DOE/NV--1448

Nevada
Environmental
Restoration
Project

Completion Report for Well ER-EC-13

Corrective Action Units 101 and 102: Central and Western Pahute Mesa

May 2011

Environmental Restoration Project

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

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Corrective Action Units 101 and 102: Central and Western Pahute Mesa

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

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Las Vegas, NV

May 2011

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Completion Report for Well ER-EC-13

Corrective Action Units 101 and 102: Central and Western Pahute Mesa

Approved by: ______________________ Date: 5/10/2011

Bill R. Wilborn
Federal Sub-Project Director
Underground Test Area Project

Approved by: ______________________ Date: 5/11/11

Robert F. Boehlecke
Federal Project Director
Environmental Restoration Project

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Abstract

Well ER-EC-13 was drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, in support of the Nevada Environmental Restoration Project at the Nevada National Security Site (formerly Nevada Test Site), Nye County, Nevada. The well was drilled in October 2010 as part of the Pahute Mesa Phase II drilling program. A main objective was to provide detailed hydrogeologic information for the Fortymile Canyon composite unit hydrostratigraphic unit in the Timber Mountain moat area, within the Timber Mountain caldera complex, that will help address uncertainties within the Pahute Mesa–Oasis Valley hydrostratigraphic framework model. This well may also be used as a long-term monitoring well.

The main 52.1-centimeter (cm) hole was drilled to a depth of 335.0 meters (m) and cased with 40.6-cm casing to 330.9 m. The hole diameter was then decreased to 37.5 cm, and drilling continued to a total depth of 914.4 m. The completion casing string, set to the depth of 806.1 m, consists of 19.4-cm carbon-steel casing, which telescopes down with two different stainless-steel casing diameters: an upper 16.8-cm stainless-steel casing and a lower 14.0-cm stainless-steel casing. The stainless-steel casing has two slotted intervals open to a rhyolite lava within the Beatty Wash Formation.

Three piezometer strings were installed in Well ER-EC-13. All three piezometer strings, each with one slotted interval, consist of 6.0-cm carbon-steel tubing at the surface, then cross over to 7.3-cm stainless-steel tubing just above the water table. The shallow piezometer string was inserted inside the 40.6-cm casing for access to the water table, and landed at the depth of 333.5 m. The intermediate piezometer string was inserted within the 37.5-cm borehole for access to a lava-flow aquifer within the Beatty Wash Formation, and landed at the depth of 640.0 m. The deep piezometer string was also inserted within the 37.5-cm borehole for access to a lower portion of lava-flow aquifer within the Beatty Wash Formation, and landed at the depth of 832.7 m.

Data collected during and shortly after hole construction include composite drill cuttings samples collected every 3.0 m, 29 percussion gun and rotary sidewall core samples, various geophysical logs, fluid samples (for groundwater chemistry analysis and tritium measurements), and water-level measurements. The well penetrated 908.3 m of Tertiary volcanic rock, including two lava-flow aquifers.

The fluid level measured after the total depth was reached was 308.5 m when measured in the shallow piezometer string on October 25, 2010. On November 5, 2010, the fluid level in the shallow piezometer string was measured at the depth of 308.0 m.

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List of Acronyms and Abbreviations

BN	Bechtel Nevada
CAIP	Corrective Action Investigation Plan
CAU	Corrective Action Unit
cm	centimeter(s)
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
EPA	U.S. Environmental Protection Agency
FAWP	Field Activity Work Package
FCCM	Fortymile Canyon composite unit
FFACO	Federal Facility Agreement and Consent Order
FMP	Fluid Management Plan
ft	foot (feet)
gpm	gallon(s) per minute
HFM	hydrostratigraphic framework model
HSU	hydrostratigraphic unit
HWDP	Hevi-Wate drill pipe
id	inside diameter
in.	inch(es)
km	kilometer(s)
LANL	Los Alamos National Laboratory
LFA	lava-flow aquifer
LLNL	Lawrence Livermore National Laboratory
Lpm	liter(s) per minute
m	meter(s)
mi	mile(s)
m^3	cubic meter(s)
Ma	million years ago
MDC	minimum detectable concentration
mg/L	milligram(s) per liter
NAD	North American Datum
N-I	Navarro-Intera, LLC
NAIL	nuclear annular investigation log
NARA	National Archives and Records Administration

List of Acronyms and Abbreviations (continued)

NNES	Navarro Nevada Environmental Services, LLC
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSA/NV	U.S. Department of Energy, National Nuclear Security Administration Nevada Operation Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
PM–OV	Pahute Mesa–Oasis Valley
pCi/L	picocurie(s) per liter
RCT	radiological control technician
SNJV	Stoller-Navarro Joint Venture
TD	total depth
TMCC	Timber Mountain caldera complex
TWG	Technical Working Group
UGTA	Underground Test Area
UGT	underground nuclear test
UDI	United Drilling, Incorporated
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
yd^3	cubic yard(s)

1.0 Introduction

1.1 Project Description

Well ER-EC-13 was drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) in support of the Nevada Environmental Restoration Project at the Nevada National Security Site (NNSS; formerly Nevada Test Site), Nye County, Nevada. Well ER-EC-13 was the seventh well drilled as part of the Underground Test Area (UGTA) Sub-Project Phase II hydrogeologic investigation well-drilling program in the southwestern Pahute Mesa area of Nye County, Nevada. It was the third well of the second drilling campaign of the Phase II drilling program, and was constructed in the fall of 2010.

The Pahute Mesa Phase II drilling program is part of the Corrective Action Investigation Plan (CAIP) for the Central and Western Pahute Mesa Corrective Action Units (CAUs) 101 and 102, respectively (NNSA/NSO, 2009a). The CAIP is a requirement of the *Federal Facility Agreement and Consent Order* (FFACO, 1996, as amended March 2010).

The Central and Western Pahute Mesa CAUs and the associated well drilling program are part of the NNSA/NSO Environmental Restoration Project's UGTA Sub-Project at the NNSS. Two goals of the UGTA Sub-Project are to evaluate the nature and extent of contamination in groundwater due to underground nuclear testing, and to establish a long-term groundwater monitoring network. As part of the UGTA Sub-Project, scientists are developing computer models to predict groundwater flow and contaminant migration within and near the NNSS. To build and test these models, it is necessary to collect geologic, geophysical, and hydrologic data from new and existing wells to define groundwater quality, migration pathways, and migration rates. Data from these wells will allow for more accurate modeling of groundwater flow and radionuclide migration in the region. Some of the wells may be used as long-term monitoring wells.

Well ER-EC-13 is located on the Nevada Test and Training Range, approximately 6.4 kilometers (km) (4 mile [mi]) southwest of the Area 20 underground test area (Figure 1-1). The primary purpose of this well was to provide detailed hydrogeologic information for the Fortymile Canyon composite unit (FCCM) hydrostratigraphic unit (HSU) in the northwestern portion of the Timber Mountain moat area (Figure 1-2). Detailed hydrogeologic information about the Tertiary volcanic section obtained from this well may help address uncertainties within

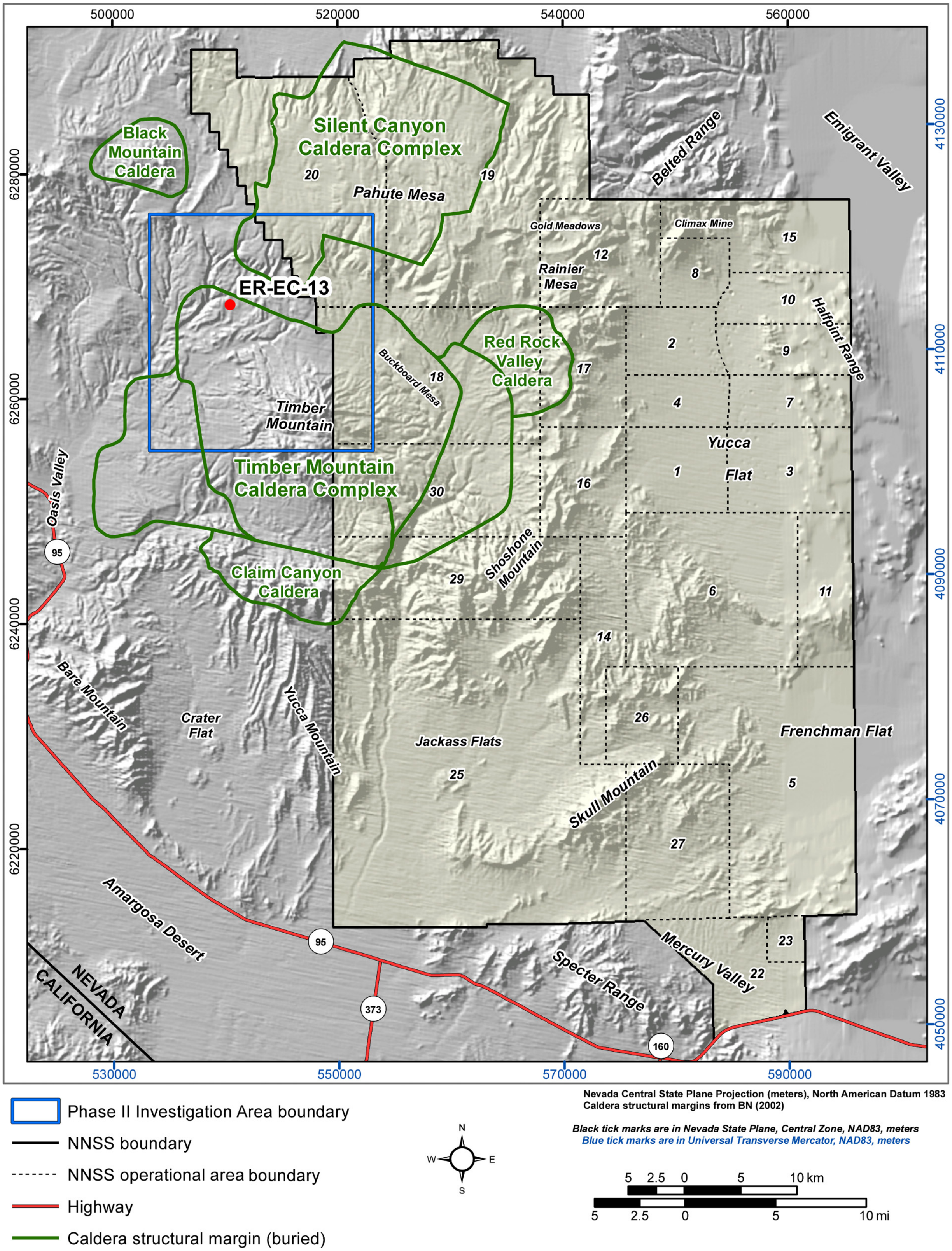


Figure 1-1
Reference Map Showing Location of Well ER-EC-13

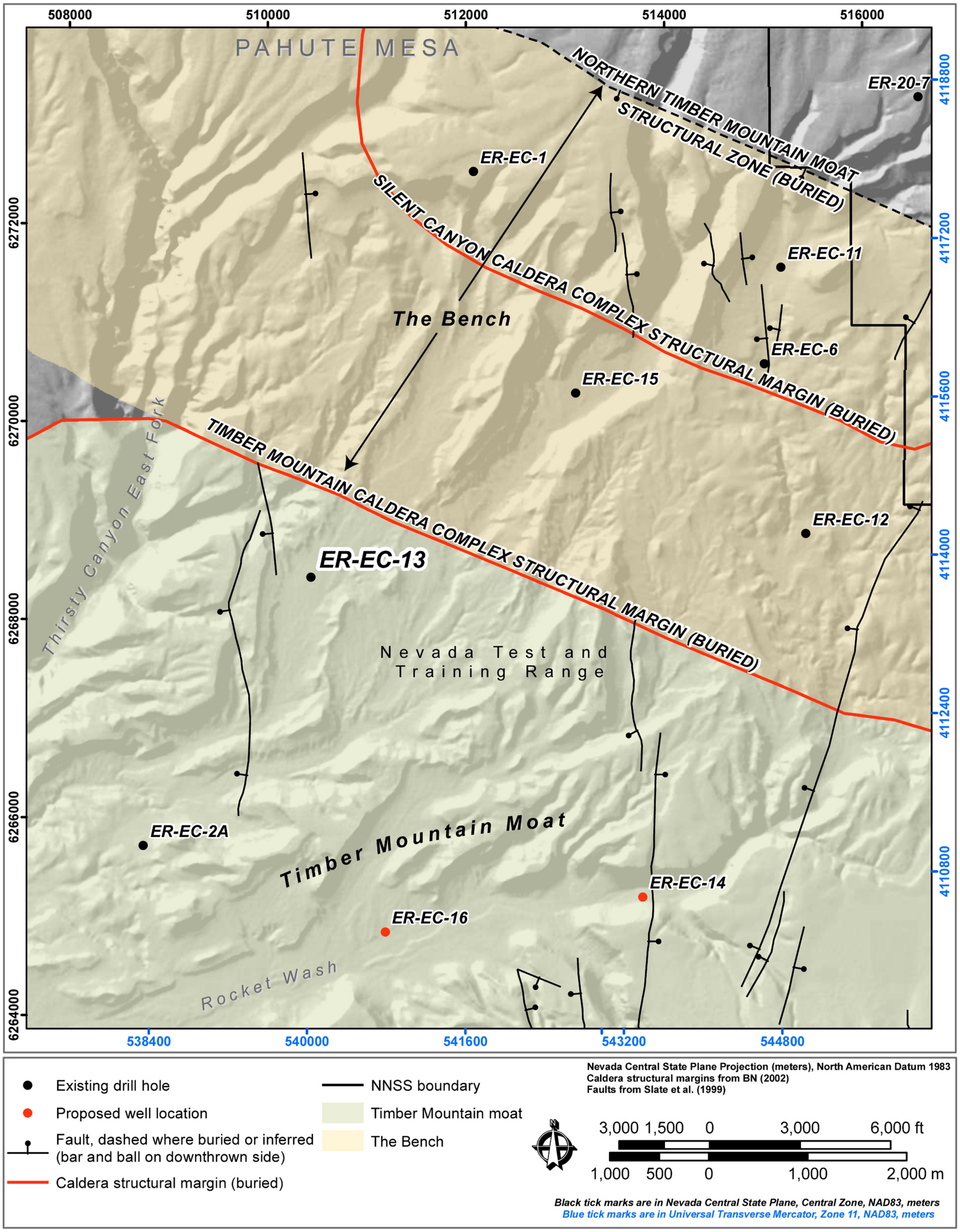


Figure 1-2
Shaded Relief Map of the Well ER-EC-13 Area Showing Location of the Timber Mountain Moat

the Pahute Mesa–Oasis Valley (PM–OV) hydrostratigraphic framework model (HFM) (Bechtel Nevada [BN], 2002) and subsequent flow and transport modeling (Stoller-Navarro Joint Venture [SNJV], 2009a).

1.2 Project Organization

The construction of Well ER-EC-13 was intended to help fulfill the goals of the UGTA Sub-Project. Several groups function within the sub-project, whose responsibilities include ensuring that the sub-project goals are properly planned and achieved. The roles of these groups regarding successful construction of Well ER-EC-13 are described in this section.

The UGTA Technical Working Group (TWG) is a committee of scientists and engineers from NNSA/NSO, Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), the Nevada Division of Environmental Protection, the Desert Research Institute (DRI), the U.S. Geological Survey (USGS), National Security Technologies, LLC (NSTec; NNSS management and operating contractor), and Navarro-Intera, LLC (N-I; NNSS environmental contractor, formerly Navarro Nevada Environmental Services, LLC [NNES]). The TWG has responsibility for providing technical advice and recommendations to the UGTA Sub-Project Manager to promote the effective closure of CAUs on the NNSS and ensure the continuing protection of the public health. The TWG's Pahute Mesa CAU Guidance Team and the TWG CAIP subcommittee assisted NNSA/NSO in developing the CAIP for the Pahute Mesa CAUs. The TWG's Well ER-EC-13 Drilling Advisory Team, which included the NNSA/NSO UGTA Sub-Project Manager, the N-I field manager, the NSTec UGTA manager/drilling engineer, a hydrologist, a geologist, and a radio-chemist, provided technical advice during drilling, design, and construction of the well, to ensure that Well ER-EC-13 was constructed to meet scientific objectives identified in the CAIP and the drilling criteria. See *Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2009a) and *Addendum to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (NNES, 2010a) for descriptions of the general plan and goals of the Pahute Mesa Phase II drilling initiative project, as well as specific goals for each well.

N-I was the principal environmental contractor for the project, and N-I personnel collected geologic and hydrologic data during drilling. Site supervision, engineering, construction, inspection, and geologic support were provided by NSTec. The drilling company was United Drilling, Inc. (UDI), a subcontractor to NSTec. The roles and responsibilities of these and other contractors involved in the project are described in NSTec subcontract number 107553 and in field activity work package (FAWP) numbers D-003-001.10 and D-009-001.10 (NSTec, 2010a; 2010b).

General guidelines for managing fluids used and generated during drilling, completion, and testing of UGTA wells are provided in the UGTA Fluid Management Plan (FMP) (NNSA/NSO, 2009b). Estimates of expected production of fluid and drill cuttings for the Pahute Mesa holes are given in Appendix O of the drilling and completion criteria document for the drilling project (SNJV, 2009a), along with sampling requirements and contingency plans for management of any hazardous waste produced. All activities were conducted according to specific FAWPs (e.g., NSTec, 2010a and 2010b; NNES, 2010b) and the UGTA Project Health and Safety Plan (NSTec, 2008).

This report presents construction data and summarizes scientific data gathered during the drilling of Well ER-EC-13. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. A well data report prepared by N-I contains additional information on fluid management, waste management, and environmental compliance for the project (N-I, 2011). Hydrogeologic information for this area is presented in the data documentation package for the PM–OV HFM prepared by BN (2002). Documentation for Phase I flow and transport modeling, which guided this Phase II data collection activity, can be found in (SNJV, 2006, 2007, and 2009b). Pre-drilling geologic information for this area (including any changes in the geologic interpretation since production of the PM–OV HFM [BN, 2002]) is compiled in the addendum to the Phase II drilling criteria document (NNES, 2010a). Information on well development, aquifer testing, and groundwater analytical sampling (which are outside the scope of this report) are typically compiled and disseminated separately.

1.3 Location and Significant Nearby Features

Well ER-EC-13 is located south of Pahute Mesa on the Nevada Test and Training Range at an elevation of 1,577.4 meters (m) (5,175.1 feet [ft]). Wells drilled as part of the Phase I drilling program include Well ER-EC-2A (U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office [NNSA/NV], 2002), which is located approximately 3.2 km (2.0 mi) to the southwest, Well ER-EC-1 (U.S. Department of Energy, Nevada Operations Office [DOE/NV], 2000a), which is located about 4.3 km (2.7 mi) to the north-northeast, and Well ER-EC-6 (DOE/NV, 2000b), which is located about 5.0 km (3.1 mi) to the northeast of Well ER-EC-13. Wells drilled as part of the Phase II drilling program in 2009/2010 include Well ER-EC-15 (NNSA/NSO, 2011a), which is located approximately 3.2 km (2.0 mi) to the northeast, Well ER-EC-12 (NNSA/NSO, 2011b), which is located about 5.0 km (3.1 mi) to the east, and Well ER-EC-11 (NNSA/NSO, 2010), which is located approximately 5.6 km (3.5 mi) to the northeast. The locations of these wells and features in relation to Well ER-EC-13 are shown in Figure 1-3. Additional information about Well ER-EC-13 is provided in Table 1-1.

The Well ER-EC-13 site is located in an area known as the Timber Mountain moat structural domain, a structural region defined as the area between the Bench to the north and the Timber Mountain caldera resurgent dome to the southeast (Figure 1-2). The well site is located within one of several drainages, between Thirsty Canyon East Fork and Rocket Wash, the two major drainages from Pahute Mesa (Figure 1-3). Surface drainage at the well site is to the southwest.

The underground nuclear tests (UGTs) closest to and generally up-gradient from Well ER-EC-13 are TYBO (U-20y) and BELMONT (U-20as). The TYBO test was conducted below the regional water table (DOE/NV, 1997). Well ER-EC-13 is located 8.7 km (5.4 mi) south-southwest of the TYBO test location (Figure 1-3), and 9.5 km (5.9 mi) south-southwest of the BELMONT test location. Additional information for these and other nearby tests is provided in Table 1-2.

1.4 Objectives

The primary purpose for Well ER-EC-13 is to provide detailed hydrogeologic information for the FCCM in the Timber Mountain moat area. An important secondary objective is to obtain information that will help characterize the hydrogeology of the Timber Mountain caldera complex (TMCC) structural margin and its effects on groundwater flow (NNSA/NSO, 2009a). Well ER-EC-13 is expected to produce data that will improve flow and transport modeling for CAUs 101 and 102. The Well ER-EC-13 location may be a favorable location for a long-term monitoring well.

