65.0	67.5	0.36	5	80	15	¼	SM	S	1.27	
67.5	70.0	0.36	20	68	12	%	SM	S	1.12	
70.0	72.5	0.76	15	73	12	¼	SM	M	1.07	
72.5	75.0	0.56	0	85	15	-	SM	S	0.98	
75.0	77.5	0.56	25	65	10	%	SM-SW	W	0.91	
77.5	80.0	0.56	10	75	15	¼	SM	S	0.72	
80.0	82.5	0.40	5	83	12	¼	SM	S	0.84	Excessive cuttings
82.5	85.0	0.44	5	83	12	¼	SM	S	0.76	
85.0	87.5	1.30	5	83	12	¼	SM	S	0.92	
87.5	90.0	0.98	2	88	10	¼	SM-SP	S	1.07	
90.0	92.5	0.44	2	86	12	¼	SM	M	0.97	
92.5	95.0	0.48	2	86	12	¼	SM	W	0.97	Excessive cuttings
95.0	97.5	0.56	2	83	15	¼	SM	S	0.77	Excessive cuttings
97.5	100.0	0.52	2	86	12	¼	SM	S	1.07	Excessive cuttings
100.0	102.5	0.48	2	86	12	¼	SM	S	1.38	

Appendix B.4 Drill cuttings log data for UE-3b1-U1 (Continued).

102.5	105.0	0.64	2	86	12	¼	SM	W-M	0.77	
105.0	107.5	0.52	10	78	12	¾	SM	W	0.66	
107.5	110.0	0.48	5	83	12	¼	SM	S	0.97	
110.0	112.5	0.52	5	83	12	¼	SM	S	0.79	
112.5	115.0	0.68	2	86	12	¼	SM	S	0.94	
115.0	117.5	0.68	10	78	12	¼	SM	S	1.11	
117.5	120.0	0.68	0	88	12	-	SM	S	0.92	
120.0	122.5	0.48	10	80	10	¼	SM-SW	S	1.08	
122.5	125.0	0.49	10	80	10	¼	SM-SW	S	1.13	
125.0	127.5	0.48	20	70	10	¾	SM-SW	S	0.93	
127.5	130.0	0.50	20	70	10	¾	SM-SW	S	1.16	
130.0	132.5	0.48	20	72	8	¾	SM-SW	W-M	1.41	Poor recovery
132.5	135.0	0.44	15	77	8	¼	SM-SW	W-M	1.46	Poor recovery
135.0	137.5	0.52	20	70	10	¾	SM-SW	S	1.30	Poor recovery
137.5	140.0	0.52	20	75	5	¾	SM	W-N	1.22	Poor recovery
140.0	142.5	0.56	20	70	10	¾	SM-SW	M-S	1.73	
142.5	145.0	0.56	10	78	12	¼	SM	S	1.12	
145.0	147.5	0.72	5	83	12	¼	SM	S	1.18	
147.5	150.0	0.56	30	50	10	¾	SM-SW	S	1.18	
150.0	152.5	0.64	5	83	12	¼	SM	M-S	1.09	

Appendix B.4 Drill cuttings log data for UE-3bl-U1 (Continued).

152.5	155.0	0.64	5	83	12	¼	SM	S	1.07	
155.0	157.5	0.64	5	83	12	¼	SM	S	1.10	
157.5	160.0	0.72	5	83	12	¼	SM	M-S	1.34	
160.0	162.5	0.68	20	68	12	¾	SM	S-M	1.20	
162.5	165.0	0.76	0	85	15	-	SM	S	0.87	
165.0	167.5	0.72	5	83	12	¼	SM	S	1.43	
167.5	170.0	0.68	5	83	12	¼	SM	S	1.37	
170.0	172.5	0.64	5	83	12	¼	SM	S	1.24	
172.5	175.0	0.76	5	83	12	¼	SM	S	1.22	
175.0	177.5	0.72	5	85	10	¼	SM-SW	M	1.16	
177.5	180.0	0.56	5	85	10	¼	SM-SW	M	1.35	
180.0	182.5	0.88	10	85	5	¼	SW	W	1.54	
182.5	185.0	0.60	5	80	15	¼	SM	M	1.40	
185.0	187.5	0.60	5	80	15	¼	SM	S	0.89	
187.5	190.0	0.68	15	75	10	¾	SM-SW	S	1.95	Excessive cuttings
190.0	192.5	0.60	5	83	12	¼	SM	S	1.08	
192.5	195.0	0.56	5	83	12	¼	SM	S	1.35	
195.0	197.5	0.56	15	75	10	¾	SM-SW	M-S	1.92	
197.5	200.0	0.60	15	75	10	¾	SM-SW	M	1.19	
200.0	202.5	0.60	15	75	10	¾	SM-SW	W	1.41	Poor recovery

Appendix B.4 Drill cuttings log data for UE-3bl-U1 (Continued).

202.5	205.0	0.64	10	78	12	¼	SM	W	1.17	Poor recovery
205.0	207.5	0.76	0	88	12	-	SM	N	0.82	
207.5	210.0	0.68	0	88	12	-	SM-SP	N	1.69	Fine sand
210.0	212.5	0.80	20	70	10	¼	SM-SW	N	1.27	
212.5	215.0	0.68	50	40	10	¾	GM-GP ³	N	1.20	
215.0	217.5	0.76	15	73	12	¾	SM	W	1.35	
217.5	220.0	0.76	0	85	15	-	SM	W-N	1.31	
220.0	222.5	0.60	5	83	12	¼	SM	W-M	2.39	
222.5	225.0	0.84	5	83	12	¼	SM	S	1.16	
225.0	227.5	0.80	15	75	10	¾	SM-SW	S	1.81	
227.5	230.0	0.72	15	75	10	¾	SM-SW	M-S	1.63	
230.0	232.5	0.76	5	85	10	¼	SM-SP	W	1.48	
232.5	235.0	1.12	0	88	12	-	SM	S	1.06	Longer drill times
235.0	237.5	1.24	0	88	12	-	SM	S	1.19	Longer drill times
237.5	240.0	1.00	10	80	10	¼	SM-SP	N	0.98	Longer drill times
240.0	242.5	0.88	10	78	12	¼	SM	S	1.27	
242.5	245.0	0.84	25	65	10	¾	SM-SW	M	0.95	
245.0	247.5	1.44	5	90	5	¼	SP	M	1.12	Medium sand

¹Visual estimate by field geologist

²Visual estimate (N-none, W-weak, M-moderate, S-strong)

³GM-GP represents poorly graded gravel with silt or with silt and sand

U3ax/bl Exploratory Boreholes

Appendix C

Laboratory Testing Data of Geologic Samples

U3ax/bl Exploratory Boreholes

Appendix C Laboratory Testing Data of Geologic Samples

- C.1 Results of Laboratory Tests for Hydrogeologic Properties for Core Samples from UE-3bl-D1
- C.2 Results of Laboratory Tests for Physical and Pneumatic Properties for Core Samples from UE-3bl-D1
- C.3 Results of Laboratory Tests for Chemical Properties and Environmental Tracer Data for Core Samples from UE-3bl-D1
- C.4 Results of Gravimetric Water Content Measurements for Drill Cuttings Samples from UE-3bl-D1
- C.5 Results of Unenriched Tritium Analysis for Drill Cuttings and Core Samples from UE-3bl-D1
- C.6 Results of Laboratory Tests for Hydrogeologic Properties for Core Samples from UE-3bl-U1
- C.7 Results of Laboratory Tests for Physical and Pneumatic Properties for Core Samples from UE-3bl-U1
- C.8 Results of Laboratory Tests for Chemical Properties and Environmental Tracer Data for Core Samples from UE-3bl-U1
- C.9 Results of Gravimetric Water Content Measurements for Drill Cuttings Samples from UE-3bl-U1
- C.10 Moisture Retention Data for Core Samples from UE-3bl-D1
- C.11 Moisture Retention Data for Core Samples from UE-3bl-U1
- C.12 Parameters Required to Calculate Unsaturated Hydraulic Conductivities for Core Samples from the U3ax/bl Exploratory Boreholes
- C.13 Results of Unenriched Tritium Analysis for Core Samples from UE-3bl-U1

Appendix C.1 Results of laboratory tests for hydrologic properties for core samples from UE-3bl-D1.