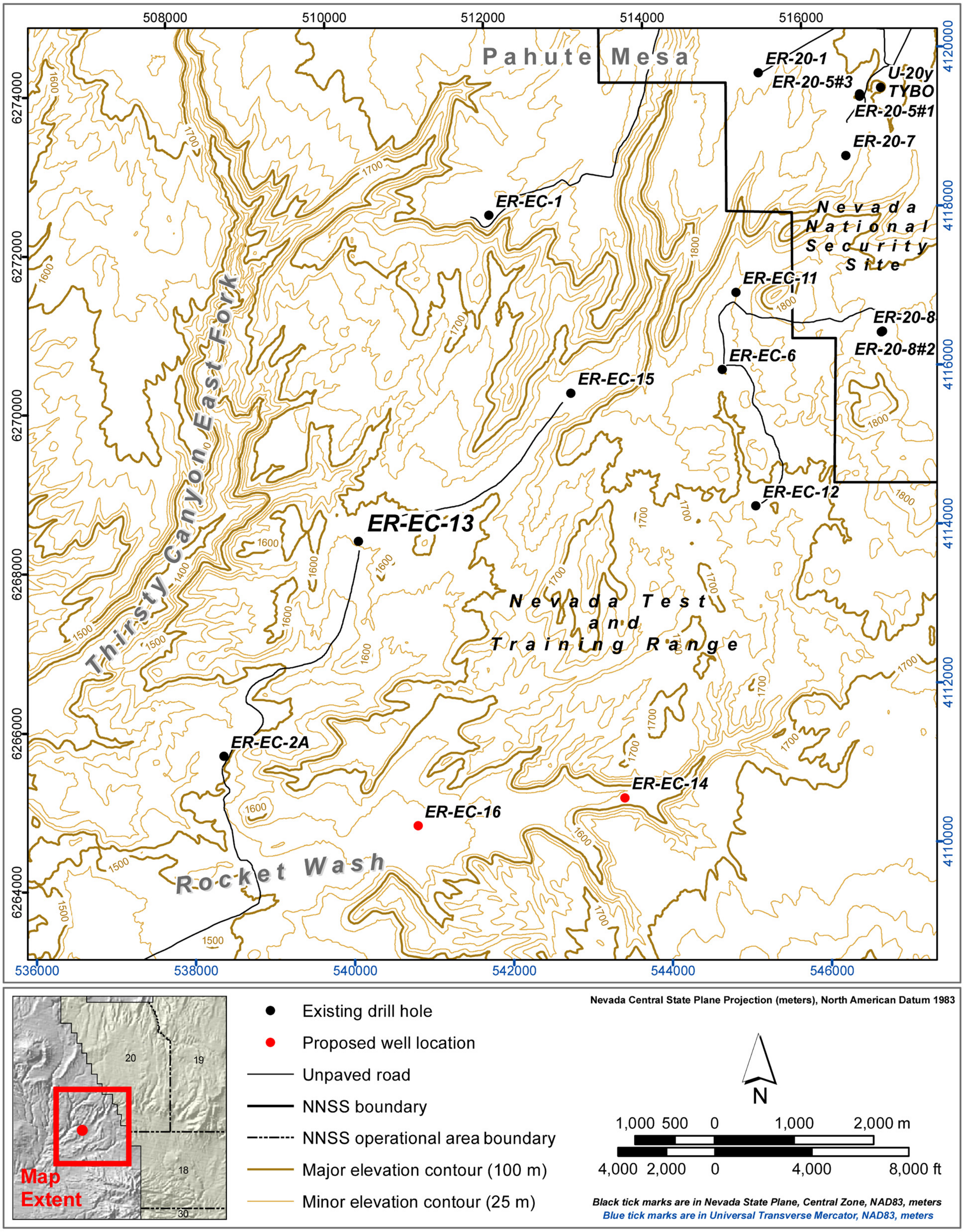


Figure 1-3
Topographic Map of the Well ER-EC-13 Area Showing the Locations of Roads and Nearby Drill Holes

Table 1-1
Well ER-EC-13 Site Data Summary

Site Coordinates [a]	**Nevada State Plane (Central Zone) (NAD 27)** N 880,647.9 ft E 534,487.2 ft **Nevada State Plane (Central Zone) (NAD 83)** N 6,268,422.5 m E 510,432.1 m **UTM (Zone 11) (NAD 83)** N 4,113,750.2 m E 540,021.9 m **UTM (Zone 11) (NAD 27)** N 4,113,553.2 m E 540,102.2 m **Geographic (NAD 83)** (degrees, minutes, seconds) 37° 10' 10" / 116° 32' 57" **Township and Range** [b] Southwest¼ of Northwest ¼ of Section 7 Township 9 South, Range 49 East
Surface Elevation [c]	1,577.4 m (5,175.1 ft)
Drilled Depth	914.4 m (3,000 ft)
Fluid-Level Depth [d]	308.0 m (1,010.6 ft)
Fluid-Level Elevation	1,269.3 m (4,164.5 ft)
Surface Geology	young alluvial deposits

a Measurements made by NSTec Survey using NAD 27 Nevada State Plane coordinates in feet. All other coordinates listed were calculated from NAD 27 feet using Corpscon (U.S. Army Corps of Engineers, 2004). NAD = North American Datum (National Archives and Records Administration [NARA], 1989; U.S. Coast and Geodetic Survey, 1927). UTM = Universal Transverse Mercator.

b Quarter and quarter/quarter section values visually estimated, using data from Public Land Survey System (Bureau of Land Management Cadastral Survey, 2006).

c Measurement made by NSTec Survey. Elevation above mean sea level at top of construction pad. National Geodetic Vertical Datum, 1929 (NARA, 1973).

d Measured in the shallow piezometer string by N-I on November 5, 2010.

Table 1-2
Information for Underground Nuclear Tests Relevant to Well ER-EC-13

Emplacement Hole Name	Test Name [a]	Test Date [a]	Surface Elevation [b] meters (feet)	Working Point		Regional Water Level		Announced Yield [a] (kilotons)	Working Point Formation [c, d]	Working Point HSU [c, e]
				Depth [b] meters (feet)	Elevation meters (feet)	Depth [b] meters (feet)	Elevation meters (feet)			
U-20y	TYBO	05/14/1975	1,907 (6,257)	765 (2,510)	1,142 (3,747)	630 (2,067)	1,277 (4,190)	200–1,000	Tpt	TSA
U-20as	BELMONT	10/16/1986	1,898 (6,227)	605 (1,985)	1,293 (4,242)	614 (2,014)	1,284 (4,213)	20–150	Tpb(b)	UPCU
U-20ag	MOLBO	02/12/1982	1,900 (6,234)	638 (2,093)	1,262 (4,141)	619 (2,031)	1,281 (4,203)	20–150	Tbp	BA
U-20c	BENHAM	12/19/1968	1,914 (6,281)	1,402 (4,600)	512 (1,681)	639 (2,096)	1,275 (4,185)	1,150	Th	CHZCM

a DOE/NV (2000c)
b NNSA/NSO (2009a)
c BN (2002)

d Stratigraphic nomenclature:
- **Tpt** = Topopah Spring Tuff
- **Tpb(b)** = rhyolite of Benham, bedded
- **Tpb** = rhyolite of Benham
- **Th** = Calico Hills Formation

e HSU = hydrostratigraphic unit
Hydrostratigraphic nomenclature:
- **TSA** = Topopah Spring aquifer
- **UPCU** = upper Paintbrush confining unit
- **BA** = Benham aquifer
- **CHZCM** = Calico Hills zeolitic composite unit

The objectives for Well ER-EC-13, as described in Appendix E of the addendum to the drilling and completion criteria (NNES, 2010a), are listed below, along with well-specific activities necessary to accomplish the objectives:

1. Characterize the hydrogeology of the Timber Mountain moat to help reduce uncertainties within this area of the PM–OV HFM. In particular, data from the well are expected to aid in accomplishing the following specific goals:
   - Provide detailed hydrogeologic information for the shallow- to moderate-depth Tertiary volcanic section, focusing on the volcanic units that constitute the FCCM.
   - Ascertain whether or not lava-flow aquifers (LFAs) (as indicated by an aeromagnetic anomaly) are associated with the TMCC caldera structural margin.
2. Obtain hydraulic properties such as detailed fracture data and hydrologic information for the FCCM to improve subsequent flow and transport modeling for the area generally down-gradient of the former test areas in western Pahute Mesa (SNJV, 2009b).

The following activities are necessary to accomplish these goals:

- Collect drill cuttings and other geologic samples for geologic evaluation and for detailed mineralogic analysis. The mineralogic data will help define the vertical distribution of reactive minerals such as clays, zeolites, and iron oxides in the Tertiary volcanic section.
- Obtain geophysical log data from the borehole, including image logs for fracture identification and other logs for lithologic and stratigraphic identification and interpretation of rock properties.
- Collect aqueous geochemistry samples for analysis to determine whether tritium and other radionuclides have migrated to the well location. These analyses will also make it possible to better define possible groundwater flow paths based on water chemistry.
- Obtain detailed water-level data to determine the regional water level.

Additional data that will help characterize the hydrology in southwestern Pahute Mesa will be obtained during later hydraulic testing at this well. Specific criteria for these later tests will be provided in future documents (e.g., FAWPs and a well development and testing plan), but ultimately, Well ER-EC-13 is expected to provide data for determination of horizontal and vertical conductivity and hydraulic properties of saturated hydrogeologic units penetrated.

The completed well will accommodate single-well hydraulic testing. This well could also be a potential observation well for multiple-well aquifer tests.

1.5 Project Summary

This section summarizes Well ER-EC-13 construction operations; the details are provided in Sections 2.0 through 7.0 of this report.

A 106.7-centimeter (cm) (42-inch [in.]) diameter conductor hole was constructed by drilling to the depth of 22.6 m (74 ft), and installing a string of 76.2-cm (30-in.) conductor casing to the depth of 21.9 m (72 ft). Drilling of the main hole with a 20½-in. tricone bit, using an air-foam/polymer fluid in conventional circulation, began on October 2, 2010, and continued to the depth of 335.0 m (1,099 ft), reached on October 8, 2010. A string of 16-in. surface casing was set to 330.9 m (1,085.6 ft), then a 37.5-cm (14.75-in.) hole was drilled to the total depth (TD) of 914.4 m (3,000 ft) which was reached on October 18, 2010.

The well was completed with 5½-in. stainless-steel casing suspended from 6⅝-in. stainless-steel casing. The stainless-steel portion of the completion string is suspended from 7⅝-in. internally epoxy-coated carbon-steel casing (which ends 8.5 m [28 ft] above the water level). The completion casing was landed at the depth of 806.1 m (2,644.7 ft) and is slotted in two intervals. The upper interval (6⅝-in. casing) is slotted from 575.4 to 639.1 m (1,887.8 to 2,096.8 ft) to allow access to an LFA within the FCCM, and the lower interval (5½-in. casing) is slotted from 696.7 to 792.7 m (2,285.8 to 2,600.6 ft) to allow access to a deeper LFA also within the FCCM. Three piezometer strings were set to monitor water levels during hydraulic testing. For each piezometer, a string of 2⅞-in. stainless-steel tubing was suspended from a string of 2⅜-in. carbon-steel tubing connected via a cross-over sub. The shallow piezometer string was landed at 333.5 m (1,094.3 ft) to monitor the water table. The shallow piezometer string is slotted from 308.9 to 333.5 m (1,013.6 to 1,094.3 ft). Intermediate and deep piezometer strings were landed at 640.0 m (2,099.8 ft) and 832.7 m (2,731.9 ft), respectively, to monitor LFAs within the FCCM. The intermediate piezometer string is slotted from 579.0 to 640.0 m (1,899.7 to 2,099.8 ft), and the deep piezometer string is slotted from 698.7 to 795.7 m (2,292.4 to 2,610.7 ft) for monitoring LFAs within the FCCM.

The open-hole fluid level was measured at the depth of 308.5 m (1,012 ft) on October 9, 2010, during geophysical logging conducted prior to installation of the surface casing. The water level was again measured at the depth of 308.5 m (1,012 ft) on October 20, 2010, shortly after the well had reached TD. On November 5, 2010, N-I field personnel measured a water level of 308.0 m (1,010.6 ft) in the shallow piezometer string.

Composite drill cuttings were collected every 3.0 m (10 ft) from the depth of 21.3 m (70 ft) to TD, and 29 sidewall core samples were obtained at various depths between 358.1 and 902.2 m (1,175 and 2,960 ft). Open-hole geophysical logging of the well was conducted to help verify the geology and characterize the hydrologic properties of the rocks; some logs also aided in the construction of the well by indicating borehole volume and condition. The well was drilled entirely within Tertiary volcanic rocks with the exception of 6.1 m (20 ft) of Quaternary alluvium at the surface.

1.6 Contact Information

Inquiries concerning Well ER-EC-13 should be directed to the UGTA Federal Project Director at:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Environmental Restoration Project
P.O. Box 98518
Las Vegas, Nevada 89193-8518

2.0 Drilling Summary

2.1 Introduction

This section contains detailed descriptions of the drilling process and a discussion of fluid management issues. The general drilling requirements for all the Pahute Mesa Phase II wells were provided in *Addendum to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (NNES, 2010a). Specific requirements for Well ER-EC-13 were outlined in FAWP numbers D-003-001.10 and D-009-001.10 (NSTec, 2010a and b). Figure 2-1 shows the layout of the drill site, and Figure 2-2 is a chart of the drilling and completion history for Well ER-EC-13. A summary of drilling statistics for the well is given in Table 2-1. The following information was compiled primarily from NSTec daily drilling reports.

2.2 Drilling History

Field operations at Well ER-EC-13 began on September 9, 2010, when NSTec drillers used the Auger II drill rig to auger the 106.7-cm (42-in.) conductor hole to the depth of 22.6 m (74 ft). A string of 30-in. conductor casing was set at the depth of 21.9 m (72 ft). The conductor casing was cemented in place on September 9, 2010, using 3.4 cubic meters (m^3) (4.4 cubic yards [yd^3]) of Redi-Mix Formula 400 (see cement composition in Appendix A-3). The cement was pumped into the annulus between the casing and the formation, with a rise inside the casing of 3.7 m (12 ft) to the depth of 18.9 m (62 ft).

The UDI crews began mobilizing from Well ER-20-4 on September 20, 2010, and completed rigging up the Wilson Mogul 42B drill rig at Well ER-EC-13 on October 2, 2010. The crew began drilling through the cement at the bottom of the 30-in. casing at 18.9 m (62 ft) with a center-punch assembly consisting of a 20½-in. rotary bit mounted 3.9 m (12.8 ft) below a 26-in. hole opener. The drilling fluid was an air/water/soap mix with a polymer additive (when necessary) in conventional circulation. The 26-in. hole opener was removed and replaced with two 20½-in. roller reamers when the hole reached the depth of 26.5 m (87 ft). On October 3, 2010, an additional roller reamer and a shock sub were added to the bottom hole assembly. While making a connection at 45.4 m (149 ft) the collar clamp fell and struck one of the rig crew members on the left shoulder. The site was placed on a safety stand-down for approximately 24 hours, and drilling resumed near midnight on October 4, 2010.

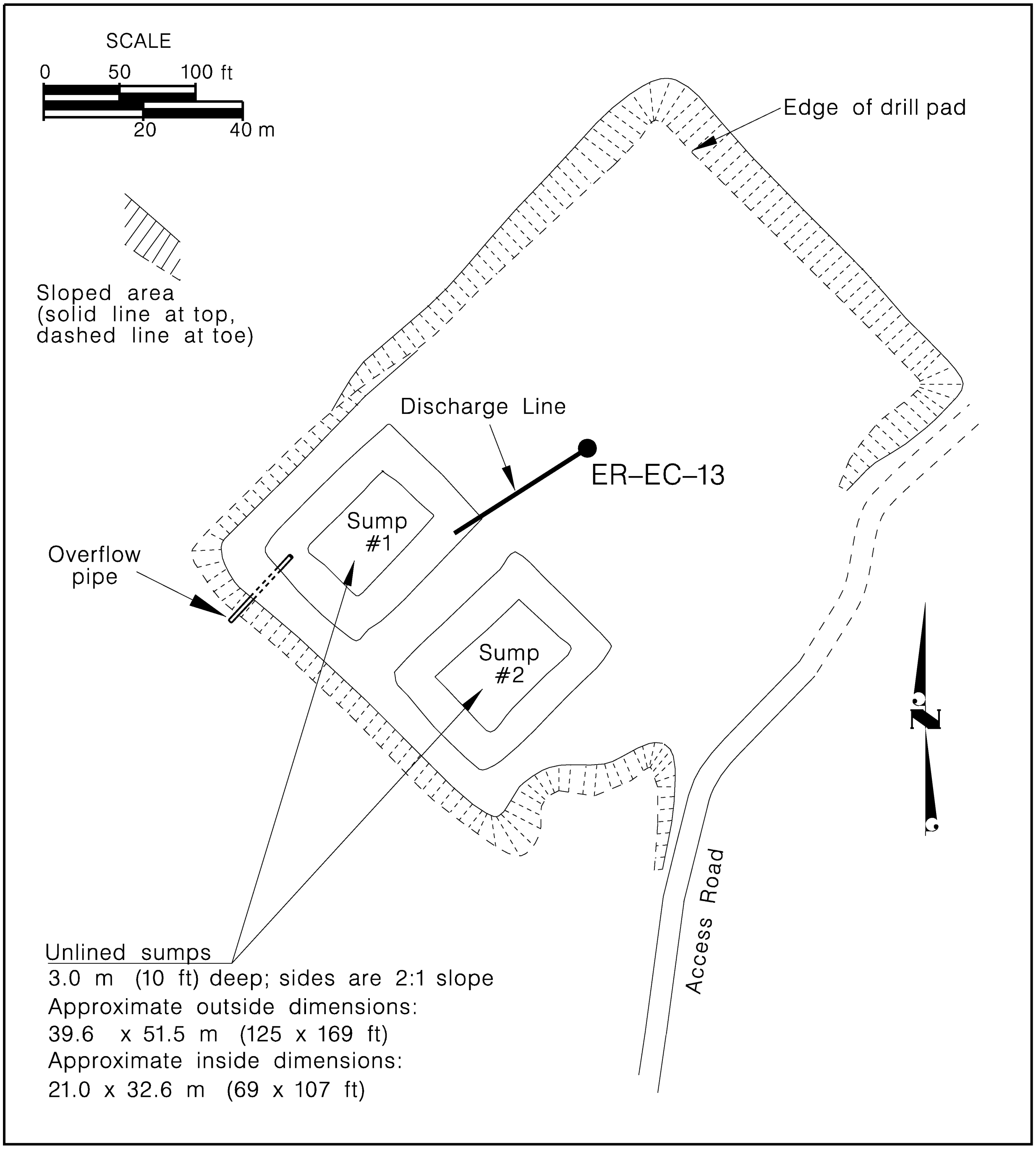
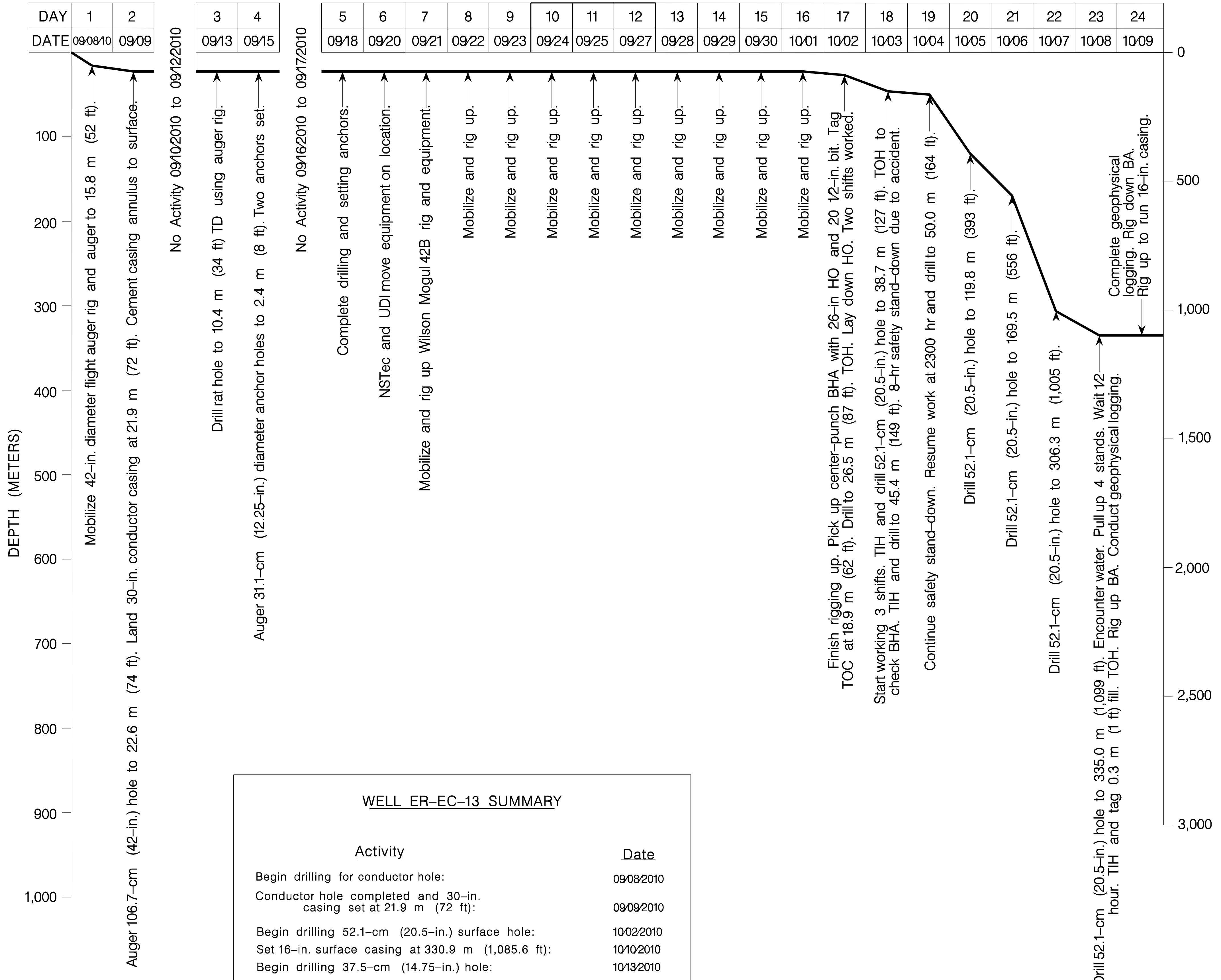


Figure 2-1
Drill Site Configuration for Well ER-EC-13

LEGEND

BA	Baker Atlas
BHA	bottom hole assembly
cm	centimeter(s)
CT	chemistry/temperature
DPS	deep piezometer string
DRI	Desert Research Institute
ft	foot (feet)
ft^3	cubic feet
HO	hole opener
hr	hour(s)
in.	inch(es)
IPS	intermediate piezometer string
m	meter(s)
m^3	cubic meters
NAIL	nuclear annular investigation log
NSTec	National Security Technologies, LLC
P–SWC	percussion sidewall core
RIH	run in hole
R–SWC	rotary sidewall core
SLM	steel line measurement
SPS	shallow piezometer string
TD	total depth
TFL	thermal flow log
TIH	trip into hole
TL	temperature log
TOC	top of cement
TOH	trip out of hole
UDI	United Drilling Inc.