Borehole Depth Interval				Saturated Hydraulic Conductivity (cm/s)	Water Content (percent)						Water Potential (bars)	Gravitational Potential (m) ¹	Total Hydraulic Potential (bars) ²
from		to			Gravimetric			Volumetric					
(m)	(ft)	(m)	(ft)		DBI	DR11	HGC	DBI	DR11	HGC			
6.32	6.40	20.75	21.00			6.8			9.8				
6.55	6.63	21.50	21.75		9.2			12.4		-48.2	-4.6	-48.6	
6.63	6.71	21.75	22.00	7.4			11.0						
9.14	9.22	30.00	30.25			3.8			5.6				
9.22	9.30	30.25	30.50		4.4			7.3		-51.0	-6.5	-51.6	
9.30	9.37	30.50	30.75	4.2			6.8						
12.42	12.50	40.75	41.00			9.1			13.2				
12.50	12.57	41.00	41.25	7.1			9.6						
12.73	12.80	41.75	42.00		7.8			10.7		-45.3	-8.9	-46.2	
15.32	15.39	50.25	50.50		8.6			12.3		-42.6	-10.7	-43.7	
15.39	15.47	50.50	50.75				11.5						
15.62	15.70	51.25	51.50	8.1									
18.59	18.67	61.00	61.25			7.5			10.8				
18.67	18.75	61.25	61.50	8.1		8.6			12.4				
21.56	21.64	70.75	71.00			7.1			10.3				
21.72	21.79	71.25	71.50		7.2			10.5		-31.5	-15.1	-33.0	
21.95	22.02	72.00	72.25	6.6			10.0						
24.69	24.77	81.00	81.25			8.1			11.8				
24.77	24.84	81.25	81.50	8.5			11.3						
24.99	25.07	82.00	82.25		7.2			10.7		-26.6	-17.3	-28.3	
30.79	30.86	101.00	101.25	9.1			11.8						
30.86	30.94	101.25	101.50			9.6			13.9				
33.76	33.83	110.75	111.00			11.2			16.2				
33.83	33.91	111.00	111.25	11.6			14.5						
34.06	34.14	111.75	112.00		9.1			12.3		-20.4	-23.5	-22.7	
36.88	36.96	121.00	121.25			5.5			7.9				
36.96	37.03	121.25	121.50		6.7			10.0		-21.1	-25.5	-23.6	
37.03	37.11	121.50	121.75	6.0			8.5						
39.78	39.85	130.50	130.75		6.7			9.8		-19.8	-27.4	-22.4	
39.85	39.93	130.75	131.00	6.4			9.1						
40.01	40.08	131.25	131.50			6.6			9.5				
42.82	42.90	140.50	140.75	7.8 ³			11.3						

Appendix C.1 Results of laboratory tests for hydrologic properties for core samples from UE-3bl-D1 (Continued).

Borehole Depth Interval			Saturated Hydraulic Conductivity (cm/s)	Water Content (percent)						Water Potential (bars)	Gravitational Potential (m) ¹	Total Hydraulic Potential (bars) ²
from	to	(ft)		Gravimetric			Volumetric					
(m)				DBI	DRII	HGC	DBI	DRII	HGC			
46.03	46.10	151.00	151.25	8.7 ³				12.6				
48.77	48.84	160.00	160.25	5.8 ³				8.4				
52.12	52.20	171.00	171.25	1.1e-03				10.9				
52.20	52.27	171.25	171.50									
52.27	52.35	171.50	171.75					7.9			11.4	
55.02	55.09	180.50	180.75		7.6			8.9			12.9	
55.09	55.17	180.75	181.00	1.3e-02								
55.47	55.55	182.00	182.25		11.2			14.3				
61.27	61.34	201.00	201.25		8.3			7.2			10.4	
61.34	61.42	201.25	201.50	7.6e-04	7.4			10.3				
61.57	61.65	202.00	202.25	1.6e-02	5.6			8.4				
64.16	64.24	210.50	210.75		9.0							
64.24	64.31	210.75	211.00		6.6							
64.54	64.62	211.75	212.00					6.5			9.4	
67.36	67.44	221.00	221.25		8.6			9.4			13.6	
67.44	67.51	221.25	221.50									
67.67	67.74	222.00	222.25	8.2e-05	8.8							
70.33	70.41	230.75	231.00	2.0e-02	6.5			14.1				
70.56	70.64	231.50	231.75					10.1				
70.64	70.71	231.75	232.00		11.1			9.5			13.8	
73.31	73.38	240.50	240.75		5.8							
73.46	73.53	241.00	241.25	2.5e-02	5.9			9.3				
73.69	73.76	241.75	242.00					5.0				

Vertical depth below ground surface.

¹ Vertical depth below ground surface

² Water potential and gravitational potential

³ Archived sample measured by REEC SPS

Appendix C.2 Results of laboratory tests for physical and pneumatic properties for core samples from UE-3bl-D1.

Borehole Depth Interval				Air Permeability (m ²)	Permeability Calculated (m ²)	Particle Size Distribution (percent passing)		USCS Group Name	Bulk Density (g/cm ³)		Particle Density (g/cm ³)	Porosity (percent)			
from (m)	to (m)	from to (ft)	No. 4			No. 200	DBI		DRII	DBI		DRII	Saturated		
6.40	6.48	21.00	21.25	3.9e-12	88.12	3.80	SW	1.48	1.35	2.54	41.9	47.0		37.2	
6.55	6.63	21.50	21.75												
6.63	6.71	21.75	22.00												
9.22	9.30	30.25	30.50												
9.30	9.37	30.50	30.75												
12.50	12.57	41.00	41.25			75.82	2.95	SW	1.64	1.66	2.57	36.3	34.8		29.2
12.73	12.80	41.75	42.00			90.88	6.87	SW-SM	1.35		2.58	47.7			35.4
15.32	15.39	50.25	50.50							1.37			46.2		
15.39	15.47	50.50	50.75							1.44			43.5		
18.67	18.75	61.25	61.50			92.69	6.66	SW-SM	1.42		2.50	43.3			40.9
21.72	21.79	71.25	71.50		95.47	34.81	SM	1.40		2.54	44.7			41.6	
21.95	22.02	72.00	72.25						1.46			42.7			
24.77	24.84	81.25	81.50		87.38	22.13	SM	1.52		2.56	40.7			40.3	
24.99	25.07	82.00	82.25		98.79	35.25	SM	1.32		2.52	47.4			46.9	
30.79	30.86	101.00	101.25						1.48			41.9			
33.83	33.91	111.00	111.25		77.86	6.92	SW-SM	1.30		2.51	48.1			46.6	
34.06	34.14	111.75	112.00		98.55	9.36	SW-SM	1.25		2.57	51.2			48.2	
36.96	37.03	121.25	121.50						1.35			47.0			
37.03	37.11	121.50	121.75		95.02	23.95	SM	1.41	1.51	2.55	44.7	40.7		41.0	
37.11	37.19	121.75	122.00	5.9e-13											
39.78	39.85	130.50	130.75												
39.85	39.93	130.75	131.00			97.71	14.40	SM	1.42	1.46			42.7		
52.12	52.20	171.00	171.25			86.30	9.24	SP-SM	1.40		2.53	43.9			44.4
											2.55	45.1			42.9

Appendix C.2 Results of laboratory tests for physical and pneumatic properties for core samples from UE-3bl-D1 (Continued).