WELL ER–EC–13 SUMMARY

Activity	Date
Begin drilling for conductor hole:	09/08/2010
Conductor hole completed and 30–in. casing set at 21.9 m (72 ft):	09/09/2010
Begin drilling 52.1–cm (20.5–in.) surface hole:	10/02/2010
Set 16–in. surface casing at 330.9 m (1,085.6 ft):	10/10/2010
Begin drilling 37.5–cm (14.75–in.) hole:	10/13/2010
Reach total drilled depth of 914.4 m (3,000 ft):	10/18/2010
Well completed:	10/26/2010

FIGURE 2–2

WELL ER–EC–13
DRILLING AND COMPLETION HISTORY
SHEET 1 OF 2

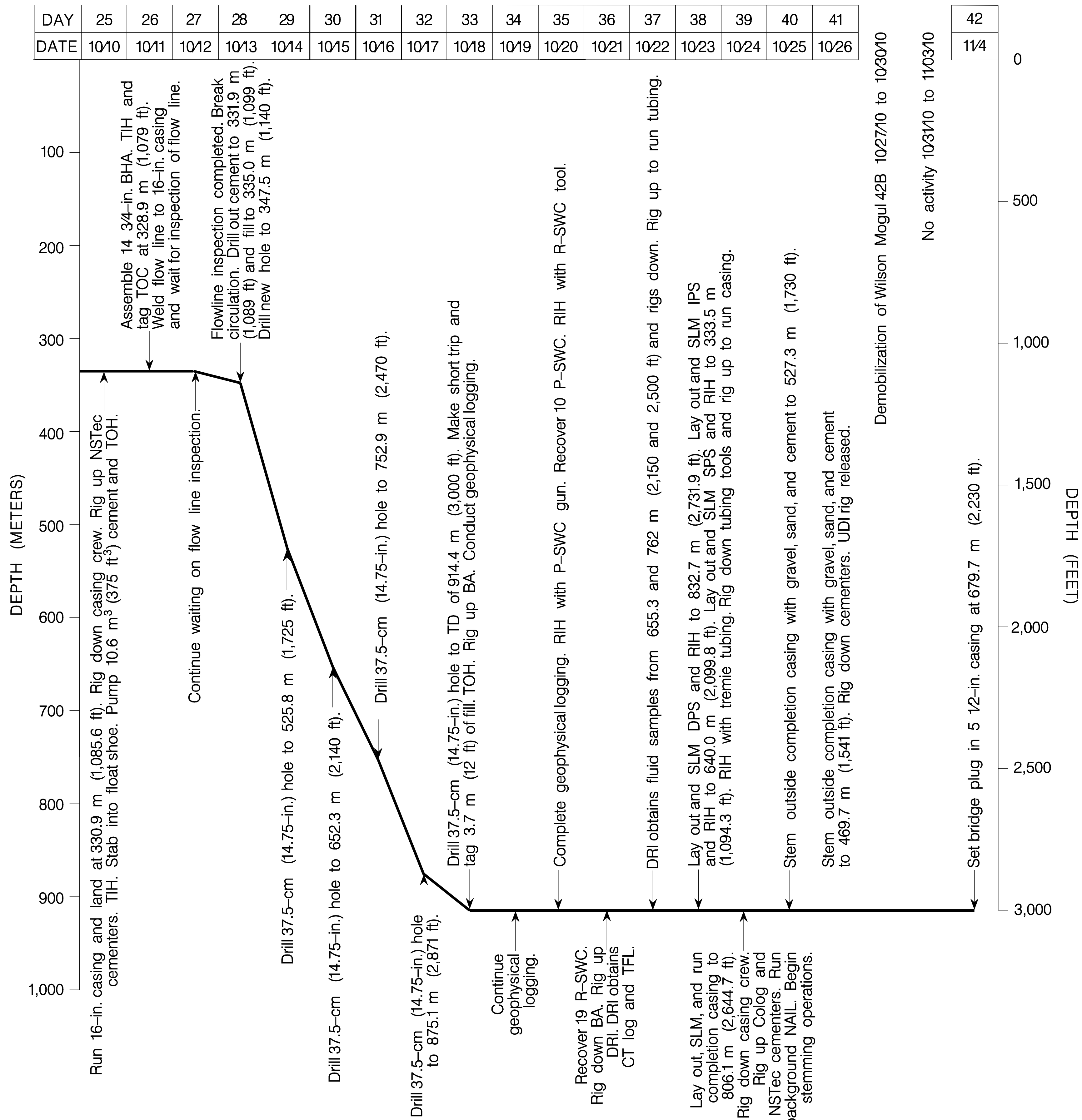


FIGURE 2-2

WELL ER-EC-13
DRILLING AND COMPLETION HISTORY

SHEET 2 OF 2

Table 2-1
Abridged Drill Hole Statistics for Well ER-EC-13

LOCATION DATA:

Coordinates:				
	Nevada State Plane (Central Zone)	(NAD 27):	N 880,647.9 ft	E 534,487.2 ft
	Nevada State Plane (Central Zone)	(NAD 83):	N 6,268,422.5 m	E 510,432.1 m
	Universal Transverse Mercator (Zone 11)	(NAD 83):	N 4,113,750.2 m	E 540,021.9 m
	Universal Transverse Mercator (Zone 11)	(NAD 27):	N 4,113,553.2 m	E 540,102.2 m

Surface Elevation [a]: 1,577.4 m (5,175.1 ft)

DRILLING DATA:

Spud Date: 10/2/2010 (main hole drilling with Wilson Mogul 42B rig)

Total Depth (TD): 914.4 m (3,000 ft)

Date TD Reached: 10/18/2010

Date Well Completed: 10/26/2010 (date completion string was cemented in place)

Hole Diameter: 106.7 cm (42 in.) from surface to 22.6 m (74 ft); 52.1 cm (20.5 in.) from 22.6 to 335.0 m (74 to 1,099 ft); 37.5 cm (14.75 in.) from 335.0 m (1,099 ft) to TD of 914.4 m (3,000 ft).

Drilling Techniques: Dry-hole auger from surface to 22.6 m (74 ft); center-punch with 20½-in. tricone bit mounted below a 26-in. hole opener to 26.5 m (87 ft); rotary drill with 20½-in. tricone bit to 335.0 m (1,099 ft); rotary drill with 14¾-in. tricone bit to TD at 914.4 m (3,000 ft).

CASING DATA: 30-in. conductor casing to 21.9 m (72 ft); 16-in. surface casing to 330.9 m (1,085.6 ft).

WELL COMPLETION DATA [b]:

A string of 5½-in. stainless-steel casing hangs from 6⅝-in. stainless-steel casing, which hangs from 7⅝-in. epoxy-coated carbon-steel casing, all via crossover subs. The carbon-steel casing extends through the unsaturated zone to approximately 8.5 m (28 ft) above the water table. The 6⅝-in. casing (inside diameter [id] of 15.5 cm [6.104 in.]) has one slotted interval. The 5½-in. casing (id of 12.8 cm [5.047 in.]) has one slotted interval and was landed at 806.1 m (2,644.7 ft). The slotted zones access different lava-flow aquifers within the Fortymile Canyon composite unit (FCCM).

Three 2⅞-in. piezometer stings (id of 5.99 cm [2.36 in.]) were also installed to monitor different portions of the FCCM. In all three, the 2⅞-in. stainless-steel tubing hangs from a string of 2⅜-in. carbon-steel tubing (id of 5.07 cm [1.995 in.]), connected via a crossover sub. Each 2⅞-in. piezometer string has one slotted interval. The shallow piezometer was landed at 333.5 m (1,094.3 ft) and was inserted inside the 16-in. casing. The intermediate piezometer was landed at 640.0 m (2,099.8 ft) and was inserted inside the 37.5-cm (14.75-in.) hole. The deep piezometer was landed at 832.7 m (2,731.9 ft) and was inserted inside the 37.5-cm (14.75-in.) hole.

Depth of Slotted Section:		
	5½-in. completion casing:	696.7 to 792.7 m (2,285.8 to 2,600.6 ft)
	6⅝-in. completion casing:	575.4 to 639.1 m (1,887.8 to 2,096.8 ft)
	Shallow 2⅞-in. piezometer string:	308.9 to 333.5 m (1,013.6 to 1,094.3 ft)
	Intermediate 2⅞-in. piezometer string:	579.0 to 640.0 m (1,899.7 to 2,099.8 ft)
	Deep 2⅞-in. piezometer string	698.7 to 795.7 m (2,292.4 to 2,610.7 ft)

Depth of Sand Packs: 559.3 to 567.2 m (1,835 to 1,861 ft)
682.8 to 689.8 m (2,240 to 2,263 ft)

Depth of Gravel Packs: 567.2 to 651.1 m (1,861 to 2,136 ft)
689.8 to 816.9 m (2,263 to 2,680 ft)

Depth of Pump: Not installed at the time of completion

Water Depth [c]: Fluid-level depths measured on November 5, 2010: 308.0 m (1,010.6 ft) in the shallow 2⅞-in. piezometer string; 308.0 m (1,010.6 ft) in the intermediate 2⅞-in. piezometer string; and 308.0 m (1,010.5 ft) in the deep 2⅞-in. piezometer string.

DRILLING CONTRACTOR: United Drilling, Inc.

GEOPHYSICAL LOGS BY: Baker Atlas

SURVEYING CONTRACTOR: National Security Technologies, LLC

a Elevation of ground level at wellhead, relative to mean sea level. National Geodetic Vertical Datum of 1929 (NARA, 1973).

b See Section 7.0 of this report for more detailed data on completion intervals. See Table A-2-1 for more details about the casing and tubing materials.

c Fluid level tags by Navarro-Intera, LLC.

On October 5, 2010, excessive rotary torque became problematic, resulting in swinging of the blocks (wobble) and rig "chatter" (bouncing of the drill bit). The drill crew made several attempts to correct this problem, including reducing the rotations per minute with the bit, increasing weight on the bit, and servicing various rig components. On the morning of October 6, 2010, the crew replaced ten joints of "Hevi-Wate" drill pipe (HWDP) with eight drill collars, jars, and one HWDP to increase the weight of the drill string. When drilling resumed, they were able to maintain a steady drill rate with only minor bouncing of the bit, and with little to no fill on connections.

The first observation of water in the drilling effluent was reported at the depth of 318.5 m (1,045 ft) on October 8, 2010. When the borehole had reached the depth of 335.0 m (1,099 ft), the decision was made to suspend drilling to conduct open-hole geophysical logging in the unsaturated zone. Geophysical logging began October 8, 2010, and a fluid level of 308.5 m (1,012 ft) was measured early the next day, on October 9, 2010. Logging operations were completed later that same day.

On October 10, 2010, a casing subcontractor installed a string of 16-in. casing, which was set at the depth of 330.9 m (1,085.6 ft). The bottom of the surface casing was cemented with 10.6 m^3 (13.9 yd^3) of Type II neat cement. The top of cement in the annulus is estimated to be at the depth of 284.7 m (934 ft), based on geophysical logging.

After the flow line was welded onto the surface casing at the well head, operations at the rig site were placed on stand-by for approximately 2.5 days until the new flow line configuration could be inspected. Operations resumed on October 13, 2010, when drilling of the 37.5-cm (14.75-in.) hole began.

The top of cement was tagged inside the surface casing at the depth of 328.9 m (1,079 ft). Cement and the casing shoe were drilled to 331.9 m (1,089 ft), and fill was drilled from 331.9 to 335.0 m (1,089 to 1,099 ft). Drilling continued with little to no fill on connections until October 18, 2010, when a TD of 914.4 m (3,000 ft) was reached, after which drillers circulated fluid in the hole for approximately 30 minutes. After the drill string was pulled up a short distance and then lowered again, 3.7 m (12 ft) of fill was found to have accumulated.

Geophysical logging and sidewall sampling began later that same day, and logging operations were completed on October 22, 2010, after DRI personnel ran chemistry, temperature, and flow logs, and collected water samples.

On October 23, 2010, the drill crew installed three piezometer strings, each with one slotted interval. The deep piezometer string was set at 832.7 m (2,731.9 ft), the intermediate piezometer string was set at 640.0 m (2,099.8 ft), and the shallow piezometer string was set at 333.5 m (1,094.3 ft). A casing subcontractor inserted the completion string, which has two slotted intervals, on October 24, 2010, landing at a depth of 806.1 m (2,644.7 ft). The annulus around the completion casing and the two deepest piezometer strings were packed with sand and gravel, and cemented. See Section 7.2 for more information about the completion operations.

Stemming operations were completed on October 26, 2010, and the drillers started demobilizing the rig and drilling equipment. The crews worked one shift per day after that, until demobilization was completed on October 31, 2010.

The inclination of the borehole was determined from borehole orientation logs run by Baker Atlas during each logging operation (October 9 and October 18, 2010). The composite survey plot shows a dogleg effect (abrupt change) in borehole orientation at approximately 55.5 m (182 ft). Around this depth the borehole was penetrating a series of dense, stoney rhyolitic lavas, and the drillers made several attempts to improve penetration rates by varying weight on the bit, which may have caused this deviation in the borehole path. Starting at approximately 304.8 m (1,000 ft), the borehole path gradually deviates from a northwestern to southeastern direction, and the average deviation was 2 degrees. The remainder of the borehole trends to the southeast with an average deviation of 2.5 degrees. The bottom of the borehole is approximately 27.7 m (91 ft) southeast of the wellhead. At the lowest logged depth of 408.3 m (2,980 ft), the true vertical depth is calculated to be 407.4 m (2,977.0 ft), a difference of 0.9 m (3.0 ft).

A graphical depiction of drilling parameters, including penetration rate, rotary revolutions per minute, pump pressure, and weight on the bit, is presented in Appendix A-1. See Appendix A-2 for a listing of tubing and casing materials. Drilling fluids and cements used in Well ER-EC-13 are listed in Appendix A-3.

2.3 Drilling Problems

Drilling delays at Well ER-EC-13 were mainly due to operational problems rather than drilling problems. However, throughout the upper part of the drill hole, drilling progressed slowly and numerous adjustments were being made to relieve excessive rotary torque. Efforts to reduce torque included varying weight on bit, repairing the automatic driller, and adjusting the configuration of the bottom-hole assembly.

The site was on standby for approximately one day during an accident investigation and supplemental safety briefing. A delay of about 2.5 days was experienced due to construction and subsequent inspection on the new flow line assembly.

2.4 Fluid Management

During drilling of Well ER-EC-13, the drilling effluent was monitored according to the methods prescribed in the UGTA Project FMP (NNSA/NSO, 2009b) and the associated state-approved, well-specific, fluid management strategy letter (N-I, 2010). The air-foam/polymer drill fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional or direct circulation) and then discharged into a sump. Water used to prepare drilling fluids came from Well ER-EC-8. Lithium bromide was added to the drill fluid as a tracer to provide a means of estimating groundwater production. The rate of water production was estimated from the dilution of the tracer in the drill fluid returns.

2.4.1 Drilling Effluent Sump Information

To manage the anticipated water production, two sumps were constructed prior to drilling (Figure 2-1). Radionuclides exceeding fluid quality objectives were not expected at Well ER-EC-13 based on Phase I flow and transport modeling (SNJV, 2006; 2007; 2009b), so neither sump was lined prior to drilling. On October 15, 2010, the fluid level reached approximately 2.1 m (7 ft) on the staff gauge in sump #1, so fluid from sump #1 was pumped to a surface infiltration area at a rate of approximately 757 liters per minute (Lpm) (200 gallons per minute [gpm]). The transfer line was pressure tested prior to pumping, and the line was checked for leaks, with none found.

2.4.2 Radionuclide Monitoring

Samples of drilling effluent were collected hourly by N-I and analyzed on site by radiological control technicians (RCTs) for the presence of tritium. As detailed in the N-I data report (N-I, 2011), the onsite monitoring results for the drilling indicated that tritium levels measured in the drilling fluid were less than the minimum detection limit of the field instruments, well below drinking water standards.

No lead monitoring was performed. Lead monitoring is not initiated until discharge fluids exceed the UGTA Fluid Management Criteria for tritium (200,000 picocuries per liter [pCi/L]), as specified in the Well ER-EC-13 Fluid Management Strategy Letter (N-I, 2010) approved by the Nevada Division of Environmental Protection. N-I personnel checked all down-hole equipment for lead and none was found.

2.4.3 Fluid Quality Objectives

All fluid quality objectives were met, as shown on the fluid management reporting form (Appendix B). The form lists volumes of solids (drill cuttings) and fluids produced during well-construction operations (vadose-zone drilling and saturated-zone drilling only; well development and aquifer testing are not addressed in this report). The volume of solids produced was calculated using the diameter of the borehole (from caliper logs) and the depth drilled, and includes added volume attributed to a rock bulking factor. The volumes of fluids listed on the report are estimates of total fluid production, and do not account for any infiltration or evaporation of fluids from the sumps.

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3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-EC-13 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology in the southern portion of PM–OV CAU was among the primary objectives of Well ER-EC-13, so the proper collection of geologic and hydrogeologic data from the borehole was considered fundamental to successful completion of the drilling project.

Geologic data collected at Well ER-EC-13 consist of drill cuttings, sidewall core samples, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures, as listed in the N-I FAWP (NNES, 2010b).

3.2 Drill Cuttings

Four samples were collected at 6.1-m (20-ft) intervals by NSTec during construction of the conductor hole, from the surface to the depth of 22.6 m (74 ft). N-I personnel collected composite drill cuttings samples at 3.0-m (10-ft) intervals during drilling of the main hole. Triplicate samples, each consisting of approximately 550 cubic centimeters of material, were collected from 292 intervals to from the depth of 22.6 m (74 ft) to TD at 914.4 (3,000 ft). Samples are missing from two intervals, 868.7 to 871.7 m (2,850 to 2,860 ft) and 871.7 to 874.8 m (2,860 to 2,870 ft), due to poor returns and lost circulation.

These samples are stored under environmentally controlled, secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample, one set was left unsealed in the original sample containers, and the third set was washed and stored according to standard USGS Core Library procedures. The washed set was used by NSTec geologists to construct the detailed lithologic log presented in Appendix C. The N-I field representative collected an additional set of reference drill cuttings samples from each of the cuttings intervals. This set was examined at the drill site for use in preparing field lithologic descriptions, and remains in the custody of N-I.

3.3 Sidewall Core Samples

Sidewall core samples were collected at selected depths in Well ER-EC-13 to verify the stratigraphy and lithology and for special analytical tests. Sample locations were selected by NSTec geologists and the N-I field representative on the basis of field lithologic logs, with consideration of borehole conditions determined from caliper logs. Baker Atlas used a percussion-gun sidewall coring tool to collect samples between the depths of 358.1 and 902.2 m (1,175 and 2,960 ft), in which 25 sample depths were attempted and 10 cores were recovered. Baker Atlas also used a rotary sidewall coring tool to obtain sidewall samples between 358.1 and 899.8 m (1,175 and 2,952 ft), in which 20 rotary sample depths were attempted and 19 samples were recovered. Table 3-1 summarizes the results of sidewall coring operations at Well ER-EC-13.

3.4 Sample Analysis

Fourteen samples of drill cuttings, three percussion sidewall cores, and nine rotary sidewall cores from various depths were submitted to Comprehensive Volcanic Petrographics, LLC, for petrographic analysis. A split of the same 14 drill cuttings samples, 3 percussion sidewall cores, and 9 rotary sidewall cores from the similar depths were submitted to the Hydrology, Geochemistry, and Geology Group of the Earth and Environmental Sciences Division at LANL for mineralogic (x-ray diffraction) and chemical (x-ray fluorescence) analyses. The samples were selected after initial geologic evaluation of cuttings and core samples and geophysical logs.

The primary purpose of the analytical data is to confirm stratigraphic identification and to characterize mineral alteration. In addition, the data provide detailed information on mineralogic composition, which will be used in transport modeling and will aid in evaluation of geophysical log signatures. The results of the petrographic analyses are reported in Warren (2011), and the results of the mineralogic and chemical analyses are reported in WoldeGabriel et al. (2011). Table 3-2 lists all samples analyzed.

3.5 Geophysical Log Data

Geophysical logs were run in the borehole to further characterize the lithology, structure, and hydrologic properties of the rocks encountered, and to evaluate borehole conditions. Geophysical logging was conducted in two stages. The unsaturated zone was logged after completion of the 52.1-cm (20.5-in.) borehole, before installation of the 16-in. surface casing at 330.9 m (1,085.6 ft). The saturated portion of the borehole was logged after the hole had reached TD, before installation of the completion casing. A complete listing of the logs, dates run, depths, and service companies is provided in Table 3-3.