Borehole Depth Interval			Air Permeability (m ²)	Permeability Calculated (m ²)	Particle Size Distribution (percent passing)		USCS Group Name	Bulk Density (g/cm ³)		Particle Density (g/cm ³)	Porosity (percent)	
from (m)	to (ft)	from (m)			No. 4	No. 200		DBI	DRJI		Calculated	Saturated DBI
52.27	52.35	171.50	171.75						1.51		40.7	
55.09	55.17	180.75	181.00	1.3e-11	90.65	29.58	SM	1.28		2.54	49.7	40.9
55.47	55.55	182.00	182.25						1.42		44.2	
61.34	61.42	201.25	201.50	7.8e-13	96.69	10.95	SW-SM	1.41		2.56	45.0	41.9
61.57	61.65	202.00	202.25						1.40		45.0	
64.16	64.24	210.50	210.75	1.6e-11	88.17	2.32	SP	1.48		2.54	41.6	40.9
64.24	64.31	210.75	211.00						1.49		41.5	
67.44	67.51	221.25	221.50						1.59		37.6	
67.51	67.59	221.50	221.75	1.1e-12								
67.67	67.74	222.00	222.25									
70.33	70.41	230.75	231.00	8.4e-14	92.31	22.71	SM	1.61		2.56	37.2	35.7
70.41	70.49	231.00	231.25	2.0e-11	77.74	5.01	SW-SM	1.55		2.60	40.3	34.1
70.64	70.71	231.75	232.00									
73.31	73.38	240.50	240.75								54.5	
73.46	73.53	241.00	241.25								31.3	
73.53	73.61	241.25	241.50	2.6e-11	51.56	1.83	SW	1.59		2.52	36.9	30.5
				1.1e-11								

Appendix C.3 Results of laboratory tests for chemical properties and environmental tracer data for core samples from UE-3bl-D1.

Borehole Depth Interval			Inorganic Carbon		Cation Exchange Capacity (meq/100g)	Chloride in dry soil (ppm)		Bromide in soil water (ppm)		Cl/Br Ratio	Stable Isotopes (per mil)	
from (m)	to (m)	from (ft)	percent	to		Chloride	Bromide	Chloride	Bromide		δD	$\delta^{18}O$
6.17	6.25	20.25		20.50							-92.0	-9.2
6.25	6.32	20.50	1.63	20.75	18.3							
6.32	6.40	20.75		21.00								
9.14	9.22	30.00		30.25		2.15	0.018	34	0.28	122		
12.27	12.34	40.25		40.50		5.22	0.037	141	1.00	141		
12.34	12.42	40.50	0.53	40.75	20.0						-94.0	-10.5
12.42	12.50	40.75		41.00								
15.62	15.70	51.25		51.50		3.50	0.037	42	0.45	94		
15.70	15.77	51.50	0.01	51.75	23.0	1.17	0.019	17	0.27	62		
18.36	18.44	60.25		60.50								
18.52	18.59	60.75	0.18	61.00	23.5						-100.0	-12.0
18.59	18.67	61.00		61.25								
21.41	21.49	70.25		70.50		1.18	0.018	15	0.23	64		
21.56	21.64	70.75		71.00								
21.64	21.72	71.00	0.72	71.25	17.2	0.95	0.019	14	0.28	51	-97.0	-11.6
24.46	24.54	80.25		80.50								
24.61	24.69	80.75	0.77	81.00	21.9						-106.0	-13.0
24.69	24.77	81.00		81.25								
30.48	30.56	100.00		100.25		1.10	0.022	15	0.29	50		
30.86	30.94	101.25		101.50								
30.94	31.01	101.50		101.75		1.06	0.022	12	0.26	47	-98.0	-12.2
33.68	33.76	110.50	0.63	110.75	21.9							
33.76	33.83	110.75	0.94	111.00	19.5							
36.65	36.73	120.25		120.50		1.13	0.020	11	0.20	56		
36.81	36.88	120.75	0.91	121.00	15.9						-111.0	-14.1
36.88	36.96	121.00		121.25								
39.93	40.01	131.00	0.24	131.25	16.2	0.61	0.011	12	0.21	57		
40.01	40.08	131.25		131.50								
42.90	42.98	140.75		141.00		0.91	0.016	15	0.26	56		
42.98	43.05	141.00	0.18	141.25	20.7						-112.0	-14.5
45.87	45.95	150.50		150.75								
45.95	46.03	150.75	0.74	151.00	20.5						-110.0	-14.4

Appendix C.3 Results of laboratory tests for chemical properties and environmental tracer data for core samples from UE-3bl-D1
(Continued).

Borehole Depth Interval			Inorganic Carbon		Cation Exchange Capacity (meq/100g)	Chloride		Bromide	Chloride		Bromide	Cl/Br Ratio	Stable Isotopes (per mil)	
from	to	from	to	(percent)		in dry soil (ppm)	in soil water (ppm)		in dry soil (ppm)	in soil water (ppm)			δD	$\delta^{18}O$
(m)		(ft)												
48.84	48.92	160.25	160.50										-110.0	-14.5
48.92	49.00	160.50	160.75	1.17	20.4									
51.97	52.05	170.50	170.75										-113.0	-14.8
52.05	52.12	170.75	171.00	1.06	19.3									
52.20	52.27	171.25	171.50											
55.02	55.09	180.50	180.75			0.76	10	0.016	10	0.22	48			
55.17	55.25	181.00	181.25	1.00	22.3	0.80	10	0.017	10	0.21	47			
55.40	55.47	181.75	182.00											
61.11	61.19	200.50	200.75										-115.0	-15.1
61.19	61.27	200.75	201.00										-115.0	-15.1
61.27	61.34	201.00	201.25	0.57	18.6									
64.08	64.16	210.25	210.50	0.39	17.4	0.70	10	0.014	10	0.21	49			
64.31	64.39	211.00	211.25	0.12	22.1									
64.54	64.62	211.75	212.00											
64.62	64.69	212.00	212.25			0.81	13	0.015	13	0.25	53			
67.29	67.36	220.75	221.00										-115.0	-15.3
67.36	67.44	221.00	221.25	0.57	20.9									
67.74	67.82	222.25	222.50			0.71	8	0.014	8	0.17	49			
70.26	70.33	230.50	230.75										-113.0	-14.5
70.56	70.64	231.50	231.75										-117.0	-15.5
70.71	70.79	232.00	232.25	1.00	29.4	0.69	8	0.010	8	0.12	67			
73.38	73.46	240.75	241.00											
73.69	73.76	241.75	242.00										-114.0	-15.5
73.76	73.84	242.00	242.25	0.03	15.8	0.53	11	0.007	11	0.15	75			

Appendix C.4

Results of gravimetric water content measurements for drill cuttings samples from the UE-3bl-D1.

Borehole Depth Interval				Gravimetric Water Content (percent)	Borehole Depth Interval				Gravimetric Water Content (percent)
from	to	from	to		from	to	from	to	
(m)	(ft)	(ft)	(ft)		(m)	(ft)	(ft)	(ft)	
3.0	3.8	10.0	12.5	3.3	38.9	39.6	127.5	130.0	5.3
3.8	4.6	12.5	15.0	3.3	39.6	40.4	130.0	132.5	5.8
4.6	5.3	15.0	17.5	4.3	40.4	41.1	132.5	135.0	7.0
5.3	6.1	17.5	20.0	3.7	41.1	41.9	135.0	137.5	7.6
6.1	6.9	20.0	22.5	5.7	41.9	42.7	137.5	140.0	6.5
6.9	7.6	22.5	25.0	6.1	42.7	43.4	140.0	142.5	5.8
7.6	8.4	25.0	27.5	7.0	43.4	44.2	142.5	145.0	6.4
8.4	9.1	27.5	30.0	6.5	44.2	45.0	145.0	147.5	5.4
9.1	9.9	30.0	32.5	3.6	45.0	45.7	147.5	150.0	5.1
9.9	10.7	32.5	35.0	4.1	45.7	46.5	150.0	152.5	5.8
10.7	11.4	35.0	37.5	3.4	46.5	47.2	152.5	155.0	5.0
11.4	12.2	37.5	40.0	3.1	47.2	48.0	155.0	157.5	6.0
12.2	13.0	40.0	42.5	5.6	48.0	48.8	157.5	160.0	5.6
13.0	13.7	42.5	45.0	6.4	48.8	49.5	160.0	162.5	5.8
13.7	14.5	45.0	47.5	4.5	49.5	50.3	162.5	165.0	5.6
14.5	15.2	47.5	50.0	4.6	50.3	51.1	165.0	167.5	6.6
15.2	16.0	50.0	52.5	5.3	51.1	51.8	167.5	170.0	5.2
16.0	16.8	52.5	55.0	6.7	51.8	52.6	170.0	172.5	6.4
16.8	17.5	55.0	57.5	4.5	52.6	53.3	172.5	175.0	7.2
17.5	18.3	57.5	60.0	4.2	53.3	54.1	175.0	177.5	5.4
18.3	19.1	60.0	62.5	6.0	54.1	54.9	177.5	180.0	6.2
19.1	19.8	62.5	65.0	5.1	54.9	55.6	180.0	182.5	5.3
19.8	20.6	65.0	67.5	4.5	55.6	56.4	182.5	185.0	5.7
20.6	21.3	67.5	70.0	4.5	56.4	57.2	185.0	187.5	6.6
21.3	22.1	70.0	72.5	4.3	57.2	57.9	187.5	190.0	4.9
22.1	22.9	72.5	75.0	5.1	57.9	58.7	190.0	192.5	7.2
22.9	23.6	75.0	77.5	4.3	58.7	59.4	192.5	195.0	6.2
23.6	24.4	77.5	80.0	5.4	59.4	60.2	195.0	197.5	4.2
24.4	25.1	80.0	82.5	4.6	60.2	61.0	197.5	200.0	4.5
25.1	25.9	82.5	85.0	6.5	61.0	61.7	200.0	202.5	5.6
25.9	26.7	85.0	87.5	5.6	61.7	62.5	202.5	205.0	5.2
26.7	27.4	87.5	90.0	5.2	62.5	63.2	205.0	207.5	4.8
27.4	28.2	90.0	92.5	5.1	63.2	64.0	207.5	210.0	5.7
28.2	29.0	92.5	95.0	5.6	64.0	64.8	210.0	212.5	5.1
29.0	29.7	95.0	97.5	4.2	64.8	65.5	212.5	215.0	4.4

Appendix C.4

Results of gravimetric water content measurements for drill cuttings samples from UE-3bl-D1 (Continued).

Borehole Depth Interval				Gravimetric Water Content (percent)	Borehole Depth Interval				Gravimetric Water Content (percent)
from	to	from	to		from	to	from	to	
(m)	(ft)				(m)	(ft)			
29.7	30.5	97.5	100.0	4.2	65.5	66.3	215.0	217.5	8.1
30.5	31.2	100.0	102.5	5.1	66.3	67.1	217.5	220.0	7.6
31.2	32.0	102.5	105.0	3.7	67.1	67.8	220.0	222.5	4.4
32.0	32.8	105.0	107.5	2.7	67.8	68.6	222.5	225.0	5.2
32.8	33.5	107.5	110.0	5.3	68.6	69.3	225.0	227.5	4.9
33.5	34.3	110.0	112.5	5.7	69.3	70.1	227.5	230.0	3.4
34.3	35.1	112.5	115.0	5.9	70.1	70.9	230.0	232.5	3.1
35.1	35.8	115.0	117.5	3.5	70.9	71.6	232.5	235.0	4.1
35.8	36.6	117.5	120.0	5.5	71.6	72.4	235.0	237.5	7.3
36.6	37.3	120.0	122.5	3.4	72.4	73.2	237.5	240.0	5.3
37.3	38.1	122.5	125.0	5.1	73.2	73.9	240.0	242.5	3.3
38.1	38.9	125.0	127.5	5.5					

Appendix C.5 Results of unenriched tritium analysis for drill cuttings and core samples from UE-3bl-D1.

Borehole Depth Interval for Drill Cuttings				Top of sample ¹				Middle of sample ¹			
from	to	from	to	(pCi/L)	(+/-)	Low	High	(pCi/L)	(+/-)	Low	High
(m)		(ft)									
3.8	4.6	12.5	15.0	3,570	172	3,398	3,742	3,446	175	3,271	3,621
18.3	19.1	60.0	62.5	760	176	584	936	895	196	699	1,091
45.7	46.5	150.0	152.5	3,060	280	2,780	3,340	3,310	190	3,120	3,500
73.2	73.9	240.0	242.5	6,470	303	6,167	6,773	9,240	291	8,949	9,531

¹ Subsamples removed from different locations in 3.8-L (1-gal) container

Borehole Depth Interval for Core Samples ¹					
from	to	from	to	(pCi/L)	(+/-)
(m)		(ft)			
6.1	6.2	20.0	20.25	1350	316
12.2	12.3	40.0	40.25	1020	245
18.3	18.4	60.0	60.25	471	323
30.5	30.6	100.0	100.25	3660	316
36.6	36.7	120.0	120.25	1810	310
42.7	42.8	140.25	140.50	2320	300
54.9	55.0	180.25	180.50	4330	293
61.0	61.1	200.25	200.50	7300	1400
67.0	67.1	220.0	220.25	5180	439
73.2	73.3	240.25	240.50	5480	616

¹ Samples were archive core segments that were analyzed after the tritium analyses for the drill cuttings showed concentrations above the detection limit of 350 pCi/L.

Appendix C.6 Results of laboratory tests for hydrologic properties for core samples from UE-3bl-U1.

Borehole Depth Interval			Saturated Hydraulic Conductivity (cm/s)	Water Content (percent)						Water Potential (bars)	Gravitational Potential (m) ¹	Total Hydraulic Potential (bars) ²
				Gravimetric			Volumetric					
from (m)	to (m)	to (ft)		DBI	DR11	HGC	DBI	DR11	HGC			
4.04	4.11	13.25	13.50	5.4			8.0					
4.11	4.19	13.50	13.75		6.6					-61.6	-2.9	-61.9
4.19	4.27	13.75	14.00			7.1		9.6	10.6			
6.40	6.48	21.00	21.25	4.6			6.9					
6.48	6.55	21.25	21.50			8.8			13.1	-52.4	-4.7	-52.9
6.71	6.78	22.00	22.25		10.7			14.4		-60.2	-6.5	-60.8
9.30	9.37	30.50	30.75		5.2			7.7				
9.37	9.45	30.75	31.00	5.3			7.6					
9.60	9.68	31.50	31.75			4.4			6.5			
12.34	12.42	40.50	40.75	4.1			7.2					
12.42	12.50	40.75	41.00		5.4							
12.65	12.73	41.50	41.75			10.2		9.1	15.3	-45.4	-8.6	-46.2
15.47	15.54	50.75	51.00		9.4			12.7		-40.5	-10.7	-41.5
15.54	15.62	51.00	51.25			8.4			12.6			
15.62	15.70	51.25	51.50	8.4			11.9		11.7			
18.59	18.67	61.00	61.25			7.8						
18.67	18.75	61.25	61.50	6.6			10.1					
18.90	18.97	62.00	62.25		7.8			12.5		-34.9	-13.0	-36.2
24.61	24.69	80.75	81.00	7.7			10.8			-27.3	-16.9	-29.0
24.69	24.77	81.00	81.25		7.2			9.7	10.0			
24.77	24.84	81.25	81.50			6.7						
27.66	27.74	90.75	91.00	7.8			11.2					
27.74	27.81	91.00	91.25		8.4			12.6	13.9	-21.8	-19.0	-23.7
27.81	27.89	91.25	91.50			9.3						
30.79	30.86	101.00	101.25	4.2			6.9		5.9			
30.86	30.94	101.25	101.50			4.0						
30.94	31.01	101.50	101.75		3.6			6.1		-23.2	-21.1	-25.3
33.68	33.76	110.50	110.75		5.6			7.9		-19.8	-22.9	-22.0
33.76	33.83	110.75	111.00	5.4			7.4					
33.99	34.06	111.50	111.75			5.2			7.7			
39.93	40.01	131.00	131.25	5.5			8.4					
40.01	40.08	131.25	131.50			4.9			7.4			

Appendix C.6 Results of laboratory tests for hydrologic properties for core samples from UE-3b1-U1 (Continued).