Table 3-1
Sidewall Samples from Well ER-EC-13

Core Depth [a]		Tool Used [b]	Recovery [c] centimeters (inches)	Stratigraphy and Lithology All samples are from the Beatty Wash Formation
meters	feet			
358.1	1,175	SWC	E	Nonwelded tuff; zeolitic
358.1	1,175	SWC [d]	E	Nonwelded tuff; zeolitic
358.1	1,175	RC	4.06 (1.60)	Nonwelded tuff; zeolitic
366.7	1,203	SWC	M	Block-and-ash flow and/or debris-flow deposits; zeolitic
366.7	1,203	SWC [d]	3.81 (1.50)	Block-and-ash flow and/or debris-flow deposits; zeolitic
373.7	1,226	SWC	4.45 (1.75)	Nonwelded tuff; zeolitic
382.2	1,254	SWC	L	Block-and-ash flow and/or debris-flow deposits; zeolitic
382.2	1,254	SWC [d]	M	Block-and-ash flow and/or debris-flow deposits; zeolitic
382.2	1,254	RC	2.03 (0.80)	Block-and-ash flow and/or debris-flow deposits; zeolitic
397.5	1,304	SWC	E	Block-and-ash flow and/or debris-flow deposits; zeolitic
397.5	1,304	RC	3.18 (1.25)	Block-and-ash flow and/or debris-flow deposits; zeolitic
412.7	1,354	SWC	4.45 (1.75)	Nonwelded tuff; zeolitic
412.7	1,354	SWC [d]	3.81 (1.50)	Nonwelded tuff; zeolitic
425.2	1,395	SWC	E	Block-and-ash flow and/or debris-flow deposits; zeolitic
426.7	1,400	SWC	M	Block-and-ash flow and/or debris-flow deposits; zeolitic
435.6	1,429	RC	3.05 (1.20)	Block-and-ash flow and/or debris-flow deposits; zeolitic
437.7	1,436	SWC	E	Block-and-ash flow and/or debris-flow deposits; zeolitic
438.9	1,440	SWC	E	Block-and-ash flow and/or debris-flow deposits; zeolitic
460.2	1,510	SWC	M	Block-and-ash flow and/or debris-flow deposits; zeolitic
460.2	1,510	SWC [d]	3.81 (1.50)	Nonwelded tuff; zeolitic
479.8	1,574	SWC	M	Block-and-ash flow and/or debris-flow deposits; zeolitic
479.8	1,574	RC	2.79 (1.10)	Block-and-ash flow and/or debris-flow deposits; zeolitic
485.9	1,594	SWC	3.81 (1.50)	Nonwelded tuff; zeolitic
492.3	1,615	RC	1.91 (0.75)	Pumiceous rhyolite lava; zeolitic
499.9	1,640	RC	3.18 (1.25)	Pumiceous rhyolite lava; zeolitic
548.6	1,800	RC	3.56 (1.40)	Stoney rhyolite lava; devitrified
585.8	1,922	RC	1.27 (0.50)	Stoney rhyolite lava; devitrified
615.7	2,020	RC	2.79 (1.10)	Stoney rhyolite lava; devitrified
624.8	2,050	RC	1.02 (0.40)	Vitrophyric and pumiceous rhyolite lava; vitric and zeolitic
651.1	2,136	RC	E	Vitrophyric and pumiceous rhyolite lava; vitric and zeolitic
701.0	2,300	RC	3.81 (1.50)	Stoney rhyolite lava, devitrified

Table 3-1
Sidewall Samples from Well ER-EC-13 (continued)

Core Depth [a]		Tool Used [b]	Recovery [c] centimeters (inches)	Stratigraphy and Lithology All samples are from the Beatty Wash Formation
meters	feet			
755.3	2,478	RC	3.18 (1.25)	Vitrophyric rhyolite lava, vitric and quartzo-feldspathic
801.6	2,630	SWC	5.08 (2.00)	Bedded tuff, quartzo-feldspathic
810.8	2,660	SWC	M	Bedded tuff, quartzo-feldspathic
811.4	2,662	SWC	E	Bedded tuff, quartzo-feldspathic
817.5	2,682	RC	3.30 (1.30)	Bedded tuff, quartzo-feldspathic
845.8	2,775	RC	3.05 (1.20)	Bedded tuff, quartzo-feldspathic
860.1	2,822	RC	2.79 (1.10)	Bedded tuff, quartzo-feldspathic
865.6	2,840	RC	3.05 (1.20)	Bedded tuff, quartzo-feldspathic
869.0	2,851	RC	3.18 (1.25)	Bedded tuff, quartzo-feldspathic
883.9	2,900	SWC	3.81 (1.50)	Bedded tuff, quartzo-feldspathic
890.0	2,920	SWC	3.18 (1.25)	Bedded tuff, quartzo-feldspathic
899.8	2,952	SWC	M	Bedded tuff, quartzo-feldspathic
899.8	2,952	RC	4.06 (1.60)	Bedded tuff, quartzo-feldspathic
902.2	2,960	SWC	3.18 (1.25)	Bedded tuff, quartzo-feldspathic

a All depths are drilled depths.

b SWC = percussion-gun sidewall coring tool; core diameter: 17.3 millimeters (0.68 in.).
RS = rotary sidewall coring tool; core diameter: 25.4 millimeters (1 in.).

c Shaded rows indicate samples attempted but not recovered. E = empty barrel; L = lost barrel; M = misfire.

d Second attempt.

Table 3-2
Rock Samples from Well ER-EC-13 Selected for Petrographic, Mineralogic, and Chemical Analysis

Depth [a]		Sample Identifier [b]
meters	feet	
76.2	250	EREC13–250D
94.5	310	EREC13–310D
134.1	440	EREC13–440D
155.4	510	EREC13–510D
182.9	600	EREC13–600D
228.6	750	EREC13–750D
274.3	900	EREC13–900D
313.9	1,030	EREC13–1,030D
362.7	1,190	EREC13–1,190D
373.7	1,226	EREC13–1,226PS
412.7	1,354	EREC13–1,354PS
435.6	1,429	EREC13–1,429RS
475.5	1,560	EREC13–1,560D
499.9	1,640	EREC13–1,640RS
548.6	1,800	EREC13–1,800RS
615.7	2,020	EREC13–2,020RS
682.8	2,240	EREC13–2,240D
701.0	2,300	EREC13–2,300RS
740.7	2,430	EREC13–2,430D
755.3	2,478	EREC13–2,478RS
801.6	2,630	EREC13–2,630PS
817.5	2,682	EREC13–2,682RS
856.5	2,810	EREC13–2,810D
860.1	2,822	EREC13–2,822RS
899.8	2,952	EREC13–2,952RS
914.4	3,000	EREC13–3,000D

a All depths are drilled depths. Analysis represent base of 3.0-m (10-ft sample interval for drill cuttings samples.

b “D” in sample identifier indicates drill cuttings sample. “RS” indicates rotary sidewall core sample. “PS” indicates percussion-gun sidewall core sample.

c See results of petrographic analysis of thin sections in Warren (2011). See results of mineralogic analysis by x-ray diffraction and chemical analysis by x-ray fluorescence in WoldeGabriel et al. (2011).

Table 3-3
Well ER-EC-13 Geophysical Log Summary

Geophysical Log Type [a]	Log Purpose	Logging Service [b]	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
Differential Temperature / Gamma Ray [d]	Saturated zone: groundwater temperature, stratigraphic and depth correlation	BA	10/18/2010	TL-1 / GR-4	910.7 (2,988)	237.7 (780)
Aligned borehole profile (i.e., oriented * 6-Arm Caliper) / Gamma Ray	Borehole conditions, cement volume calculation, lithologic features, borehole orientation, stratigraphic and depth correlation	BA	10/08/2010 10/18/2010	CA6-1 / ORIT-1 / GR-1 CA6-2 / ORIT-2 / GR-5	332.5 (1,091) 907.7 (2,978)	21.9 (72) 304.8 (1,000)
* Digital Spectralog / * Gamma Ray	Stratigraphy, mineralogy, and natural and man-made radiation determination	BA	10/08/2010 10/18/2010	SGR-1 / GR-1 SGR-2 / GR-5	325.8 (1,069) 901.0 (2,956)	0 259.1 (850)
* High Definition Induction / Gamma Ray / Spontaneous Potential	Lithologic determinations, saturation of formations, stratigraphic and depth correlation	BA	10/09/2010	HDIL-1 / GR-2 / SP-1	331.0 (1,086)	21.9 (72)
* R_t Explorer / Gamma Ray / Spontaneous Potential	Lithologic determinations, identification of alteration, recognition of welding; distinguishing low versus high porosity	BA	10/19/2010	RTEX-1 / GR-6 / SP-2	905.3 (2,970)	331.6 (1,088)
* Compensated Z-Densilog / * Compensated Neutron / Gamma Ray	Stratigraphic and lithologic determinations, identification of welding, alteration, rock porosity, and water content	BA	10/09/2010 10/19/2010	ZDL-1 / CN-1 / GR-3 ZDL-2 / CN-2 / GR-7	333.1 (1,093) 910.1 (2,986)	21.9 (72) 243.8 (800)
Circumferential Borehole Imaging / Gamma Ray	Structural analysis, including fracture characterization; recognition of lithologic features	BA	10/20/2010	CBIL-1 / GR-10	909.5 (2,984)	308.5 (1,012)
* X-Multipole Array Acoustilog / Gamma Ray	Primary matrix porosity	BA	10/19/2010	XMAC-1 / GR-8	905.6 (2,971)	304.8 (1,000)
Resistivity Imaging / Gamma Ray	Saturated zone: lithologic characterization, bedding dip, fracture and void analysis	BA	10/19/2010	STAR-1 / GR-9	909.5 (2,984)	335.3 (1,100)
Percussion Gun Sidewall Tool / Gamma Ray	Geologic samples	BA	10/20/2010	SWC-1 / GR-11	902.2 (2,960)	358.1 (1,175)

Table 3-3
Well ER-EC-13 Geophysical Log Summary (continued)

Geophysical Log Type [a]	Log Purpose	Logging Service [b]	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
Rotary Sidewall Coring Tool / Gamma Ray	Geologic samples	BA	10/20/2010	RCOR-1 / GR-12	899.8 (2,952)	358.1 (1,175)
* Chemistry / * Temperature Log	Groundwater chemistry and temperature	DRI	10/21/2010	Chem-1 / TL-2	911.0 (2,989)	308.5 (1,012)
* Heat Pulse Flow Log	Groundwater flow rate and direction	DRI	10/21/2010	HPFlow-1	899.2 (2,950)	309.4 (1,015)

a Logs presented in geophysical log summary, Appendix D, are indicated by *.

b BA = Baker Atlas; DRI = Desert Research Institute; Colog = Layne Christensen Co., Colog Division

c Drilled depth

d A gamma-ray log is included on each logging run to aid in depth control.

The logs are available from NSTec in Mercury, Nevada, and copies are on file at the office of N-I in Las Vegas, Nevada, and at the USGS Geologic Data Center and Core Library in Mercury, Nevada. Plots of selected geophysical data are provided in Appendix D.

4.0 Geology and Hydrogeology

4.1 Introduction

This section describes the geology and hydrogeology of Well ER-EC-13. The basis for the discussions here is the detailed geologic characterization of Well ER-EC-13 presented as a lithologic log in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, and drilling characteristics. Preliminary data from petrographic, mineralogic, and chemical analyses on select lithologic samples from Well ER-EC-13 were incorporated into the detailed lithologic log. Information on bedding dip orientations and fractures was obtained from the interpretation of borehole image logs (Prothro, 2011).

4.2 Geology

This section is divided into three discussions relating to the geology of Well ER-EC-13. Section 4.2.1 briefly describes the geologic setting of the Timber Mountain moat area and Well ER-EC-13. The stratigraphic and lithologic units penetrated at the well are discussed in detail in Section 4.2.2. Because of the significant influence some alteration products have on the hydraulic properties of certain rocks, alteration of the rocks encountered at the well is discussed separately in Section 4.2.3. Detailed descriptions of the stratigraphy, lithology, and alteration of the rocks encountered are provided in the detailed lithologic log presented in Appendix C. Tables 4-1 and 4-2 provide the definitions of stratigraphic units and HSUs, respectively, used in various figures in this report.

4.2.1 Geologic Setting

Well ER-EC-13 is located within a geologically complex area shaped mainly as the result of volcanism and related structural movements associated with nearby calderas that formed approximately 9 to 14 million years ago (Ma) (Sawyer et al., 1994). The well was drilled south of Pahute Mesa, within the northwestern moat area of the TMCC (Figure 4-1). Analysis of the data from Well ER-EC-13 and regional geologic and geophysical data suggest that the well is located within the Rainier Mesa and Ammonia Tanks calderas, two of several "nested" calderas in the TMCC. The formation of these calderas is the result of the eruption of the Rainier Mesa Tuff (erupted 11.6 Ma [Sawyer, et al., 1994]) and the Ammonia Tanks Tuff (erupted 11.45 Ma [Sawyer, et al., 1994]); both tuffs are considered stratigraphically to be part of the Timber Mountain Group. Following the collapse of the Ammonia Tanks caldera, resurgence of a central

Table 4-1
Key to Stratigraphic Units and Symbols for the Well ER-EC-13 Area

Stratigraphic Unit	Map Symbol
Quaternary and Tertiary Alluvial Deposits	**QTa**
Young alluvial deposits	Qay
Colluvium	QTc
Intermediate alluvial deposits	Qai
Caldera moat-filling sediments	Tgc
Thirsty Canyon Group	**Tt**
Trail Ridge Tuff	Ttt
Pahute Mesa Tuff	Ttp
Comendite of Ribbon Cliff	Ttc
Volcanics of Fortymile Canyon	**Tf**
Beatty Wash Formation	Tfb
rhyolite of Beatty Wash	Tfbw
Timber Mountain Group	**Tm**
tuff of Buttonhook Wash	Tmaw
Ammonia Tanks Tuff	Tma
mafic-rich Ammonia Tanks Tuff	Tmar
mafic-poor Ammonia Tanks Tuff	Tmap
debris-flow breccia related to the Ammonia Tanks Tuff	Tmax
rhyolite of Tannenbaum Hill	Tmat
landslide deposits	Tmatx
Rainier Mesa Tuff	Tmr
mafic-rich Rainier Mesa Tuff	Tmrr
mafic-poor Rainier Mesa Tuff	Tmrp
pre-Grouse Canyon caldera units	**To**

Table 4-2
Key to Hydrostratigraphic Units and Symbols Used in This Report

Hydrostratigraphic Unit	Symbol
Alluvial aquifer	AA
Thirsty Canyon volcanic aquifer	TCVA
Fortymile Canyon composite unit	FCCM
Timber Mountain composite unit	TMCM
Pre-Belted Range composite unit	PBRCM

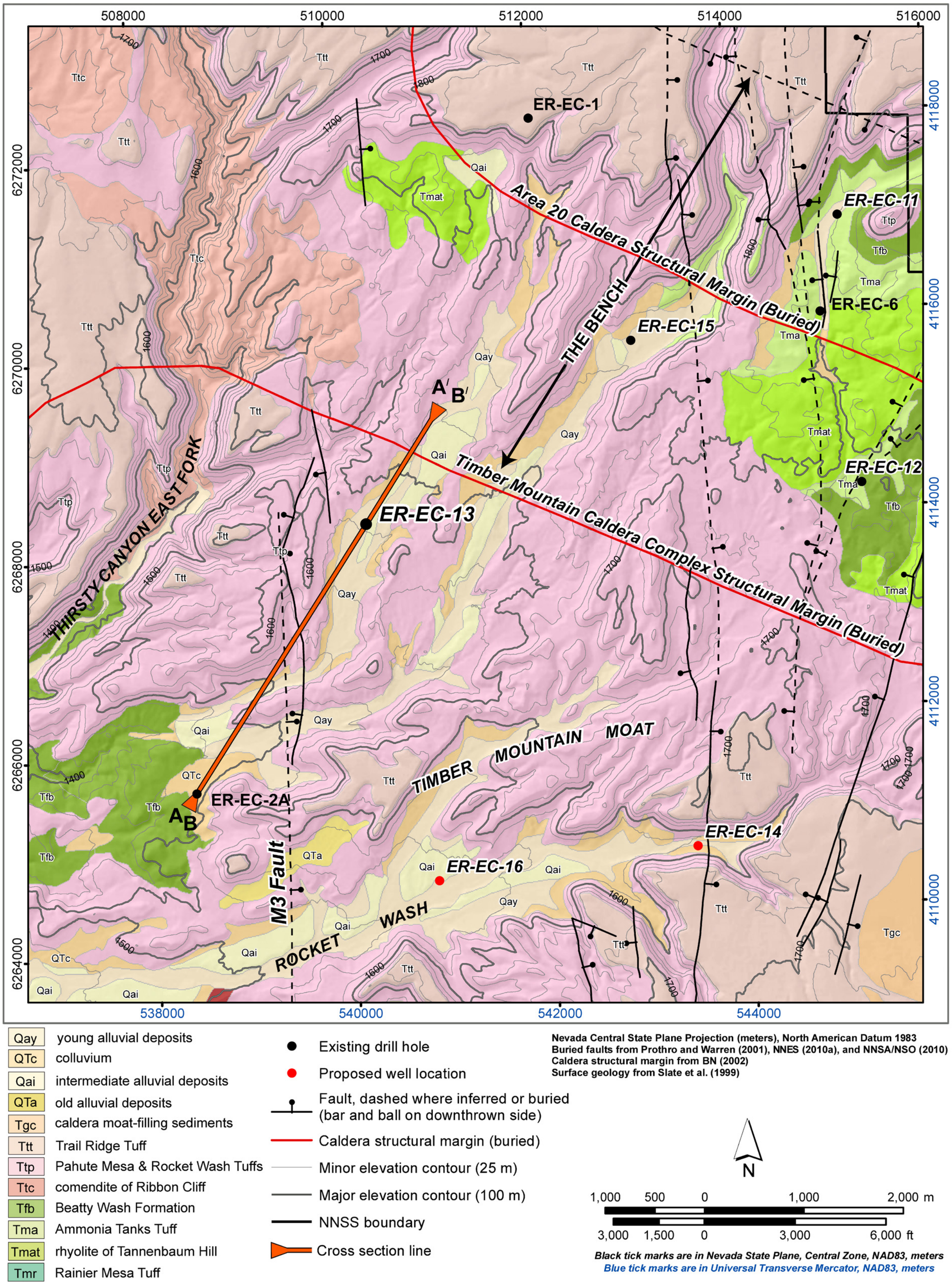


Figure 4-1
Surface Geologic Map of the Well ER-EC-13 Site

dome created the present topographic expression of the TMCC, including Timber Mountain and the surrounding moat (Figure 4-1). Younger volcanic rocks partially fill the moat, and bury most of the Timber Mountain Group rocks within the moat. Moat-filling units exposed at the surface near Well ER-EC-13 include tuff and lava of the Volcanics of Fortymile Canyon (erupted from various vents near the TMCC shortly after resurgence of the central dome of the Ammonia Tanks caldera), ash-flow tuff of the Thirsty Canyon Group (erupted from the Black Mountain caldera located north of Well ER-EC-13; see Figure 1-1), and younger colluvium and alluvium.

Few normal faults have been mapped at the surface within the vicinity of Well ER-EC-13. A gravity-inferred, east-dipping fault, referred to as the M3 fault, is projected to the surface at about 869 m (2,850 ft) west of Well ER-EC-13 at closest approach (NNES, 2010a) (Figure 4-1). The surface trace of a small, north-south-oriented, high-angle, down-to-the-west normal fault (Slate et al., 1999) is located about 750 m (2,460 ft) to the southwest of Well ER-EC-13 at closest approach (Figure 4-1).

4.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Well ER-EC-13 are illustrated in Figure 4-2, and a preliminary interpretation of the distribution of stratigraphic units in the vicinity of the well is shown in cross section in Figure 4-3. The determination of the stratigraphic and lithologic units penetrated by Well ER-EC-13 was aided by examination of, and correlation with, nearby Well ER-EC-2A (NNSA/NV, 2002), which is located 3,192.8 m (10,475 ft) southwest of the Well ER-EC-13 site and also is inside the structural margin of the TMCC (BN, 2002).

Drilling at Well ER-EC-13 began in Quaternary alluvium, which forms the ground surface in the vicinity of the well (O'Conner et al., 1966; Slate et al., 1999) (Figure 4-1). Quaternary alluvium was encountered from the surface to the depth of 6.1 m (20 ft). Below the alluvium, the borehole penetrated a 141.7-m (465-ft) thick rhyolite lava flow from 6.1 to 147.8 m (20 to 485 ft). Typical rhyolite lava-flow facies were encountered including an upper pumiceous zone overlying a stoney lava interior. Below the stoney interior, a lower vitrophyric zone and a basal flow-brecciated pumiceous zone were also encountered. Features common to rhyolite lava were observed in the lithologic samples, including flow banding, spherulites, and lithophysae. The rhyolite lava is assigned stratigraphically to the rhyolite of Beatty Wash, a subunit of the Beatty Wash Formation of the Volcanics of Fortymile Canyon. This assignment is based on the mineralogic assemblage including the absence of quartz phenocrysts and the presence of sphene, and its stratigraphic position at the top of the Volcanics of Fortymile Canyon.

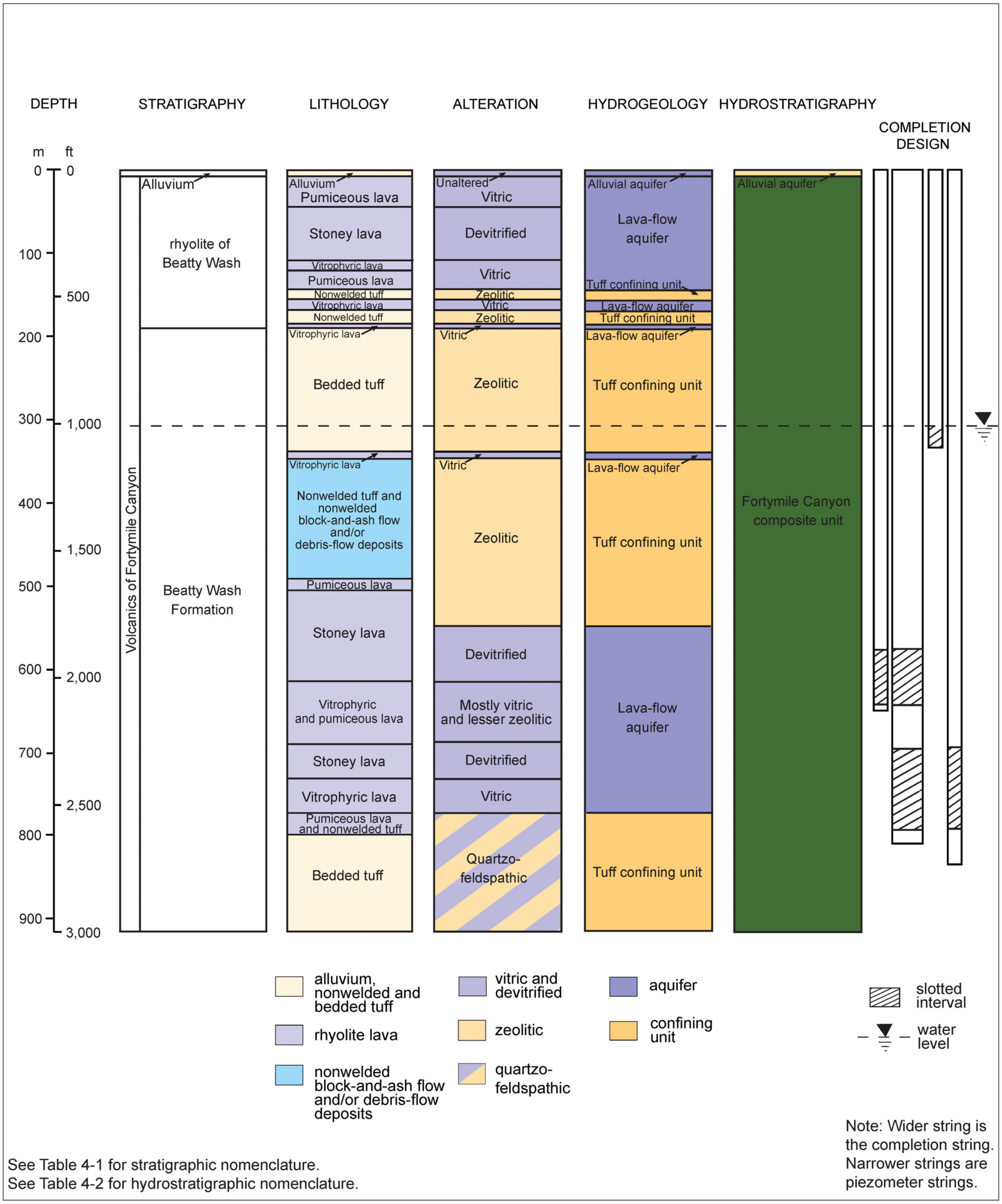


Figure 4-2
Geology and Hydrogeology of Well ER-EC-13

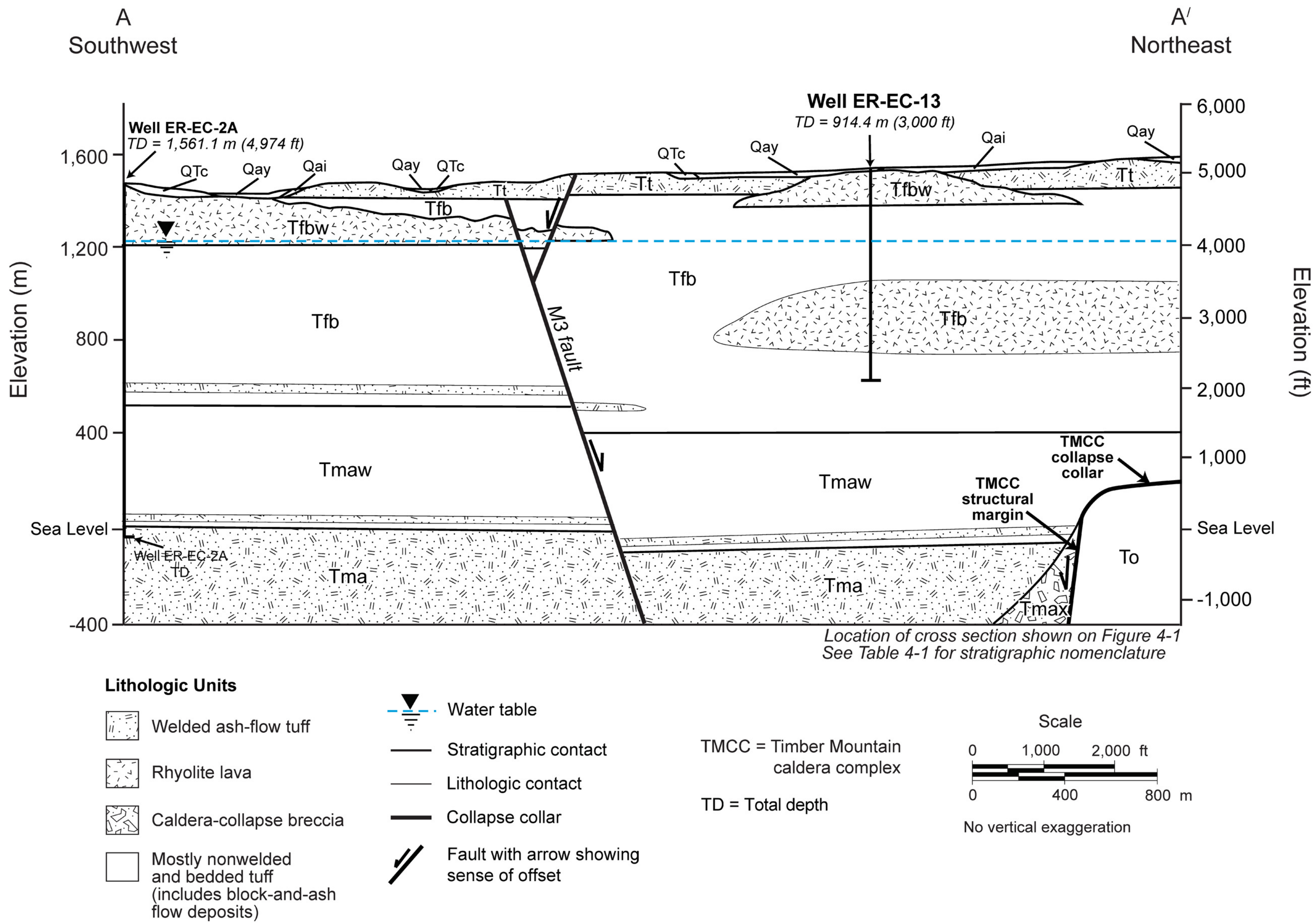


Figure 4-3
Southwest–Northeast Geologic Cross Section A–A' through Well ER-EC-13

Below the uppermost rhyolite lava and within the depth interval 147.8 to 189.0 m (485 to 620 ft), the borehole encountered two thin (less than 10 m [33 ft] thick) but highly conspicuous vitrophyric intervals, each overlain by nonwelded tuff. Very minor amounts of pumiceous lava appear to be associated with each of the vitrophyres, suggesting that the vitrophyres are most likely thin, small-volume, obsidian-like rhyolite lava flows. This interpretation is further supported by the absence within the interval of any welded ash-flow tuff, which would be expected if the vitrophyre units were associated with ash-flow tuffs. The thin vitrophyric lava flows and associated nonwelded tuffs may represent near-vent precursor eruptions related to the overlying rhyolite lava flow. The interval is assigned to the rhyolite of Beatty Wash, based on its mineralogic assemblage and its stratigraphic position just below the thick uppermost rhyolite lava flow.

Well ER-EC-13 penetrated 157.3 m (516 ft) of mostly zeolitic bedded tuff from 189.0 to 346.3 m (620 to 1,136 ft). Thin intercalated vitrophyric intervals are present from 253.6 to 255.7 m (832 to 839 ft) and at the base of the interval, from 338.9 to 346.3 m (1,112 to 1,136 ft). These are interpreted to represent small-volume rhyolite lava flows, based on their similarity to the thin vitrophyric flows described in the overlying interval. The bedded tuff and intercalated vitrophyres are assigned to the Beatty Wash Formation based on the mineralogic assemblage that includes relatively common biotite, the presence of hornblende and sphene, but no quartz phenocrysts.

Below the bedded tuff and intercalated vitrophyres, the well encountered a 145.1-m (476-ft) thick sequence of nonwelded tuff intercalated with distinct zones that are rich in lithic fragments. The lithic-rich zones are interpreted to be nonwelded block-and-ash flow and/or debris-flow deposits. They are conspicuous on geophysical logs as zones of higher resistivity and density. The zones are also clearly observed in the borehole image log, which shows the deposits to be matrix-supported, but with some clasts as large as 0.5 m (1.6 ft) in size. The lithic-rich intervals range in thickness from 0.6 to 21.9 m (2 to 72 ft). Both the upper and lower contacts with nonwelded tuffs are typically sharp, and only crude coarsening-upward grading is observed in some intervals. Analysis of lithologic samples indicates that the matrix consists of zeolitic tuff, and that the lithic fragments are mono-lithologic, consisting almost exclusively of fragments of rhyolite lava with mineral assemblages similar to that of the Beatty Wash Formation. This composition suggests that most of the deposits may best be described as block-and-ash flow deposits. The entire sequence is assigned to the Beatty Wash Formation, based on the mineralogic assemblages of the nonwelded tuffs and matrix fraction of the lithic-rich zones.

The next major lithologic interval encountered in the well occurs from 491.3 to 795.5 m (1,612 to 2,610 ft). This 304.2-m (998-ft) interval is a complex sequence of rhyolite lava-flow facies and much less nonwelded tuff. The upper 129.5 m (425 ft) of the interval above the depth of 620.9 m (2,037 ft) consists mostly of stoney rhyolite lava that is zeolitic in its upper portion and devitrified in the lower portion. The interval is rather conspicuous on the resistivity log, showing relatively low resistivity throughout. Features common to rhyolite lavas were observed, including flow brecciated pumiceous lava at the top of the interval, and spherulites and lithophysae throughout. Flow layering is observed on the borehole image log. Below the depth of 620.9 m (2,037 ft), to the bottom of the interval at 795.5 m (2,610 ft), the section is more complex and diverse, and appears to consist of a stacked series of relatively thin rhyolite lava flows. Vitrophyre is common and conspicuous throughout much of the interval as observed in the lithologic samples and produces distinctive higher spikes on the resistivity log. Zeolitic and quartzo-feldspathic, pumiceous lava is also common and appears associated with the vitrophyres. Typical devitrified stoney rhyolite lava occurs within the middle portion of the sequence from 690.1 to 732.7 m (2,264 to 2,404 ft). Zeolitic tuff is generally scarce, occurring mainly in the lowermost 24.4 m (80 ft) of the interval. The entire interval is assigned to the Beatty Wash Formation, based on its mineralogic assemblage, particularly the absence of quartz phenocrysts and the relative abundance of biotite and sphene.

Zeolitic bedded tuff was encountered from 795.5 m (2,610 ft) to the TD of the well at 914.4 m (3,000 ft). This interval is 118.9 m (390 ft) thick and is assigned to the Beatty Wash Formation, based on its mineralogic assemblage.

4.2.3 Alteration

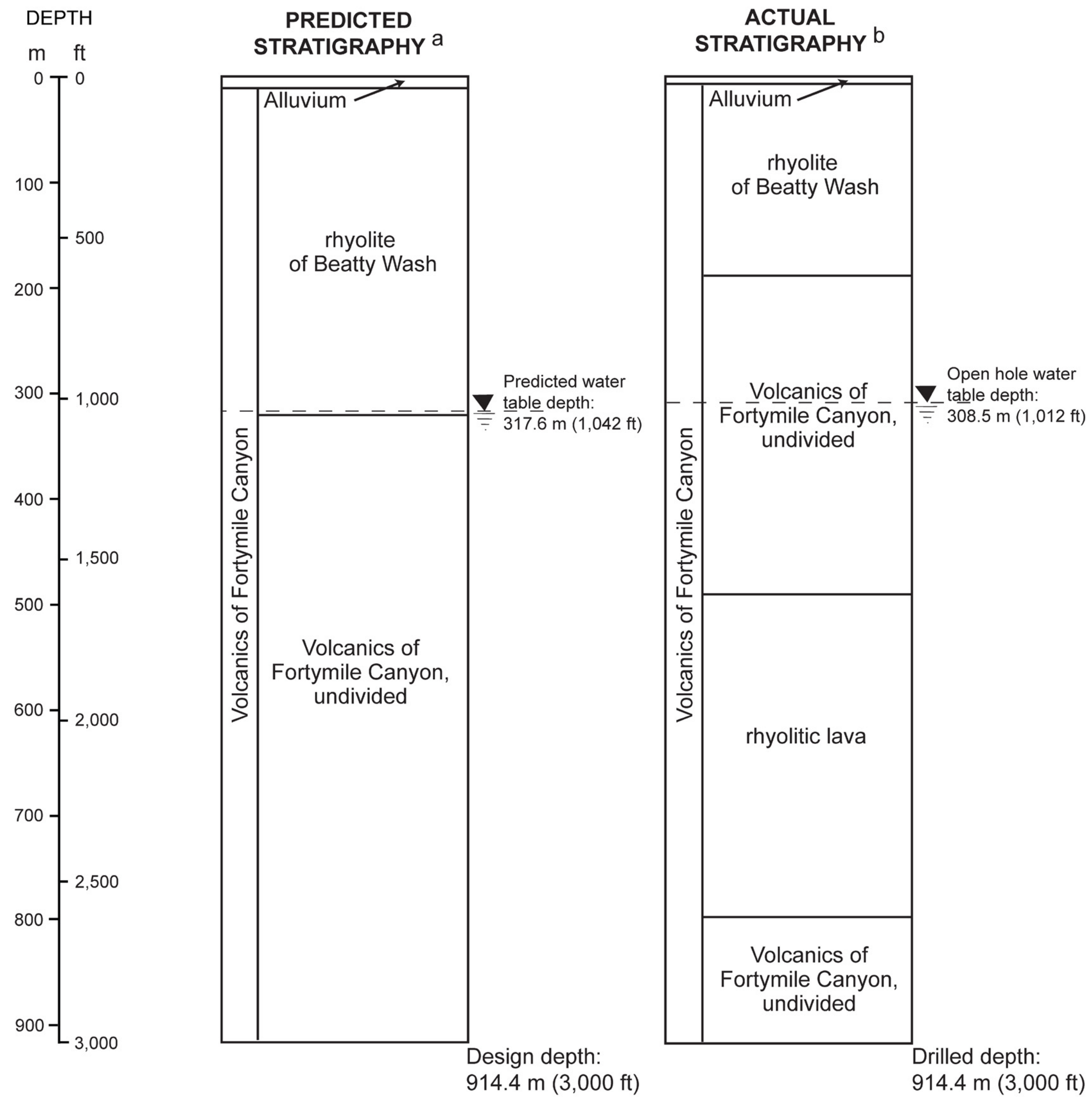
The volcanic rocks penetrated at Well ER-EC-13 show a variety of secondary alteration mineral assemblages that can significantly affect both flow and transport properties. These mineral assemblages result from three main alteration processes: devitrification, zeolitization, and quartzo-feldspathic alteration.

Above 147.8 m (485 ft) in Well ER-EC-13, rocks are either unaltered and, thus, retain their original vitric (i.e., glassy) character, or are devitrified as a result of the original glass being converted to micro-crystalline quartz and feldspar during cooling and degassing shortly after emplacement. Below 147.8 m (485 ft), which can be considered the top of pervasive zeolitization in the well, the less dense and more porous units such as nonwelded and bedded tuffs, pumiceous lavas, and block-and-ash flows are zeolitic as a result of the original glass within these rocks being converted to zeolite minerals such as clinoptilolite. Other rock types that occur below the upper level of zeolitization, however, are resistant to zeolitic alteration. These include devitrified rocks such as stoney lava, which is mineralogically resistant, and vitrophyric lava, which is typically so dense (i.e., has an impervious matrix) that these rocks tend to retain their original glassy character well below the upper level of zeolitization. Below the depth of 771.1 m (2,530 ft), quartzo-feldspathic alteration is pervasive. This higher temperature alteration process has resulted in secondary micro-crystalline quartz and feldspar replacing zeolite as the dominant alteration assemblage.

4.3 Predicted and Actual Geology

The geology encountered at Well ER-EC-13 is similar to that predicted prior to drilling (Figure 4-4). As predicted, the well encountered a very thick section of the Volcanics of Fortymile Canyon, and the well reached TD within these rocks at 914.4 m (3,000 ft), also as predicted. Although not exposed at the surface in the vicinity of the well location, a near-surface rhyolite lava belonging to the rhyolite of Beatty Wash, a subunit of the Beatty Wash Formation, was predicted to be encountered at very shallow depths in the well based on a strong aeromagnetic anomaly observed by Grauch et al. (1999). Very similar to the prediction, Well ER-EC-13 encountered the top of rhyolite lava of the rhyolite of Beatty Wash at 6.1 m (20 ft), but penetrated 168.2 m (552 ft) less than the predicted thickness.

Below the rhyolite of Beatty Wash lava, it was predicted that Well ER-EC-13 would penetrate a very thick and monotonous section of mostly nonwelded tuff to TD, a section similar to that encountered at Well ER-EC-2A (NNSA/NV, 2002). However, the well actually encountered a much more diverse section that includes not only nonwelded and bedded tuffs, but also rhyolite lava and possible block-and-ash flow deposits, all assigned to the Beatty Wash Formation. Although it was recognized prior to drilling that additional deeper rhyolite lavas could be present in the area (Figure E.5-1 in NNES, 2010a), the occurrence of relatively thin rhyolite lava flows consisting almost entirely of vitrophyre and possible block-and-ash flow deposits was not expected, and such units have not been previously recognized in the area. The occurrence of such units is not particularly surprising, however, considering the intra-caldera setting and abundance of rhyolite lava within the Volcanics of Fortymile Canyon. The presence of these lavas may indicate that a source vent(s) of the Beatty Wash Formation is nearby.



[a] NNES, 2010a
[b] See Appendix C for lithologic descriptions

Figure 4-4
Predicted and Actual Stratigraphy at Well ER-EC-13

4.4 Hydrogeology

The saturated portion of Well ER-EC-13 consists of an alternating sequence of tuff confining units and LFAs. Devitrified and vitrophyric rhyolite lavas within the Beatty Wash Formation form LFAs. Although rhyolite lava flows stack up to form a single 224.9-m (738-ft) thick LFA in the lower portion of the well, the relatively thin nature of some individual flows may result in reduced vertical continuity and limited lateral extent. The zeolitic and quartzo-feldspathic lavas, bedded and nonwelded tuffs, and block-and-ash flow and/or debris-flow deposits form tuff confining units. All of these hydrogeologic units are grouped within the FCCM (Figure 4-2), which is shown in cross section in Figure 4-5.

Prior to drilling, it was predicted that the water table would be encountered at a depth of 317.6 m (1,042 ft), within the base of the near-surface rhyolitic lava of the rhyolite of Beatty Wash. The actual water table depth on November 5, 2010, was 308.0 m (1,010.6 ft) and was within zeolitic bedded tuff within the Beatty Wash Formation. This bedded tuff is one of the many tuff confining units that comprise the FCCM.

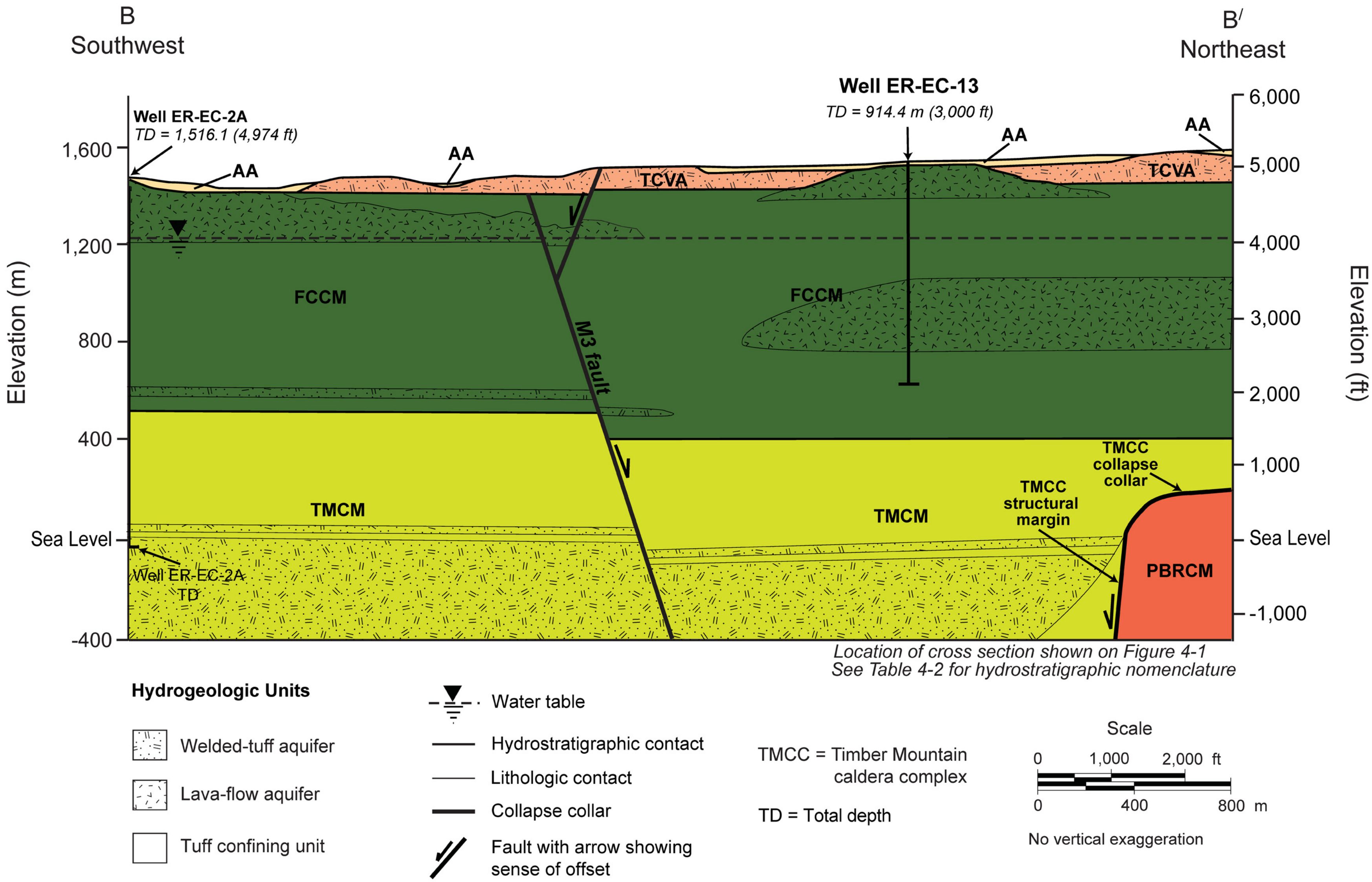


Figure 4-5
Southwest–Northeast Hydrostratigraphic Cross Section B–B’ through Well ER-EC-13

5.0 Hydrology

5.1 Water-Level Information

Prior to drilling, the water level at Well ER-EC-13 was estimated to be 317.6 m (1,042 ft) below ground surface, within the FCCM. During open-hole geophysical logging operations on October 9, 2010, after the borehole had penetrated a bedded tuff within the FCCM, a fluid-level depth of 308.5 m (1,012 ft) or 1,268.9 m (4,163.1 ft) elevation was measured. After the borehole had reached TD (October 18, 2010), a fluid-level depth for the FCCM was measured at 308.5 m (1,012 ft) on October 25, 2010. On November 5, 2010, fluid levels were measured by N-I in the three piezometer strings. In the shallow piezometer, the fluid level was 308.0 m (1,010.6 ft). In the intermediate piezometer, the water level was 308.0 m (1,010.6 ft). In the deep piezometer, the fluid level was 308.0 m (1,010.5 ft). All three piezometer strings access the FCCM.