Borehole Depth Interval				Saturated Hydraulic Conductivity (cm/s)	Water Content (percent)						Water Potential (bars)	Gravitational Potential (m) ¹	Total Hydraulic Potential (bars) ²
from to		from to (ft)	Gravimetric			Volumetric							
(m)			DBI		DRII	HGC	DBI	DRII	HGC				
40.23	40.31	132.00	132.25		4.6			7.1		-21.8	-27.2	-24.5	
43.13	43.21	141.50	141.75						6.7				
43.21	43.28	141.75	142.00							-21.8	-29.2	-24.7	
43.28	43.36	142.00	142.25	7.4e-04	4.7			7.2					
46.03	46.10	151.00	151.25		9.3				12.4	-14.3	-31.0	-17.3	
46.10	46.18	151.25	151.50					8.3					
46.33	46.41	152.00	152.25	1.1e-03	8.8			12.6					
49.15	49.23	161.25	161.50										
49.38	49.45	162.00	162.25		11.3				10.4	-14.3	-33.1	-17.5	
49.45	49.53	162.25	162.50	4.7e-03	9.2			11.4					
55.02	55.09	180.50	180.75		4.5 ³			6.7					
57.91	57.99	190.00	190.25		6.0 ³			8.9					
61.27	61.34	201.00	201.25		8.4				13.6	-13.6	-40.7	-17.6	
61.34	61.42	201.25	201.50					10.6					
61.57	61.65	202.00	202.25	1.3e-04	9.1			13.3					
64.24	64.31	210.75	211.00		5.8				9.4	-12.9	-42.6	-17.1	
64.31	64.39	211.00	211.25	1.4e-03	7.5			10.2					
64.54	64.62	211.75	212.00										
67.36	67.44	221.00	221.25			5.6			8.4				
67.59	67.67	221.75	222.00	1.6e-03	5.6			8.3	10.0				
67.67	67.74	222.00	222.25		6.0					-12.2	-44.7	-16.6	
70.41	70.49	231.00	231.25			5.9			8.8				
70.49	70.56	231.25	231.50		6.8					-11.6	-46.5	-16.1	
70.71	70.79	232.00	232.25	2.6e-04	9.2			13.7					
75.74	75.82	248.50	248.75							-9.5	-49.8	-14.4	
75.97	76.05	249.25	249.50		5.5				8.3				
76.05	76.12	249.50	249.75	3.4e-03	4.8			5.4	8.0				

¹ Vertical depth below ground surface

² Water potential and gravitational potential

³ Archived sample measured by REECo SPS

Appendix C.7 Results of laboratory tests for physical and pneumatic properties for core samples from UE-3bl-U1.

Borehole Depth Interval				Air Permeability (m ²)	Permeability Calculated (m ²)	Particle Size Distribution (percent passing)		USCS Group Name	Bulk Density (g/cm ³)		Particle Density (g/cm ³)	Porosity (percent)		
from	to	from	to			No. 4	No. 200		DBI	DRII		DBI	DRII	Calculated
(ft)														
(m)														
4.04	4.11	13.25	13.50		6.30e-12	58.29	2.63	SW	1.46		2.55	42.6		34.0
4.11	4.19	13.50	13.75							1.46			42.2	
6.40	6.48	21.00	21.25		1.90e-11	75.13	3.82	SW	1.49		2.50	40.4		34.1
6.71	6.78	22.00	22.25							1.35			46.5	
9.30	9.37	30.50	30.75							1.48			41.4	
9.37	9.45	30.75	31.00											
12.34	12.42	40.50	40.75		2.60e-13	96.21	14.39	SM	1.44		2.52	43.0		42.2
12.42	12.50	40.75	41.00		7.0e-12	59.42	2.95	SW	1.75		2.56	31.7		29.3
15.47	15.54	50.75	51.00							1.69			33.1	
15.62	15.70	51.25	51.50							1.35			46.5	
18.67	18.75	61.25	61.50		7.30e-13	91.57	12.00	SW-SM	1.41		2.57	45.0		41.9
18.90	18.97	62.00	62.25		9.50e-12	53.03	1.88	SW	1.52		2.56	40.6		33.8
24.61	24.69	80.75	81.00		1.20e-13	97.79	14.20	SM	1.41	1.60	2.58	45.5	36.6	44.1
24.69	24.77	81.00	81.25							1.36			46.1	
27.66	27.74	90.75	91.00		3.40e-12	94.85	2.58	SW	1.44		2.51	42.8		41.3
27.74	27.81	91.00	91.25							1.50			40.6	
30.79	30.86	101.00	101.25		1.0e-12	74.78	5.03	SW-SM	1.66		2.53	34.2		31.9
30.94	31.01	101.50	101.75							1.68			33.5	
33.68	33.76	110.50	110.75							1.41			44.2	
33.76	33.83	110.75	111.00		1.20e-12	95.80	6.01	SW-SM	1.38		2.45	43.7		42.4
39.93	40.01	131.00	131.25		3.50e-12	77.11	3.10	SW	1.52		2.55	40.4		37.3
40.23	40.31	132.00	132.25							1.53			39.4	
43.21	43.28	141.75	142.00							1.56			38.2	

Appendix C.7 Results of laboratory tests for physical and pneumatic properties for core samples from UE-3bl-U1 (Continued).

Borehole Depth Interval			Air Permeability (m ²)	Permeability Calculated (m ²)	Particle Size Distribution (percent passing)		Bulk Density (g/cm ³)		Particle Density (g/cm ³)	Porosity (percent)	
from (m)	to (ft)	from (m)			No. 4	No. 200	DBI	DRII		Calculated	Saturated
43.28	43.36	142.00	142.25	7.60e-13	94.15	7.36	SW-SM	1.54	2.53	39.2	36.5
46.03	46.10	151.00	151.25					1.53		39.4	
46.33	46.41	152.00	152.25	1.10e-12	88.30	6.64	SW-SM	1.44	2.55	43.7	40.3
49.38	49.45	162.00	162.25					1.27		49.7	
49.45	49.53	162.25	162.50	4.80e-12	92.06	13.26	SM	1.25	2.48	49.7	40.9
61.27	61.34	201.00	201.25					1.62		35.8	
61.57	61.65	202.00	202.25	1.30e-13	69.98	6.43	SW-SM	1.47	2.44	39.8	36.1
64.24	64.31	210.75	211.00					1.61		36.2	
64.31	64.39	211.00	211.25	1.40e-12	79.28	14.51	SM	1.35	2.54	46.8	38.7
67.59	67.67	221.75	222.00	1.60e-12	95.37	7.27	SP	1.49	2.51	40.5	38.4
67.67	67.74	222.00	222.25					1.68		33.5	
70.49	70.56	231.25	231.50					1.52		39.8	
70.71	70.79	232.00	232.25	2.70e-13	95.30	13.55	SM	1.48	2.51	41.1	38.6
75.74	75.82	248.50	248.75					1.52		39.8	
76.05	76.12	249.50	249.75	3.50e-12	97.60	5.81	SW-SM	1.45	2.54	42.9	38.8

(Continued).

-111 -13.7

Appendix C.9

Results of gravimetric water content measurements for drill cuttings samples from the UE-3bl-U1.