5.2 Water Production

Water production was determined during drilling of Well ER-EC-13 on the basis of visual estimates of discharge and on the basis of dilution of a lithium-bromide tracer, as measured by N-I field personnel (N-I, 2011). The first observation of water in the drill fluid returns was reported on October 8, 2010, at the depth of 318.5 m (1,045 ft), within bedded tuff in the Beatty Wash Formation. The production rate remained relatively low and constant (57 to 76 Lpm [15 to 20 gpm]). The decision was made to stop drilling at the depth of 335.0 m (1,099 ft), where water production had increased to 170 Lpm (45 gpm), to run geophysical logs and install the surface casing. The casing was landed at the depth of 330.9 m (1,085.6 ft) and cemented in place. When drilling resumed on October 13, 2010, the water production rate initially remained constant at 155 to 246 Lpm (41 to 65 gpm), but began to steadily increase starting at the depth of approximately 518.2 m (1,700 ft). The flow rate reached a maximum of 3,407 Lpm (900 gpm) at the depth of approximately 853.4 m (2,800 ft), within rhyolite lava of the Beatty Wash Formation. However, lithium-bromide-dilution concentrations indicate a reduction in water production below 731.5 m (2,400 ft) to 1,514 Lpm (400 gpm) or less, and do not accurately reflect visual observations of fluid production from the borehole. Below the depth of approximately 853.4 m (2,800 ft) flow rate gradually decreased to 2,839 Lpm (750 gpm) at TD.

Estimated water production rates during drilling are presented graphically in Appendix A-1. More accurate water production information will be available after hydraulic testing is conducted following completion and development of the well.

5.3 Flow Meter Data

Flow meter data, along with temperature, electrical conductivity, and pH measurements, are typically used in UGTA wells to characterize borehole fluid variability, which may indicate inflow and outflow zones. DRI personnel ran their chemistry log to obtain temperature, electrical conductivity, and pH measurements, and their heat-pulse flow log to obtain flow direction within the FCCM shortly after the TD was reached. The DRI flow log indicated a long zone of outflow between the depths of 358.1 and 640.1 m (1,175 and 2,100 ft) (DRI, 2010), with a more discrete outflow zone in its lower portion, from 531.2 to 640.1 m (1,743 to 2,100 ft). This lower outflow zone corresponds to inflections on the electrical conductivity and temperature logs. Borehole image logs through the lower outflow zone show a cluster of five fractures in the interval 600.5 to 604.7 m (1,970 to 1,984 ft) within the lower portion of a stoney lava interval. These fractures are likely to be hydraulically conductive and at least partially responsible for outflow within the lower zone. The fractures dip in a northwesterly direction between 54 to 65 degrees, and thus, are optimally oriented for openness relative to the present-day minimum horizontal stress direction. The fracture cluster also corresponds to a conspicuous perturbation in temperature as observed on the differential temperature log at a depth of 603.2 m (1,979 ft).

5.4 Groundwater Characterization Samples

Following geophysical logging on October 21, 2010, DRI personnel collected depth-discrete groundwater characterization samples within the open borehole at the depths of 655.3 and 762.0 m (2,150 and 2,500 ft). The purpose of these samples was to provide a framework of initial groundwater chemistry based on a select number of analytical parameters. These samples were analyzed for metal, organic and inorganic constituents, tritium, gross alpha and beta, and plutonium. Tritium was not detected in these samples (N-I, 2011).

Both samples were collected prior to completion and final development of the well. These analytical results should be used with care because water quality measurements may be affected by constituents of the drilling fluids, and thus may not accurately reflect natural groundwater quality. The results of groundwater analyses are typically reported in data reports prepared by the analyzing laboratories and in UGTA project reports (e.g., the water chemistry database and the transport data document).

6.0 Precompletion and Open-Hole Development

Initial well development conducted in Well ER-EC-13 consisted of using the drill string to air-lift groundwater to remove residual cuttings and drilling fluids from the borehole. This took place prior to the final logging operation, after the TD was reached.

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7.0 Well Completion

7.1 Introduction

Well completion refers to the installation in a borehole of a string of tubing or casing that is slotted or screened at one or more locations along its length. The completion process also typically includes emplacement of backfill materials around the string(s), with coarse fill such as gravel adjacent to the open intervals, and impervious materials such as cement placed between or above the open intervals to isolate them. The string(s) serves as a conduit for inserting a pump in the well, for inserting devices for measuring fluid level, and for sampling, so that accurate potentiometric and water chemistry data can be collected from known portions of the borehole.

The proposed design for Well ER-EC-13 was presented in NNES (2010a) and in the NSTec FAWP (NSTec, 2010b). The completion plans are summarized here in Section 7.2.1, and the actual well completion design, based on the hydrogeology encountered in the borehole, is presented in Section 7.2.2. The rationale for differences between the planned and actual designs is discussed in Section 7.2.3, and the completion methods are presented in Section 7.3. Figure 7-1 is a schematic diagram of the well completion design. Figure 7-2 shows a plan view and profile of the final wellhead surface completion. Table 7-1 is a construction summary for the completion strings.

7.2 Well Completion Design

The final completion design differs from the proposed design, as described in the following sections.

7.2.1 Proposed Completion Design

The original completion design (NNES, 2010a) was based on the assumption that Well ER-EC-13 would penetrate the water table within the rhyolite of Beatty Wash and reach TD within the nonwelded tuffs of the FCCM. The primary goal of the proposed completion design was to provide groundwater production data from LFAs within the FCCM and to provide access to groundwater for monitoring and sampling. A 16-in. surface casing string was intended to extend to the depth of approximately 310.9 m (1,020 ft) to stabilize and isolate the unsaturated zone from the underlying saturated rocks.

The well was planned to be completed using a string of 6⅝-in. casing with no more than two slotted intervals that would provide access to high-transmissivity zones within the FCCM.

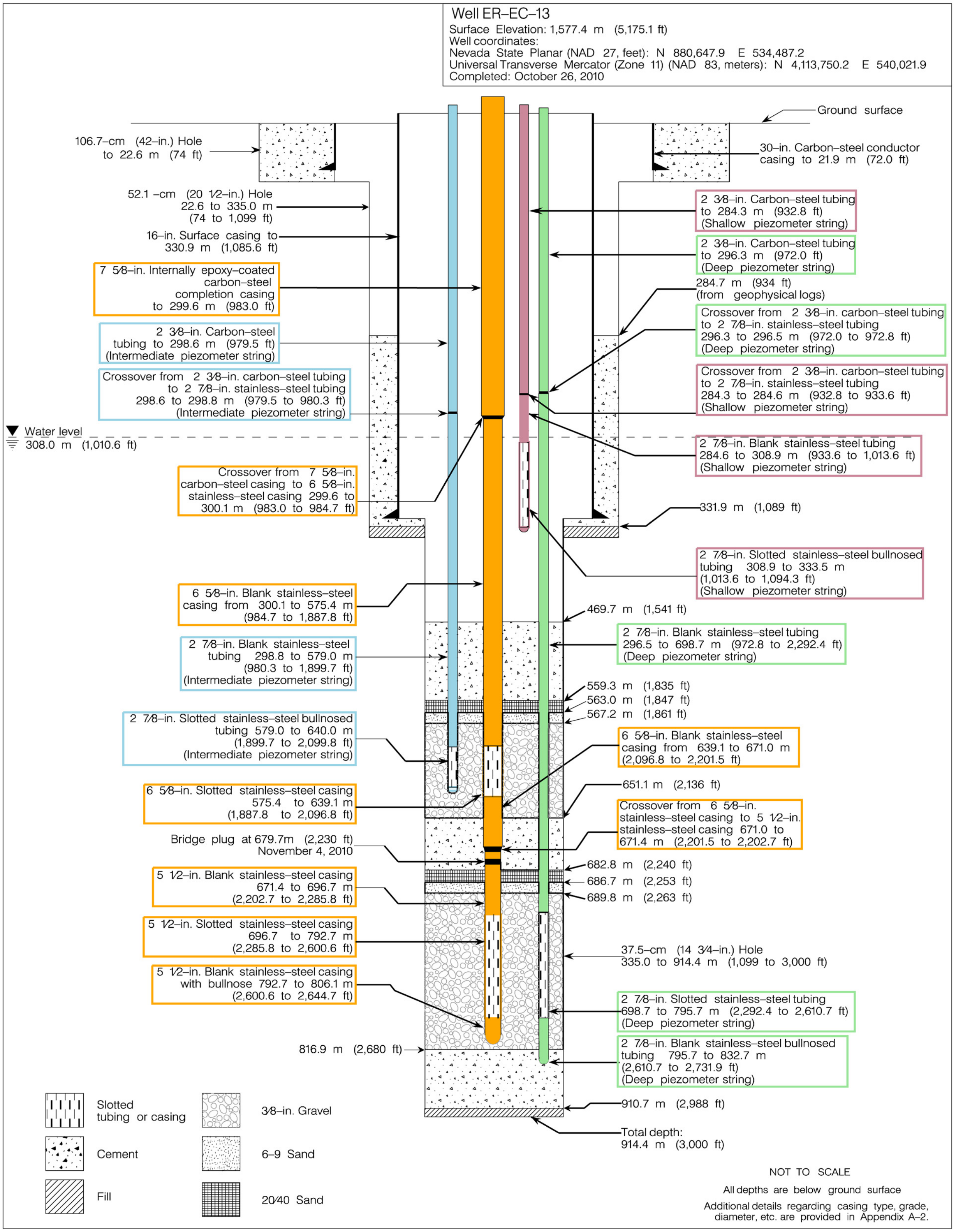

Figure 7-1
As-Built Completion Schematic for Well ER-EC-13

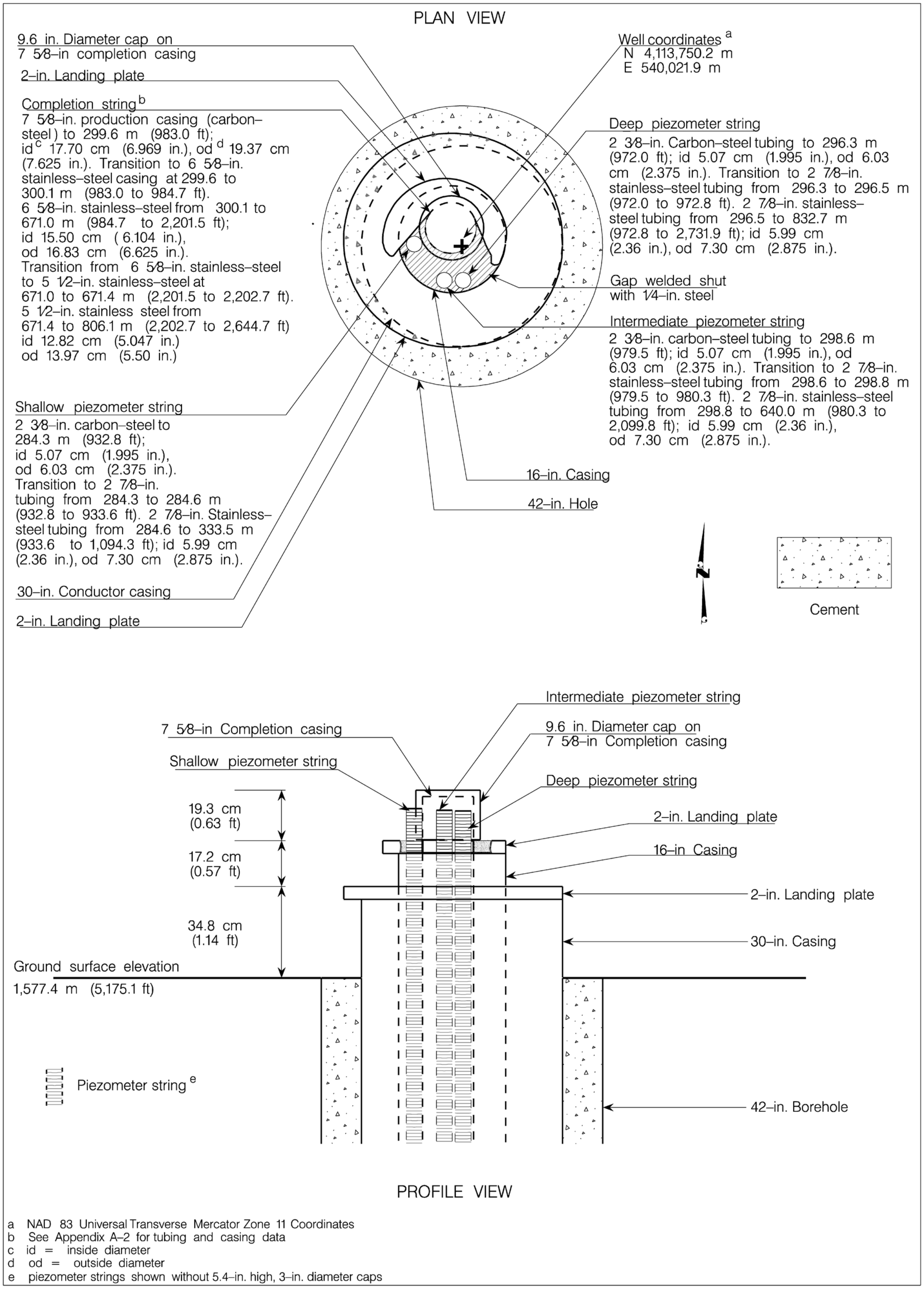

Figure 7-2
Wellhead Diagram for Well ER-EC-13

Table 7-1
Well ER-EC-13 As-Built Completion String Construction Summary

String	Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
Shallow Piezometer String	2⅜-in. carbon-steel tubing with cross-over sub	0 to 284.6 (0 to 933.6)	**Blank**	None	
	2⅞-in. stainless-steel tubing	284.6 to 333.5 (933.6 to 1,094.3)	**Blank** 284.6 to 308.9 (933.6 to 1,013.6)	None	
			2 Slotted Joints [a] (lowest joint is bullnosed) 308.9 to 333.5 (1,013.6 to 1,094.3)		
Intermediate Piezometer String	2⅜-in. carbon-steel tubing with cross-over sub	0 to 298.8 (0 to 980.3)	**Blank**	None	
	2⅞-in. stainless-steel tubing	298.8 to 640.0 (980.3 to 2,099.8)	**Blank** 298.8 to 579.0 (980.3 to 1,899.7)	**Type II Neat Cement** 469.7 to 559.3 (1,541 to 1,835)	None
			5 Slotted Joints [a] (lowest joint is bullnosed) 579.0 to 640.0 (1,899.7 to 2,099.8)	None	**20/40 Sand** 559.3 to 563.0 (1,835 to 1,847) **6-9 Sand** 563.0 to 567.2 (1,847 to 1,861) **⅜-in. Washed Gravel** 567.2 to 651.1 (1,861 to 2,136)

Table 7-1
Well ER-EC-13 As-Built Completion String Construction Summary (continued)

String	Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
Deep Piezometer String	2⅜-in. carbon-steel tubing with cross-over sub	0 to 296.5 (0 to 972.8)	**Blank**	None	
	2⅞-in. stainless-steel tubing	296.5 to 832.7 (972.8 to 2,731.9)	**Blank** 296.5 to 698.7 (972.8 to 2,292.4)	**Type II Neat Cement** 651.1 to 682.8 (2,136 to 2,240)	None
			8 Slotted Joints [a] 698.7 to 795.7 (2,292.4 to 2,610.7)	None	**20/40 Sand** 682.8 to 686.7 (2,240 to 2,253) **6-9 Sand** 686.7 to 689.8 (2,253 to 2,263) **⅜-in. Washed Gravel** 689.8 to 816.9 (2,263 to 2,680)
			Blank and Bullnosed 795.7 to 832.7 (2,610.7 to 2,731.9)	**Type II Neat Cement** 816.9 to 910.7 (2,680 to 2,988)	None
Completion Casing [c]	7⅝-in. epoxy-coated carbon-steel casing with cross-over sub	0 to 300.1 (0 to 984.7)	**Blank**	None	
	6⅝-in. stainless-steel completion casing with cross over sub	300.1 to 671.4 (984.7 to 2,202.7)	**Blank** 300.1 to 575.4 (984.7 to 1,887.8)	Same as for Intermediate Piezometer String	None
			10 Slotted Joints [b] 575.4 to 639.1 (1,887.8 to 2,096.8)	None	Same as for Intermediate Piezometer String
			Blank 639.1 to 671.4 (2,096.8 to 2,202.7)	Same as for Deep Piezometer String	None
	5½-in. stainless-steel completion casing	671.4 to 806.1 (2,202.7 to 2,644.7)	**Blank** 671.4 to 696.7 (2,202.7 to 2,285.8)	Same as for Deep Piezometer String	None
			15 Slotted Joints [b] 696.7 to 792.7 (2,285.8 to 2,600.6)	None	Same as for Deep Piezometer String
			Blank and Bullnosed 792.7 to 806.1 (2,600.6 to 2,644.7)	None	

Table 7-1
Well ER-EC-13 As-Built Completion String Construction Summary (continued)

a Slots are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long, arranged in 8 rows, on staggered 10.2-cm (4.0-in.) centers.

b Slots are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long, arranged in 12 rows, on staggered 15.2-cm (6.0-in.) centers.

c A bridge plug was set within the completion casing at 679.7 m (2,230 ft) on November 4, 2010.

The intervals selected for development were to be determined on the basis of lithologic, hydrologic, and preliminary water chemistry information obtained during drilling and from geophysical logging of the borehole. The 6⅝-in. stainless-steel casing string was to be positioned approximately 6.1 m (20 ft) above the bottom of the borehole, with a blank bullnose section at its terminal end. The two slotted sections would be separated by blank stainless-steel casing. The 6⅝-in. stainless-steel completion string would transition to a string of internally epoxy-coated carbon-steel 7⅝-in. casing at approximately 6.7 m (22 ft) above the water table via a stainless-steel crossover sub. Gravel packs were to be placed outside the slotted intervals, and layers of sand and cement were to be placed between the gravel layers to prevent communication between aquifers.

Before the installation of the well-completion string, up to two 2⅜-in. carbon-steel piezometer strings were planned to be installed between the borehole wall and the completion string so that the water levels could be monitored during testing, and water samples could be taken directly from the developed intervals. The piezometer strings were planned to be stainless steel below the water table. Similar to the completion string, the crossover from carbon-steel to stainless-steel tubing would be set at approximately 12.8 m (42 ft) above the water table.

7.2.2 As-Built Completion Design

The final design of the Well ER-EC-13 completion was determined after the final TD of 914.4 m (3,000 ft) was reached, through consultation with members of the UGTA Well ER-EC-13 Drilling Advisory Team, on the basis of on-site evaluation of data such as lithology and water production, drilling data, and data from various geophysical logs. As shown in Figure 7-1, a completion casing string and three piezometer strings were installed in Well ER-EC-13.

The main completion string consists of a section of 5½-in. stainless-steel casing suspended from 6⅝-in. stainless-steel casing, which was set at the depth of 806.1 m (2,644.7 ft). The 6⅝-in. stainless-steel casing is suspended from 7⅝-in. internally epoxy-coated carbon-steel casing which extends from the surface to the depth of 299.6 m (983.0 ft), which is 8.5 m (28 ft) above the water table. The stainless-steel 6⅝-in. casing is slotted in the interval from 575.4 to 639.1 m (1,887.8 to 2,096.8 ft), and the stainless-steel 5½-in. casing is slotted in the interval from 696.7 to 792.7 m (2,285.8 to 2,600.6 ft). The completion string was terminated with 12.8 m (42 ft) of blank stainless-steel casing and a 0.64 m (2.1 ft) stainless-steel bullnose to function as a sediment sump. The machine-cut openings in each slotted casing joint are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long. The machine-cut slots are arranged in rows of 12, with rows staggered 22.5 degrees on 15.2-cm (6-in.) centers. The two slotted intervals provide access to devitrified and vitric lava within the FCCM. The completion casing was installed in the open borehole with two separate intervals of gravel packing, sand, and cement to provide access to an LFA within the Beatty Wash Formation.

Three piezometer strings were installed in the annular space of the well. The shallow piezometer string was installed within the space between the completion casing and the 16-in. surface casing, and extends into the open hole below. The intermediate and deep piezometer strings were installed outside the two slotted intervals of the completion casing, adjacent to the borehole wall. See Table 7-1 for information about the slots in these tubing strings.

On November 4, 2010, a removable bridge plug was installed at 679.7 m (2,230 ft) between the two slotted intervals in the 5½-in. completion string to isolate the two monitoring zones from each other.

7.2.3 Rationale for Differences between Planned and Actual Well Design

The geology of Well ER-EC-13 did not differ significantly from that predicted (see Section 4.3). The original completion design was based on the geologic information from nearby UGTA Well ER-EC-2A (NNSA/NV, 2002), located approximately 3.2 km (2.0 mi.) southwest. It was predicted that at least one thick lava flow could be penetrated in the unsaturated zone. A strong aeromagnetic anomaly, observed by Grauch et al. (1999) and centered at the location of Well ER-EC-13, was interpreted to indicate this near-surface lava flow. Below this lava, it was predicted that most of the saturated portion of the borehole would be within tuff confining units of the FCCM; however, it was predicted that there could be some intercalated lava flows.

The saturated portion of the borehole is not entirely composed of a tuff confining unit. A variably altered, devitrified to vitric lava was encountered within the FCCM, so the completion design was modified to include two completion zones within this single LFA. The decision to install two separate completion intervals was made by the Well ER-EC-13 Drilling Advisory Team shortly after geophysical logging operations were completed. The decision was based on the formation as discerned from examination of drill cuttings and geophysical logs, and the incremental increases in water production as recorded during drilling. By installing two separate completions, as opposed to a single long completion interval, more can be learned about the internal complexity and interconnectivity of the intercalated lava flows of the Beatty Wash Formation. However, the basic plan of installing a single string consisting of larger diameter carbon-steel casing above the water table and smaller diameter stainless-steel casing in the saturated zone, with two completion intervals, was accomplished.

7.3 Well Completion Method

Completion activities began on October 23, 2010, when the drill crew began running the three 2⅞-in. piezometer strings. The deep 2⅞-in. stainless-steel string was landed at the depth of 832.7 m (2,731.9 ft), the intermediate 2⅞-in. piezometer string was landed at 640.0 m (2,099.8 ft), and the shallow 2⅞-in. piezometer string was landed at the depth of 333.5 m (1,094.3 ft). After the three piezometer strings were inserted, the casing crew landed the completion casing on October 24, 2010, at a depth of 806.1 m (2,644.7 ft).

The drill crew lowered a tremie line into the borehole for use during emplacement of stemming material (the tremie line was pulled up as stemming progressed). Colog ran a nuclear annular investigation log (NAIL) in the various tubing strings to monitor the stemming process.

The bottom portion of the borehole was filled with cement from the top of fill at 910.7 m (2,988 ft) to 816.9 m (2,680 ft). The lower gravel pack, consisting of ⅜-in. washed gravel, was emplaced in the annulus of the borehole from the top of cement at 816.9 m (2,680 ft) to the depth of 689.8 m (2,263 ft), encompassing the lower slotted interval of the completion string and the slotted portion of the deep piezometer string. Next, a section of sand was placed above the gravel to prevent cement from infiltrating the gravel pack. A 3.0-m (10-ft) layer of 6-9 coarse silica sand was placed through the tremie line, followed by a 4.0-m (13-ft) thick layer of 20/40 fine silica sand. The NSTec cement crew next placed 31.7 m (104 ft) of Type II cement, followed by water to balance the plug.

After waiting an hour for the cement to set, the crew placed the upper gravel pack, which had a total rise of 83.8 m (275 ft). This gravel pack encompasses the upper slotted interval of the completion casing and the slotted portion of the intermediate piezometer string. Next, two stages each of 6-9 coarse silica sand (total rise of 4.3 m [14 ft]) and 20/40 fine silica sand (total rise of 3.7 m [12 ft]) were placed. Each addition was monitored using the NAIL log, and the tremie line was pulled up as each section was added. The cement crew then emplaced the upper 89.6-m (294-ft) layer of Type II cement, again balancing the plug using water. After this final stage of stemming was completed, on October 26, 2010, the tremie line was removed and the cement and logging crews rigged down.

The UDI drill rig was released after the production casing was installed. Hydrologic testing is planned as a separate effort, so a pump was not installed in the well, and no well-development or pumping tests were conducted immediately after completion.

All well construction materials used for the completion were inspected according to relevant procedures, as listed in SNJV (2009a). Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

8.0 Planned and Actual Costs and Scheduling

The original NSTec-approved baseline task plan cost estimate for drilling and completing Well ER-EC-13 was based on drilling to a planned TD of 914.4 m (3,000 ft) from the surface and installing one completion string and up to two piezometer strings. The well was drilled to the originally planned TD (914.4 m [3,000 ft]). A single completion string with two slotted intervals and two piezometer strings were installed as planned. However, an additional piezometer string was installed for access to the water table.

The baseline schedule for drilling and completing Well ER-EC-13 was 29 days (Figure 8-1). It took 25 days to construct Well ER-EC-13, starting with the drilling of the 52.1-cm. (20.5-in.) surface hole.

The cost analysis for Well ER-EC-13 begins with the mobilization of the UDI drill rig to the drill site, where the conductor hole had already been constructed. The total cost for Well ER-EC-13 includes all drilling costs: charges by the drilling subcontractor, charges by other support subcontractors (including compressor services, drilling fluids, casing services, down-hole tools, and geophysical logging), and charges by NSTec for mobilization and demobilization of equipment, cementing services, RCT services, inspection services, site supervision, and geotechnical consultation. The cost of building the access roads, drill pad, sumps, and conductor hole is not included, nor is the cost of well-site support by N-I personnel.

The total planned cost for constructing Well ER-EC-13 was $4,343,350. The actual cost was $4,524,174, or 4.2 percent more than the planned cost. This is due to additional time spent moving the drill rig and attendant equipment from the Well ER-20-4 location on the NNSS to the Well ER-EC-13 offsite location (mobilization took a total of nine days). Additional costs were also incurred for road maintenance and installing a down-hole pump at Well ER-EC-8 to serve as the water-supply well, after the pump failed at Well ER-EC-2A. Because drilling proceeded smoothly and Well ER-EC-13 took four fewer days to drill than planned, much of the initial overrun cost was offset by the savings of a shortened drilling period. Figure 8-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-EC-13.

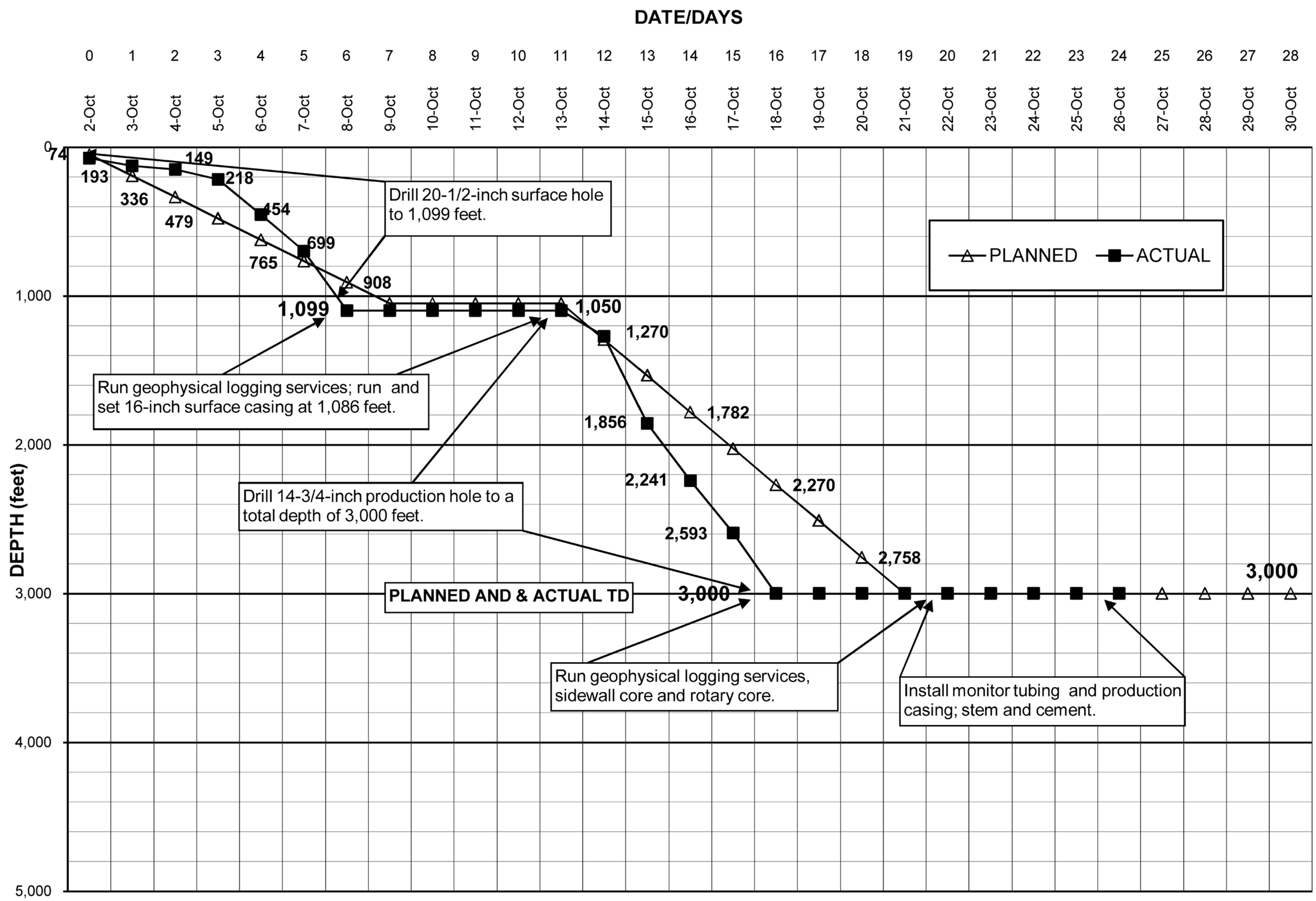

Figure 8-1
Planned and Actual Construction Progress for Well ER-EC-13

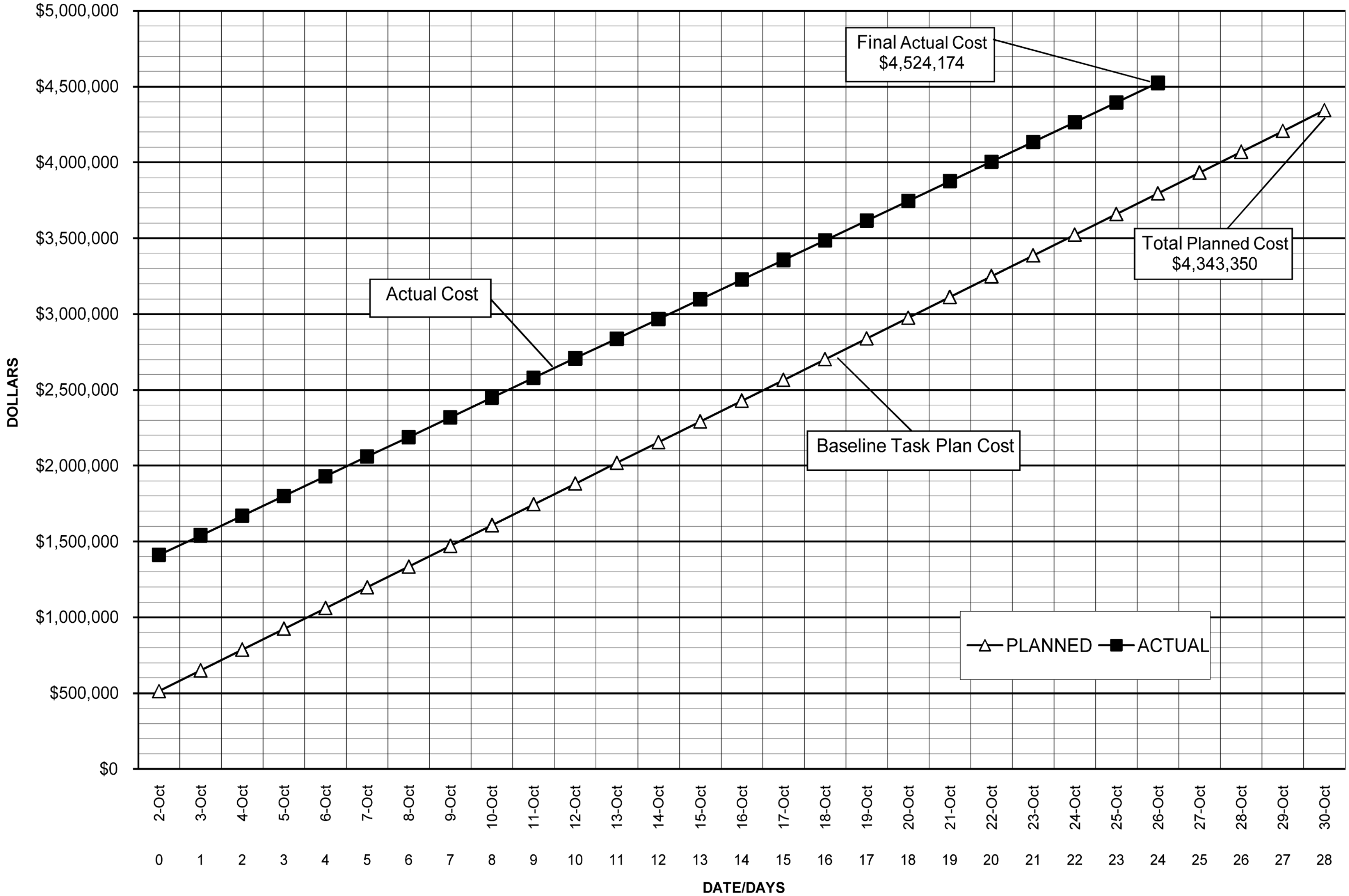

Figure 8-2
Planned and Actual Cost of Constructing Well ER-EC-13

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9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Main hole drilling at Well ER-EC-13 commenced on October 2, 2010, and concluded on October 18, 2010, at a total drilled depth of 914.4 m (3,000 ft). After geophysical logging, the completion string and three piezometer strings were installed and sand- and gravel-packed. The hole was stemmed to the depth of 469.7 m (1,541 ft) on October 24–26, 2010. The only problems encountered during construction of Well ER-EC-13 were delays due to an accident investigation (approximately 1 day) and waiting on inspection of the flow line after installing the 16-in. surface casing (approximately 2.5 days).

No radionuclides above the minimum detection limit of the equipment used were encountered in the groundwater produced from Well ER-EC-13. Lead analysis in the drilling effluent was not required, but drilling tools and other equipment used in the borehole were checked for lead, and none was found.

The main completion string consists of a section of 5½-in. stainless-steel casing suspended from 6⅝-in. stainless-steel casing, which was set at the depth of 806.1 m (2,644.7 ft). The 6⅝-in. stainless-steel casing is suspended from 7⅝-in. internally epoxy-coated carbon-steel casing which extends from the surface to the depth of 299.6 m (983.0 ft), which is 8.5 m (28 ft) above the water table. The stainless-steel 6⅝-in. casing is slotted in the interval from 575.4 to 639.1 m (1,887.8 to 2,096.8 ft), and the stainless-steel 5½-in. casing is slotted in the interval from 696.7 to 792.7 m (2,285.8 to 2,600.6 ft). The top slotted section consists of 10 consecutive stainless-steel slotted joints and the bottom slotted section consists of 15 consecutive stainless-steel slotted joints. Each slotted interval is gravel-packed, and the gravel intervals are separated by 31.7 m (104 ft) of cement. These intervals are open to rhyolite lavas within the Beatty Wash Formation (FCCM).

Three piezometer strings were set to monitor the water levels in different portions of the borehole during hydraulic testing. A shallow 2⅞-in. stainless-steel piezometer string was installed within the space between the completion casing and the 16-in. surface casing, at the depth of 333.5 m (1,094.3 ft), to monitor the water table. An intermediate 2⅞-in. stainless-steel piezometer string was set at the depth of 640.0 m (2,099.8 ft), and a deep 2⅞-in. stainless-steel piezometer string was set at the depth of 832.7 m (2,731.9 ft). All three stainless-steel piezometer strings hang from 2⅜-in. carbon-steel tubing, connected via crossover subs. The shallow string is slotted in the depth interval 308.9 to 333.5 m (1,013.6 to 1,094.3 ft), the intermediate string is slotted from 579.0 to 640.0 m (1,899.7 to 2,099.8 ft), and the deep string is slotted from 698.7 to 795.7 m (2,292.4 to 2,610.7 ft). The three piezometer strings provide access to different LFAs in the FCCM

Geologic data collected during drilling included composite drill cuttings samples collected every 3.0 m (10 ft) from 22.6 m (74 ft) to TD. In addition, 29 sidewall core samples were collected in the interval 358.1 to 902.2 m (1,175 to 2,960 ft). Open-hole geophysical logging was conducted in the upper unsaturated portion of the borehole before installation of the surface casing, and in the lower saturated portion of the borehole after the TD of the well was reached and before installation of the completion casing. Some of these logs were used to aid in construction of the well, while others help to verify the geology and determine the hydrologic characteristics of the rocks.

Well ER-EC-13 is collared in Quaternary alluvium, and penetrated 6.1 m (20 ft) of alluvium and 908.3 m (2,980 ft) of Tertiary volcanic rocks. The Tertiary volcanic rocks consist largely of rhyolite lavas, block-and-ash flow and/or debris-flow deposits, and zeolitic to quartzo-feldspathic nonwelded and bedded tuffs. Water levels were measured in the well on November 5, 2010. In the shallow piezometer, the water level was 308.0 m (1,010.6 ft). In the intermediate piezometer, the water level was 308.0 m (1,010.6 ft). In the deep piezometer, the water level was 308.0 m (1,010.5 ft). The elevation of the water level is 1,269.3 m (4,164.5 ft).

9.2 Recommendations

All the geologic and hydrologic data and interpretations from Well ER-EC-13 should be integrated into the PM–OV Phase II HFM. This will allow for more precise characterization of groundwater flow direction and velocity in the Pahute Mesa area.

The water level in Well ER-EC-13 should be monitored during the drilling and testing of nearby wells. Groundwater chemistry should be monitored on a routine basis to learn more about regional groundwater flow paths and possible migration of the contaminants from UGTs on Pahute Mesa. These data will also improve the understanding of aquifer connectivity along the flow path from UGTs on Pahute Mesa.

In addition, long-term water-level monitoring instrumentation should be installed in one or two of the piezometer strings. This would allow hydrologists to learn about how water levels within the Timber Mountain moat, and their variations over time, compare with those in other parts of

Pahute Mesa, including the Bench, and would improve the understanding of the groundwater flow system in this part of the model area.

9.3 Lessons Learned

The efficiency of drilling and constructing wells to obtain hydrogeologic data in support of the UGTA project continues to improve as experience is gained with each new well. Sometimes difficult drilling conditions are encountered and challenges are confronted. A new lesson was learned during the construction of Well ER-EC-13, the seventh well in the 2010 Pahute Mesa Phase II drilling initiative, which pertains mainly to well sites in remote areas:

- To access the Well ER-EC-13 site, over 32.2 km (20 mi) of dirt access road had to be constructed. The unavailability of water during the first part of road construction resulted in the deterioration of the road conditions. Watering the road and routine grading must be undertaken to keep driving hazards at a minimum. Caution must be observed while driving (anticipating on-coming traffic, road wash-outs, blind corners, and the location of pull-outs to yield to oncoming vehicles, etc.).