Borehole Depth Interval				Gravimetric Water Content (percent)	Borehole Depth Interval				Gravimetric Water Content (percent)
from	to	from	to		from	to	from	to	
(m)		(ft)			(m)		(ft)		
3.0	3.8	10.0	12.5	2.9	39.6	40.4	130.0	132.5	3.0
3.8	4.6	12.5	15.0	3.7	40.4	41.1	132.5	135.0	4.8
4.6	5.3	15.0	17.5	4.7	41.1	41.9	135.0	137.5	5.4
5.3	6.1	17.5	20.0	3.2	41.9	42.7	137.5	140.0	4.2
6.1	6.9	20.0	22.5	4.5	42.7	43.4	140.0	142.5	5.2
6.9	7.6	22.5	25.0	3.8	43.4	44.2	142.5	145.0	5.5
7.6	8.4	25.0	27.5	5.2	44.2	45.0	145.0	147.5	4.8
8.4	9.1	27.5	30.0	5.8	45.0	45.7	147.5	150.0	4.3
9.1	9.9	30.0	32.5	3.9	45.7	46.5	150.0	152.5	5.2
9.9	10.7	32.5	35.0	3.7	46.5	47.2	152.5	155.0	5.8
10.7	11.4	35.0	37.5	3.8	47.2	48.0	155.0	157.5	4.9
11.4	12.2	37.5	40.0	3.4	48.0	48.8	157.5	160.0	5.8
12.2	13.0	40.0	42.5	5.1	48.8	49.5	160.0	162.5	5.6
13.0	13.7	42.5	45.0	5.3	49.5	50.3	162.5	165.0	4.4
13.7	14.5	45.0	47.5	5.0	50.3	51.1	165.0	167.5	7.9
14.5	15.2	47.5	50.0	4.7	51.1	51.8	167.5	170.0	5.1
15.2	16.0	50.0	52.5	7.1	51.8	52.6	170.0	172.5	5.1
16.0	16.8	52.5	55.0	4.9	52.6	53.3	172.5	175.0	6.9
16.8	17.5	55.0	57.5	5.2	53.3	54.1	175.0	177.5	4.3
17.5	18.3	57.5	60.0	5.3	54.1	54.9	177.5	180.0	3.7
18.3	19.1	60.0	62.5	5.1	54.9	55.6	180.0	182.5	4.6
19.1	19.8	62.5	65.0	5.5	55.6	56.4	182.5	185.0	4.9
19.8	20.6	65.0	67.5	3.8	56.4	57.2	185.0	187.5	4.7
20.6	21.3	67.5	70.0	5.0	57.2	57.9	187.5	190.0	4.8
21.3	22.1	70.0	72.5	4.3	57.9	58.7	190.0	192.5	4.8
22.1	22.9	72.5	75.0	5.1	58.7	59.4	192.5	195.0	5.2
22.9	23.6	75.0	77.5	4.1	59.4	60.2	195.0	197.5	4.3
23.6	24.4	77.5	80.0	7.2	60.2	61.0	197.5	200.0	4.6
24.4	25.1	80.0	82.5	5.8	61.0	61.7	200.0	202.5	7.0
25.1	25.9	82.5	85.0	4.7	61.7	62.5	202.5	205.0	6.4
25.9	26.7	85.0	87.5	5.8	62.5	63.2	205.0	207.5	10.2
26.7	27.4	87.5	90.0	5.7	63.2	64.0	207.5	210.0	3.8
27.4	28.2	90.0	92.5	4.9	64.0	64.8	210.0	212.5	7.6
28.2	29.0	92.5	95.0	6.2	64.8	65.5	212.5	215.0	5.0
29.0	29.7	95.0	97.5	7.2	65.5	66.3	215.0	217.5	5.4

Appendix C.9

Results of gravimetric water content measurements for drill cuttings samples from UE-3bl-U1 (Continued).

Borehole Depth Interval				Gravimetric Water Content (percent)	Borehole Depth Interval				Gravimetric Water Content (percent)
from	to	from	to		from	to	from	to	
(m)	(ft)	(m)	(ft)		(m)	(ft)	(m)	(ft)	
29.7	30.5	97.5	100.0	4.2	66.3	67.1	217.5	220.0	4.5
30.5	31.2	100.0	102.5	3.6	67.1	67.8	220.0	222.5	4.0
31.2	32.0	102.5	105.0	5.0	67.8	68.6	222.5	225.0	5.7
32.0	32.8	105.0	107.5	5.0	68.6	69.3	225.0	227.5	5.4
32.8	33.5	107.5	110.0	4.1	69.3	70.1	227.5	230.0	5.1
33.5	34.3	110.0	112.5	6.1	70.1	70.9	230.0	232.5	7.5
34.3	35.1	112.5	115.0	5.3	70.9	71.6	232.5	235.0	5.4
35.1	35.8	115.0	117.5	5.8	71.6	72.4	235.0	237.5	3.9
35.8	36.6	117.5	120.0	4.6	72.4	73.2	237.5	240.0	7.7
36.6	37.3	120.0	122.5	5.2	73.2	73.9	240.0	242.5	5.7
37.3	38.1	122.5	125.0	5.7	73.9	74.7	242.5	245.0	5.0
38.1	38.9	125.0	127.5	4.8	74.7	75.4	245.0	247.5	5.3
38.9	39.6	127.5	130.0	4.6					

Appendix C.10 Moisture retention data for core samples from UE-3bl-D1.

Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)	Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)	Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)
21	12.5	-17.10	81	11.4	-18.80	181	10.1	-22.50
	14.3	-3.70		15.3	-3.30		14.3	-4.90
	17.7	-1.00		19.1	-1.00		18.9	-1.00
	18.4	-0.50		20.6	-0.50		20.6	-0.50
	23.3	-0.10		36.4	-0.10		26.4	-0.10
	25.9	-0.06		39.9	-0.06		37.3	-0.05
	29.9	-0.02		44.4	-0.02		38.5	-0.03
	37.2	0.00		46.9	0.00		40.9	0.00
31	7.6	-17.34	101	11.0	-26.00	201	8.5	-21.10
	8.7	-3.07		13.2	-3.80		10.8	-4.60
	13.0	-1.00		18.9	-0.98		13.6	-1.00
	14.3	-0.50		20.5	-0.50		14.2	-0.50
	17.4	-0.10		25.4	-0.11		22.2	-0.10
	25.5	-0.05		32.9	-0.05		30.8	-0.06
	26.9	-0.03		41.3	-0.02		40.1	-0.02
	29.2	0.00		46.6	0.00		41.9	0.00
41	10.6	-18.24	111	14.2	-15.93	211	7.8	-18.19
	12.7	-3.61		17.2	-3.93		9.1	-2.57
	17.4	-1.00		22.5	-0.98		13.0	-0.98
	19.2	-0.50		23.7	-0.50		13.6	-0.50
	25.3	-0.10		31.8	-0.10		16.4	-0.10
	32.7	-0.05		36.6	-0.05		18.1	-0.05
	34.0	-0.03		46.4	-0.01		35.8	-0.01
	35.4	0.00		48.2	0.00		40.9	0.00
51	12.5	-15.30	122	7.7	-16.50	222	10.3	-19.80
	14.2	-3.20		10.0	-3.60		12.9	-3.00
	19.6	-1.00		14.0	-0.98		16.7	-0.98
	20.7	-0.50		16.6	-0.50		19.1	-0.50
	25.0	-0.10		30.1	-0.11		26.9	-0.11
	30.5	-0.06		36.4	-0.05		31.3	-0.05
	34.3	-0.02		38.9	-0.02		34.0	-0.02
	40.9	0.00		41.0	0.00		35.7	0.00
61	12.5	-16.10	131	8.7	-16.70	231	8.8	-16.20
	15.7	-3.40		10.1	-3.70		10.4	-2.80
	20.4	-1.00		15.1	-0.98		15.3	-0.98
	21.7	-0.50		16.5	-0.50		16.6	-0.50
	29.3	-0.10		27.5	-0.10		18.0	-0.11
	32.7	-0.06		36.3	-0.05		20.1	-0.05
	36.3	-0.02		41.6	-0.01		24.6	-0.02
	41.6	0.00		44.4	0.00		34.1	0.00
72	10.9	-17.40	171	10.0	-15.20	241	8.3	-17.80
	12.8	-4.70		11.3	-3.10		9.2	-2.70
	17.7	-1.00		15.0	-0.98		13.7	-1.00
	20.0	-0.50		16.4	-0.50		14.9	-0.50
	31.7	-0.10		22.6	-0.11		16.5	-0.10
	39.3	-0.05		29.2	-0.05		26.3	-0.05
	40.0	-0.03		38.0	-0.02		28.1	-0.03
	40.3	0.00		42.9	0.00		30.5	0.00

Appendix C.11 Moisture retention data for core samples from UE-3b1-U1.

Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)	Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)	Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)	Borehole Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)
13	2.4	-1509.00	81	3.8	-1550.00	152	3.8	-1460.00	250	0.7	-2305.00
	9.7	-15.20		10.7	-20.50		10.8	-16.50		5.3	-16.10
	11.4	-5.60		16.3	-2.50		12.5	-4.90		6.6	-4.20
	17.2	-0.30		31.1	-0.30		20.0	-0.30		13.1	-0.31
	19.2	-0.10		33.1	-0.10		25.8	-0.10		13.5	-0.15
	21.1	-0.05		40.5	-0.05		34.1	-0.05		19.0	-0.05
	22.6	-0.03		42.2	-0.03		35.8	-0.03		35.7	-0.02
	34.0	0.00		44.1	0.00		40.3	0.00		38.8	0.00
21	1.8	-601.00	91	4.4	-1128.00	162	1.5	-1544.00			
	7.9	-18.00		10.1	-18.60		9.3	-16.50			
	8.6	-5.50		13.3	-3.10		13.0	-3.60			
	15.0	-0.30		19.9	-0.30		20.7	-0.30			
	16.9	-0.10		22.9	-0.10		27.3	-0.10			
	19.3	-0.05		27.0	-0.05		34.0	-0.05			
	22.4	-0.03		28.4	-0.03		36.5	-0.03			
	34.1	0.00		41.3	0.00		40.9	0.00			
31	2.9	-1391.00	101	0.5	-2128.00	202	1.1	-1600.00			
	8.0	-26.00		6.7	-20.00		10.1	-24.70			
	11.7	-3.80		9.2	-3.40		13.6	-5.20			
	19.8	-0.30		12.9	-0.31		21.6	-0.31			
	28.6	-0.10		14.8	-0.15		23.7	-0.15			
	37.2	-0.05		20.4	-0.05		27.6	-0.05			
	40.3	-0.03		28.1	-0.02		31.5	-0.02			
	42.2	0.00		31.9	0.00		36.1	0.00			
41	0.9	-1914.00	111	1.9	-1928.00	211	0.8	-1937.00			
	7.8	-21.00		7.2	-15.60		8.1	-22.60			
	10.0	-4.00		10.7	-3.10		9.3	-3.60			
	15.2	-0.30		18.5	-0.30		19.7	-0.30			
	17.1	-0.10		20.2	-0.10		26.0	-0.10			
	19.5	-0.05		29.2	-0.05		32.0	-0.05			
	21.7	-0.03		37.0	-0.03		36.2	-0.03			
	29.3	0.00		42.4	0.00		38.7	0.00			
51	3.3	-1579.00	131	2.8	-1477.00	222	0.6	-2243.00			
	12.1	-16.60		7.3	-23.00		6.7	-21.20			
	15.5	-3.00		9.1	-3.60		8.0	-3.60			
	23.9	-0.31		14.9	-0.31		14.7	-0.30			
	27.1	-0.15		15.7	-0.15		19.5	-0.10			
	32.2	-0.05		21.5	-0.05		29.0	-0.05			
	36.9	-0.02		31.3	-0.02		36.6	-0.03			
	41.9	0.00		37.3	0.00		38.4	0.00			
61	3.7	-1152.00	142	0.6	-1611.00	232	0.8	-1346.00			
	10.1	-23.70		7.4	-16.00		10.5	-17.50			
	11.9	-3.90		9.7	-4.40		13.0	-5.30			
	17.9	-0.30		15.1	-0.30		21.9	-0.30			
	19.6	-0.10		19.8	-0.10		27.4	-0.10			
	21.4	-0.05		22.5	-0.05		33.2	-0.05			
	21.4	-0.03		22.6	-0.03		36.4	-0.03			
	33.8	0.00		36.5	0.00		38.6	0.00			

Appendix C.12

Parameters required to calculate unsaturated hydraulic conductivity for core samples from the U3ax/bl Exploratory Boreholes.

UE-3bl-D1					UE-3bl-U1				
Borehole Sample Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Residual Volumetric Water Content (percent) θ_r	α (cm ⁻¹)	n^1	Borehole Sample Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Residual Volumetric Water Content (percent) θ_r	α (cm ⁻¹)	n^1
22	1.0e-03	7.4	0.137	1.23	13	6.2e-03	2.4	0.504	1.15
31	1.2e-02	6.4	0.026	1.45	21	1.9e-02	1.8	0.413	1.18
41	4.0e-04	8.6	0.017	1.43	31	2.5e-04	2.9	0.019	1.44
51	9.9e-04	4.9	0.096	1.22	41	6.9e-03	0.9	0.182	1.17
61	1.0e-04	1.5	0.067	1.19	51	7.2e-04	3.3	0.061	1.19
72	1.1e-04	10.5	0.009	1.68	61	9.3e-03	3.7	0.776	1.13
81	1.1e-04	10.2	0.015	1.54	81	1.2e-04	3.8	0.016	1.25
101	4.4e-03	9.9	0.046	1.43	91	3.3e-03	4.4	0.293	1.17
111	9.2e-04	9.9	0.049	1.31	101	1.0e-03	0.5	0.048	1.49
122	4.0e-04	6.8	0.012	1.64	111	1.2e-03	1.9	0.053	1.34
131	4.8e-04	7.4	0.023	1.55	131	3.4e-03	2.8	0.073	1.38
171	1.1e-03	10.0	0.036	1.61	142	7.4e-04	0.6	0.328	1.19
181	1.3e-02	8.8	0.023	1.41	152	1.1e-03	3.8	0.035	1.29
201	7.6e-04	10.1	0.023	1.90	162	4.7e-03	1.5	0.039	1.25
211	1.6e-02	7.9	0.079	1.78	202	1.3e-04	1.1	0.057	1.19
222	8.2e-05	7.6	0.018	1.40	211	1.4e-03	0.8	0.029	1.30
231	2.0e-02	0.0	0.457	1.15	222	1.6e-03	0.6	0.026	1.56
241	2.5e-02	8.2	0.030	1.54	232	2.6e-04	0.8	0.031	1.23
					250	3.4e-03	0.7	0.045	1.61

¹n Dimensionless curve-fitting parameter

Appendix C.13 Results of unenriched tritium analysis for core samples from UE-3bl-U1.

Borehole Depth Interval for Core Samples ¹					
from	to	from	to		
(m)		(ft)		(pCi/L)	(+/-)
3.9	4.0	12.75	13.00	849	245
6.2	6.3	20.25	20.50	745	470
12.2	12.3	40.00	40.25	420	458
18.4	18.5	60.25	60.50	<350	
27.5	27.6	90.25	90.50	<350	
33.5	33.6	110.00	110.25	<350	
39.6	39.7	130.00	130.25	<350	
48.8	48.9	160.00	160.25	459	462
61.0	61.1	200.25	200.50	417	430
70.1	70.2	230.00	230.25	<350	

¹ Samples were archive core segments that were analyzed after the tritium analyses for the drill cuttings from UE-3bl-D1 showed concentrations above the detection limit of 350 pCi/L.

U3ax/bl Exploratory Boreholes

Appendix D

Gyroscopic Survey Data

U3ax/bl Exploratory Boreholes

Appendix D Directional Survey Data

- D.1 Gyroscopic Directional Survey by Minimum Curvature for UE-3bl-D1 on August 23, 1994
- D.1 Gyroscopic Directional Survey by Minimum Curvature for UE-3bl-U1 on August 23, 1994

Appendix D.1 Gyroscopic directional survey by minimum curvature for UE-3bl-D1 on August 23, 1994.

Borehole Depth (ft)	Vertical Depth (ft)	Vertical Sect. (ft)	L/R		Bearing Azimuth (degrees)	Coordinates		D-leg /100	D-leg /CL	Station Displacement (ft)	Displacement Direction (degrees)
			Clos. (degrees)	Inclination (degrees)		Latitude (degrees)	Longitude (degrees)				
0.0	0.00	0.00	0.000	-44.80	26.00	0.00	N 0.00	E 0.00		0.00	at 0.00
10.0	7.05	7.10	-0.076	-44.79	25.78	6.38	N 3.10	E 1.56	0.16	7.05	at 25.89
20.0	14.06	14.22	-0.160	-44.37	25.86	12.80	N 6.20	E 4.24	0.42	14.06	at 25.85
30.0	21.03	21.39	-0.263	-43.97	25.49	19.26	N 9.31	E 4.78	0.48	21.03	at 25.79
40.0	27.96	28.60	-0.391	-43.80	25.48	25.77	N 12.41	E 1.70	0.17	27.96	at 25.72
50.0	34.88	35.82	-0.520	-43.66	25.47	32.29	N 15.52	E 1.40	0.14	34.88	at 25.67
60.0	41.76	43.07	-0.636	-43.40	25.71	38.83	N 18.65	E 3.11	0.31	41.76	at 25.65
70.0	48.62	50.35	-0.730	-43.16	25.81	45.39	N 21.81	E 2.52	0.25	48.62	at 25.67
80.0	55.45	57.65	-0.816	-43.00	25.84	51.96	N 24.99	E 1.61	0.16	55.45	at 25.69
90.0	62.26	64.97	-0.883	-42.86	26.11	58.54	N 28.20	E 2.47	0.25	62.26	at 25.72
100.0	69.06	72.31	-0.926	-42.74	26.21	65.13	N 31.44	E 1.39	0.14	69.06	at 25.77
110.0	75.85	79.65	-0.956	-42.83	26.33	71.71	N 34.68	E 1.24	0.12	75.85	at 25.81
120.0	82.65	86.98	-0.970	-42.84	26.44	78.28	N 37.94	E 0.87	0.09	82.65	at 25.86
130.0	89.43	94.34	-0.969	-42.53	26.57	84.86	N 41.22	E 3.23	0.32	89.43	at 25.91
140.0	96.18	101.71	-0.956	-42.39	26.67	91.45	N 44.53	E 1.58	0.16	96.18	at 25.96
150.0	102.91	109.11	-0.912	-42.19	26.99	98.05	N 47.87	E 3.11	0.31	102.91	at 26.02
160.0	109.62	116.52	-0.837	-42.09	27.15	104.66	N 51.24	E 1.57	0.16	109.62	at 26.09
170.0	116.31	123.95	-0.747	-41.98	27.24	111.26	N 54.64	E 1.28	0.13	116.31	at 26.15
180.0	122.97	131.41	-0.652	-41.53	27.21	117.90	N 58.05	E 4.50	0.45	122.97	at 26.22
190.0	129.57	138.92	-0.551	-41.06	27.32	124.57	N 61.49	E 4.77	0.48	129.57	at 26.27
200.0	136.12	146.48	-0.437	-40.71	27.40	131.29	N 64.97	E 3.55	0.35	136.12	at 26.33
210.0	142.61	154.09	-0.308	-40.24	27.55	138.04	N 68.48	E 4.84	0.48	142.61	at 26.39
220.0	149.05	161.74	-0.172	-39.93	27.48	144.82	N 72.01	E 3.16	0.32	149.05	at 26.44
230.0	155.42	169.44	-0.066	-39.29	27.10	151.67	N 75.54	E 7.02	0.70	155.42	at 26.48
240.0	161.75	177.19	0.006	-39.19	26.97	158.57	N 79.07	E 1.45	0.14	161.75	at 26.50

Borehole Depth (ft)	Vertical Depth (ft)	Vertical Sect. (ft)	L/R		Bearing Azimuth (degrees)	Coordinates		D-leg /100	D-leg /CL	Station Displacement (ft)	Displacement Direction (degrees)			
			Clos.	Inclination (degrees)		Latitude (degrees)	Longitude (degrees)							
0.0	0.00	0.00	0.000	-44.47	205.69	0.00	N	0.00	E	0.00	at	0.00		
10.0	6.96	7.18	-0.019	-43.81	205.78	6.46	N	3.12	E	6.63	0.66	7.18	at	205.74
20.0	13.88	14.40	-0.022	-43.63	205.94	12.97	N	6.27	E	2.14	0.21	14.40	at	205.80
30.0	20.77	21.65	-0.019	-43.56	205.89	19.48	N	9.43	E	0.81	0.08	21.65	at	205.84
40.0	27.64	28.91	-0.016	-43.27	205.93	26.02	N	12.61	E	2.92	0.29	28.91	at	205.86
50.0	34.48	36.21	-0.005	-42.96	206.03	32.58	N	15.81	E	3.17	0.32	36.21	at	205.88
60.0	41.28	43.54	0.008	-42.74	205.96	39.17	N	19.02	E	2.26	0.23	43.54	at	205.90
70.0	48.05	50.90	0.015	-42.47	205.94	45.79	N	22.24	E	2.70	0.27	50.90	at	205.91
80.0	54.79	58.29	0.023	-42.32	205.96	52.43	N	25.47	E	1.51	0.15	58.29	at	205.91
90.0	61.51	65.69	0.039	-42.10	206.05	59.08	N	28.72	E	2.30	0.23	65.69	at	205.92
100.0	68.20	73.12	0.062	-41.90	206.09	65.76	N	31.99	E	2.01	0.20	73.12	at	205.94
110.0	74.86	80.58	0.089	-41.67	206.10	72.45	N	35.27	E	2.30	0.23	80.58	at	205.95
120.0	81.48	88.08	0.109	-41.11	205.99	79.20	N	38.56	E	5.67	0.57	88.08	at	205.96
130.0	88.01	95.66	0.114	-40.42	205.86	86.01	N	41.87	E	6.97	0.70	95.66	at	205.96
140.0	94.47	103.28	0.111	-40.19	205.88	92.87	N	45.20	E	2.30	0.23	103.28	at	205.95
150.0	100.91	110.93	0.104	-40.00	205.80	99.75	N	48.53	E	1.99	0.20	110.93	at	205.94
160.0	107.34	118.60	0.100	-39.94	205.93	106.65	N	51.88	E	1.15	0.12	118.60	at	205.94
170.0	113.75	126.27	0.103	-39.81	205.88	113.55	N	55.23	E	1.35	0.13	126.27	at	205.94
180.0	120.14	133.96	0.106	-39.70	205.95	120.47	N	58.59	E	1.21	0.12	133.96	at	205.94
190.0	126.52	141.66	0.121	-39.52	206.05	127.39	N	61.97	E	1.95	0.19	141.66	at	205.94
200.0	132.86	149.39	0.128	-39.21	205.85	134.34	N	65.35	E	3.46	0.35	149.39	at	205.94
210.0	139.16	157.16	0.112	-38.85	205.69	141.34	N	68.72	E	3.79	0.38	157.16	at	205.93
220.0	145.42	164.96	0.069	-38.72	205.46	148.37	N	72.09	E	2.25	0.23	164.96	at	205.91
230.0	151.68	172.76	0.010	-38.71	205.45	155.42	N	75.44	E	0.13	0.01	172.76	at	205.89

Distribution List

Copies

U. S. Department of Energy

Jhon Carilli
Waste Management Division
U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
P.O. Box 98518, M/S 505
Las Vegas, NV 89193-8518

2

B. M. Crowe
Apogen Technologies
U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
P.O. Box 98518, M/S 505
Las Vegas, NV 89193-8518

1

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Technical Library
P.O. Box 98518, M/S 505
Las Vegas, NV 89193-8518

1 (uncontrolled)

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Public Reading Facility
c/o Nuclear Testing Archive
P.O. Box 98518, M/S 400
Las Vegas, NV 89193-8518

2 (electronic, uncontrolled)

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, Tennessee 37831-0062

1 (electronic, uncontrolled)

Bechtel Nevada

Max Dolenc
Bechtel Nevada
P.O. Box 98521, M/S NSF080
Las Vegas, NV 89193-8521

1

Distribution List (continued)

	<u>Copies</u>
Environmental Management Library Bechtel Nevada P.O. Box 98521, M/S NLV094 Las Vegas, NV 89193-8521	1
Steve Nacht Bechtel Nevada P.O. Box 98521, M/S NSF083 Las Vegas, NV 89193-8521	1
Stuart Rawlinson Bechtel Nevada P.O. Box 98521, M/S NTS416 Las Vegas, NV 89193-8521	1
Dan Tobiason Bechtel Nevada P.O. Box 98521, M/S NTS416 Las Vegas, NV 89193-8521	1