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Appendix A
Drilling Data

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Appendix A-1
Drilling Parameter Log for Well ER-EC-13

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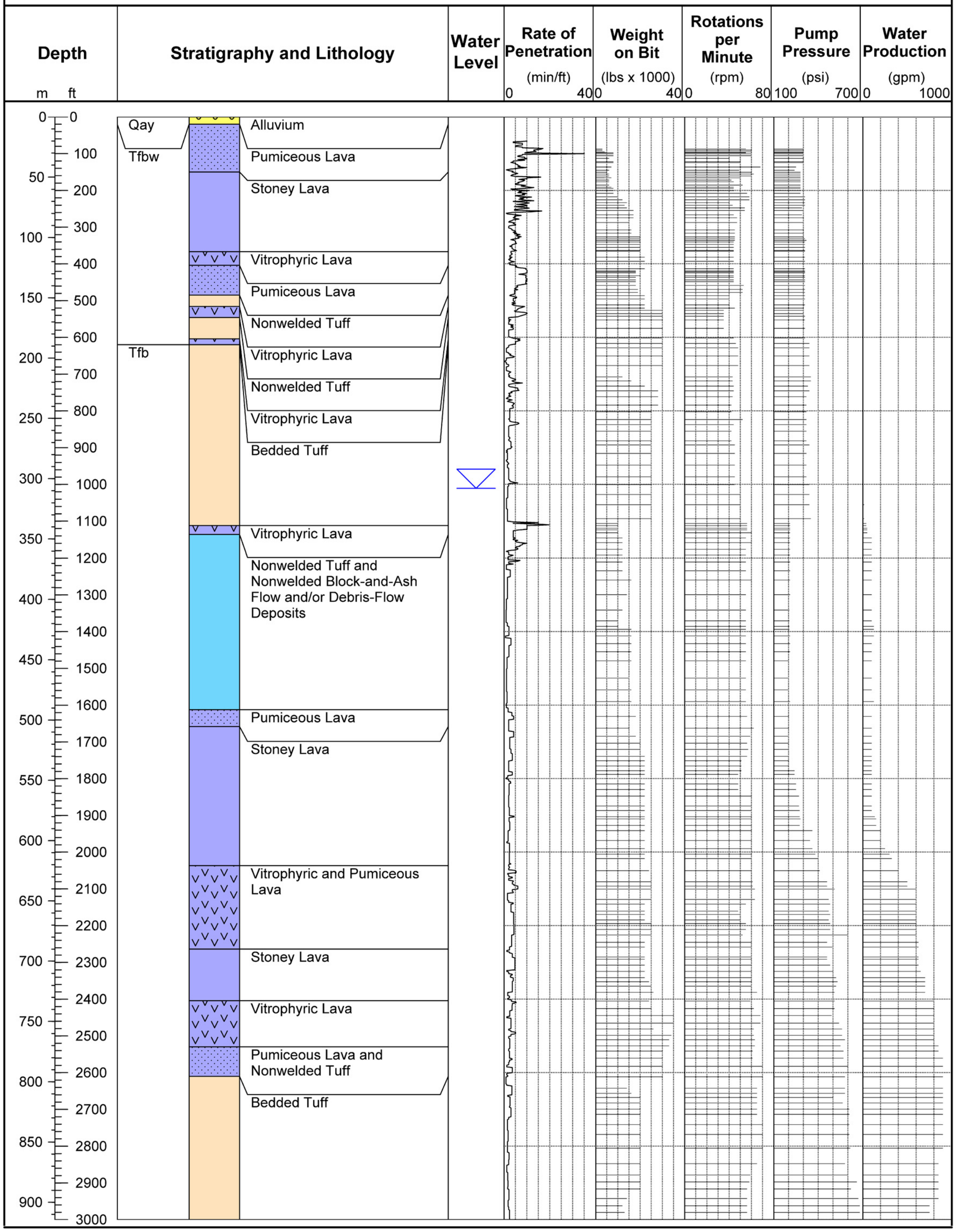
Well ER-EC-13

Logging Company: Baker Atlas
Drilled Depth: 914.4 m (3,000 ft)
Date TD Reached: October 18, 2010
Drill Method: Rotary/Air foam

Surface Elevation: 1,577.4 m (5,175.1 ft)
Coordinates (UTM [NAD 83]): 4,113,750.2 m
540,021.9 m
Water Level: 308.0 m (1,010.6 ft) on November 5, 2010



See legend for lithology symbols on page D-2.

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Appendix A-2
Tubing and Casing Data for Well ER-EC-13

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Table A-2
Tubing and Casing Data for Well ER-EC-13

Casing and Tubing	**Depth Interval** meters (feet)	**Type**	**Grade**	**Outside Diameter** centimeters (inches)	**Inside Diameter** centimeters (inches)	**Wall Thickness** centimeters (inches)	**Weight per foot** (pounds)
Conductor Casing	0 to 21.9 (0 to 72)	Carbon Steel	B	76.2 (30)	73.66 (29.0)	1.27 (0.50)	158.0
Surface Casing	0 to 204.9 (0 to 672.1)	Carbon Steel	K55	40.6 (16)	38.74 (15.25)	0.953 (0.375)	65
	204.9 to 330.9 (672.1 to 1,085.6)	Carbon Steel	K55	40.6 (16)	38.41 (15.124)	1.113 (0.438)	75
Completion Casing with Crossover	0 to 300.1 (0 to 984.7)	Epoxy Coated Carbon Steel	J55	19.37 (7.625)	17.70 (6.969)	0.833 (0.328)	26.4
Completion Casing with Crossover	300.1 to 671.4 (984.7 to 2,202.7)	Stainless Steel	L304	16.83 (6.625)	15.5 (6.104)	0.660 (0.260)	NR [a]
Completion Casing	671.4 to 806.1 (2,202.7 to 2,644.7)	Stainless Steel	L304	13.97 (5.5)	12.82 (5.047)	0.574 (0.226)	NR
Shallow Piezometer String with Crossover	0 to 296.8 (0 to 973.6)	Carbon Steel	N80	5.99 (2.36)	5.07 (1.995)	0.48 (0.19)	4.7
	296.8 to 333.5 (973.6 to 1,094.3)	Stainless Steel	L304	7.303 (2.875)	5.99 (2.36)	0.653 (0.257)	7.66
Intermediate Piezometer String with Crossover	0 to 298.8 (0 to 980.3)	Carbon Steel	N80	5.99 (2.36)	5.07 (1.995)	0.48 (0.19)	4.7
	298.8 to 640.0 (980.3 to 2,099.8)	Stainless Steel	L304	7.303 (2.875)	5.99 (2.36)	0.653 (0.257)	7.66
Deep Piezometer String with Crossover	0 to 296.5 (0 to 972.8)	Carbon Steel	N80	5.99 (2.36)	5.07 (1.995)	0.48 (0.19)	4.7
	296.5 to 832.7 (972.8 to 2,731.9)	Stainless Steel	L304	7.303 (2.875)	5.99 (2.36)	0.653 (0.257)	7.66

a NR = not recorded. Schedule 40 stainless-steel casing of this size may range in weight from approximately 18 to 19 pounds per foot.

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Appendix A-3
Well ER-EC-13 Drilling Fluids and Cement Composition

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Table A-3-1
Drilling Fluids Used in Well ER-EC-13

Typical Air-Foam/Polymer Mix
37.9 to 56.8 liters (10 to 15 gallons) Geofoam®[a]
0 to 5.7 liters (0 to 1.5 gallons) LP701®[a]
per
7,949 liters (50 barrels) water

a Geofoam® foaming agent and LP701® polymer additive are products of Geo Drilling Fluids, Inc.

NOTES:
1. All water used to mix drilling fluids for Well ER-EC-13 came from Well ER-EC-8.

2. A concentrated lithium bromide (LiBr) solution was added to all introduced fluids to make up a final concentration of 20 to 30 parts per million LiBr. The concentration was increased in zones of higher water production to make up a solution of 50 to 60 parts per million LiBr.

Table A-3-2
Well ER-EC-13 Cement Composition

Cement Composition	30-inch Conductor Casing	16-inch Surface Casing	6⅝-inch Completion Casing	5½-inch Completion Casing
Redi-Mix: Formula 400: 998 kg[a] (2,200 lbs[b]) sand, 326 kg (719 lbs) Portland cement, and 232 liters (61 gallons) water per cubic yard	Inside casing: 18.9 to 22.6 m[c] (62 to 74 ft)[d]	N/A	N/A	N/A
Type II neat	N/A	284.7 to 331.9 m (934 to 1,089 ft)	469.7 to 559.3 m (1,541 to 1,835 ft)	651.1 to 682.8 m (2,136 to 2,240 ft) 816.9 to 910.7 m (2,680 to 2,988 ft)

a kilograms
b pounds
c meter(s)
d foot (feet)

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Appendix B
Well ER-EC-13 Fluid Management Data

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Table B-1
Well ER-EC-13 Fluid Disposition Reporting Form

Site Identification: ER-EC-13
Site Location: Nellis Testing and Training Range
Site Coordinates: N 4,113,553.26 m, E 540,102.13 m
Well Classification: ER Hydrogeologic Investigation Well
N-I Project No: RU10-420

Report Date: 02/01/2010
NNSA/NSO Federal Sub-Project Director: Bill Wilborn
N-I Project Manager: Sam Marutzky
N-I Site Representative: Justin Costa Rica
N-I Field Environmental Specialist: Mark Heser

Well Construction Activity	Activity Duration		#Ops. Days [a]	Well Depth (m)	Import Fluid (m^3)	Sump #1 Volumes (m^3)		Sump #2 Volumes (m^3)		Infiltration Area [c] (m^3)	Other [d] (m^3)	Fluid Quality Objective Met?
	From	To				Solids [b]	Liquids	Solids	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	10/2/2010	10/7/2010	6	308.8	413.4	99	369	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	10/13/2010	10/18/2010	6	914.4	289.38	104	1,126	N/A	N/A	10,630	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			12	914.4	702.78	203	1,495	N/A	N/A	10,630	N/A	Yes

[a] Operational days refer to the number of days that fluids were produced during at least part (>3 hours) of one shift.

[b] Solids volume estimates include calculated added volume attributed to rock bulking factor.

[c] Ground surface discharge.

[d] Other refers to fluid conveyance to other fluid management devices or facilities: e.g., baker tank or transported to another well site for storage.

N/A = Not Applicable; m = meters; m^3 = cubic meters
Total Facility Capacities (at 8 ft fluid level): Sump #1 = 1,547 m^3 Sump #2 = 1,547 m^3
Infiltration Area (assuming very low/no infiltration) = N/A
Remaining Facility Capacity (Approximate) as of 10/31/2010: Sump #1 = 514 m^3 (33%) Sump #2 = 1,547 m3 (100 %)
Current Average Tritium = 155 pCi/L
Notes: None

N-I Authorizing Signature/Date:

2/14/2011 NI-297

Table B-2
Analytical Results for Fluid Management Samples for Well ER-EC-13

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act (RCRA)* Metals (mg/L)							
				Arsenic	**Barium**	**Cadmium**	**Chromium**	**Lead**	**Selenium**	**Silver**	**Mercury**
ER-EC-13-102210-4	10/22/2010	Sample from Sump #1	Total	0.0042	0.011 J-	0.005 U	0.01 U	0.003 U	0.0031	0.01 U	0.0002 U
			Dissolved	0.0052	0.1 U	0.005 U	0.01 U	0.003 U	0.005 U	0.01 U	0.0002 U
ER-EC-13-102210-5	10/22/2010	Duplicate Sample from Sump #1	Total	0.0044	0.0097 J-	0.005 U	0.01 U	0.003 U	0.005 U	0.01 U	0.000035
			Dissolved	0.0057	0.0005 J-	0.005 U	0.01 U	0.003 U	0.005 U	0.01 U	0.0002 U
			Detection Limit	0.01	0.1	0.005	0.01	0.003	0.005	0.01	0.0002
			Nevada Drinking Water Standard	0.05	2.0	0.005	0.1	0.015	0.05	0.1	0.002

Sample Number	Date Collected	Comment		Radiological Indicator Parameters (pCi/L)		
				Tritium	**Gross Alpha**	**Gross Beta**
ER-EC-13-102210-4	10/22/2010	Sample from Sump #1	Result	220 U	6.5	4.5
			Error	160	2	1.7
			MDC	250	1.8	2.4
ER-EC-13-102210-5	10/22/2010	Duplicate Sample from Sump #1	Result	90 U	8	6.6
			Error	150	2.2	1.9
			MDC	250	1.8	2.3
			Nevada Drinking Water Standard	15	50	20,000

Analyses for metals and radionuclides performed by ALS Laboratory Group.
Data provided by Navarro-Intera, LLC (N-I, 2011)

Sump #1 is an unlined sump located on the Well ER-EC-13 drill pad.

Notes: U = Compound was analyzed for but was not detected (“nondetect”). J- = Result is estimated bias low.
mg/L = milligrams per liter pCi/L = picocuries per liter
MDC (minimum detectable concentration) varies by matrix, instrument, and count rates.

Analytical methods: All metals except mercury: Environmental Protection Agency (EPA) *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* Method 6010 (SW-846, 6010)
Mercury: EPA SW-846, 7470
Tritium: EPA Method 906.0
Gross alpha and gross beta: EPA Method 900.0

Appendix C
Detailed Lithologic Log for Well ER-EC-13

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Table C-1
Detailed Lithologic Log for Well ER-EC-13
Logged by Dawn Haugstad and Lance Prothro, National Security Technologies, LLC, January 2011

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
0–6.1 (0–20)	6.1 (20)	AC	none	**Gravelly, Silty, Sand:** Pale brown (5YR 5/2) to grayish orange pink (5YR 7/2); unconsolidated to poorly cemented; calcareous. Gravel component consists mostly of pumiceous lava.	alluvium (Qay)
6.1–45.7 (20–150)	39.6 (130)	AC DA	none	**Pumiceous Rhyolite Lava:** White (N9) to very pale orange (10YR 8/2); mostly vitric, lesser devitrified, zeolitic and opaline; spherulitic, perlitic below 35.4 m (116 ft); flow brecciated in part; rare felsic phenocrysts of feldspar; minor biotite; sphene is present.	rhyolite of Beatty Wash (Tfbw)
45.7–88.4 (150–290)	42.7 (140)	DA	76.2 (250)	**Stoney Rhyolite Lava:** Pale brown (5YR 5/2) to pale yellowish brown (10YR 6/2); devitrified; dark reddish brown (10R 3/4) spherulite fragments present; flow banded in part; highly vesicular/lithophysal; rare felsic phenocrysts of feldspar; minor biotite; sphene is present; chalcedony occurs as coatings, cavity fillings, and loose fragments associated with vesicles/lithophysae.	
88.4–111.9 (290–367)	23.5 (77)	DA	94.5 (310)	**Stoney Rhyolite Lava:** Mottled pale red (10R 6/2) to pale reddish brown (10R 5/4) to light gray (N7); mostly devitrified; spherulitic; flow banded in part; rare to minor felsic phenocrysts of feldspar; minor biotite; sphene is present; chalcedony occurs as loose fragments probably associated with lithophysae.	
111.9–123.1 (367–404)	11.3 (37)	DA	none	**Vitrophyric Rhyolite Lava:** Dark gray (N3) to dark reddish brown (10R 3/4); vitric; perlitic; rare to minor feldspar phenocrysts; rare biotite; sphene is present.	
123.1–147.8 (404–485)	24.7 (81)	DA	134.1 (440)	**Pumiceous Rhyolite Lava:** Dark reddish brown (10R 3/4) to grayish brown (5YR 3/2); vitric to partially devitrified; perlitic where vitric; flow brecciated in part; rare felsic phenocrysts of feldspar; minor biotite; sphene is present.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
147.8–157.3 (485–516)	9.4 (31)	DA	155.4 (510)	**Nonwelded Tuff:** Pale red (5R 6/2); zeolitic; common pumice; minor feldspar phenocrysts and trace quartz; minor to common biotite; minor to common lithic fragments of various volcanic lithologies; sphene is present.	rhyolite of Beatty Wash (Tfbw)
157.3–166.4 (516–546)	9.1 (30)	DA	none	**Vitrophyric Rhyolite Lava and Lesser Pumiceous Lava:** Moderate brown (5YR 4/4) and black (N1); mostly vitric; devitrified in part; perlitic; rare feldspar phenocrysts; minor biotite; sphene is present.	
166.4–184.1 (546–604)	17.7 (58)	DA	182.9 (600)	**Nonwelded Tuff:** Moderate reddish brown (10R 4/6); zeolitic; common pumice; rare feldspar phenocrysts; minor biotite; rare lithic fragments; sphene is present.	
184.1–189.0 (604–620)	4.9 (16)	DA	none	**Vitrophyric Rhyolite Lava and Lesser Pumiceous Lava:** Light olive gray (5Y 6/2) where pumiceous and moderate-brown (5YR 4/4) to black (N1) where vitrophyric; mostly vitric and lesser devitrified; rare feldspar phenocrysts; rare biotite; sphene is present.	
189.0–338.9 (620–1,112)	150.0 (492)	DA	228.6 (750) 274.3 (900) 313.9 (1,030)	**Bedded Tuff:** Pale reddish brown (10R 5/4) to moderate orange pink (10R 7/4) to moderate reddish orange (10R 6/6); zeolitic; minor to common pumice; rare to minor felsic phenocrysts of feldspar; minor to common biotite and lesser hornblende; minor lithic fragments; sphene is present. A thin vitrophyric lava occurs within the interval of 253.6 to 255.7 m (832 to 839 ft).	Beatty Wash Formation (Tfb)
338.9–346.3 (1,112–1,136)	7.3 (24)	DA	none	**Vitrophyric Lava:** Black (N1) to very dusky red (10R 2/2) to dark reddish brown (10R 3/4); vitric to partially devitrified; weakly perlitic and pumiceous in part; rare to minor felsic phenocrysts of feldspar; rare to minor biotite. Lower contact dips 45 degrees to the west-northwest based on the borehole image log.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
346.3–419.4 (1,136–1,376)	73.2 (240)	DA PSWC PSWC	362.7 (1,190) 373.7 (1,226) 412.7 (1,354)	**Nonwelded Tuff and Nonwelded Block-and-Ash Flow and/or Debris-Flow Deposits:** Predominately nonwelded tuff with intercalated nonwelded block-and-ash flow and/or debris-flow deposits, each approximately 9.1 m (30 ft) thick Nonwelded tuff intervals are pale reddish brown (10R 5/4) to light brown (5YR 6/4); zeolitic; minor to common pumice; rare to minor felsic phenocrysts of feldspar; rare to minor biotite; rare to minor lithic fragments. Block-and-ash flow and/or debris-flow deposits are grayish orange (10YR 7/4) to pale yellowish orange (10YR 8/6) to light brown (5YR 5/6); zeolitic; minor pumice; minor to common felsic phenocrysts of feldspar; minor biotite; common to very abundant lava lithic fragments some as large as 0.5 m (1.6 ft) in diameter; numerous loose chalcedony fragments. Intervals are conspicuous on geophysical logs as zones of higher resistivity and density. Borehole image log clearly shows clast-rich character of intervals.	Beatty Wash Formation (Tfb)
419.4–491.3 (1,376–1,612)	71.9 (236)	RSWC DA	435.6 (1,429) 475.5 (1,560)	**Nonwelded Block-and-Ash Flow and/or Debris-Flow Deposits and Nonwelded Tuff:** Predominantly nonwelded block-and-ash flow and/or debris-flow deposits above approximately 457.2 m (1,500 ft), and nonwelded tuff below 457.2 m (1,500 ft), to base of interval. Block-and-ash flow and/or debris-flow deposits are light brown (5YR 5/6); zeolitic; some silicic fragments; minor pumice; minor felsic phenocrysts of feldspar; rare to minor biotite; common to very abundant lava lithic fragments; numerous loose chalcedony fragments Nonwelded tuff is zeolitic with minor to common pumice; rare to minor felsic phenocrysts of feldspar; minor biotite; common to abundant lithic fragments.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
491.3–505.4 (1,612–1,658)	14.0 (46)	RSWC	499.9 (1,640)	**Pumiceous Rhyolite Lava:** Grayish orange (10YR 7/4) to dark yellowish orange (10YR 6/6) to moderate yellowish brown (10YR 5/4); mostly zeolitic, lesser devitrified and silicic; remnant perlitic and pumiceous textures; spherulitic and lithophysal; flow-brecciated in part; minor felsic phenocrysts of feldspar; minor to common biotite; sphene is present.	Beatty Wash Formation (Tfb)
505.4–546.2 (1,658–1,792)	40.8 (134)	DA	none	**Stoney Rhyolite Lava:** Pale reddish brown (10R 5/4) to pale brown (5YR 5/2) to light brown (5YR 6/4); mostly zeolitic, partially silicic and opaline; spherulitic and lithophysal; minor felsic phenocrysts of feldspar; minor to common biotite; sphene is present. Flow layering dipping 10 to 15 degrees to the southwest observed in borehole image log.	
546.2–620.9 (1,792–2,037)	74.7 (245)	RSWC RSWC	548.6 (1,800) 615.7 (2,020)	**Stoney Rhyolite Lava:** Pale red (10R 6/2) to grayish orange pink (5YR 7/2) to light brownish gray (5YR 6/1); devitrified; minor felsic phenocrysts of feldspar; minor to common bronze biotite; numerous hairline fractures filled with secondary quartz. A prominent fracture at 604.7 m (1,984 ft) and flow layering were observed in borehole image log.	
620.9–690.1 (2,037–2,264)	69.2 (227)	DA	682.8 (2,240)	**Vitrophyric and Pumiceous Rhyolite Lava:** Predominantly vitrophyric lava with intercalated pumiceous lava. Vitrophyric lava is light brown (5YR 6/4) to moderate yellowish brown (10YR 5/4) and mostly vitric. Pumiceous lava is zeolitic with minor felsic phenocrysts of feldspar, minor biotite, and sphene is present.	
690.1–732.7 (2,264–2,404)	42.7 (140)	RSWC	701.0 (2,300)	**Stoney Rhyolite Lava:** Pale reddish brown (10R 5/4) to grayish red (10R 4/2); devitrified; minor felsic phenocrysts of feldspar; rare to minor biotite; sphene is present.	
732.7–771.1 (2,404–2,530)	38.4 (126)	DA RSWC	740.7 (2,430) 755.3 (2,478)	**Vitrophyric Rhyolite Lava:** Black (N1) to pale reddish brown (10R 5/4) to grayish red (10R 4/2); mostly vitric and lesser quartzo-feldspathic and zeolitic; rare to minor felsic phenocrysts of feldspar; minor to common biotite; sphene is present. Intercalated pumiceous lava from 755.3 to 759.6 m (2,478 to 2,492 ft).	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
771.1–795.5 (2,530–2,610)	24.4 (80)	DA	none	**Interbedded Pumiceous Rhyolite Lava and Lesser Nonwelded Tuff:** Grayish orange (10YR 7/4) to light brown (5YR 6/4) to pale reddish brown (10R 5/4); quartzo-feldspathic; pumiceous lava is silicic; rare to minor felsic phenocrysts of feldspar; minor to common biotite; minor to common lithic fragments in tuff; remnant perlitic texture in lava; sphene is present.	Beatty Wash Formation (Tfb)
795.5–830.9 (2,610–2,726)	35.4 (116)	PSWC RSWC	801.6 (2,630) 817.5 (2,682)	**Bedded Tuff:** Grayish yellow (5Y 8/4) to dusky yellow (5Y 6/4) to moderate yellow (5Y 7/6); mostly quartzo-feldspathic, lesser zeolitic; rare to minor felsic phenocrysts of feldspar; minor biotite; common lithic fragments (loose lithic fragments are sub-rounded).	
830.9–873.3 (2,726–2,865)	42.4 (139)	DA RSWC	856.5 (2,810) 860.1 (2,822)	**Bedded Tuff:** Grayish orange (10YR 7/4) to dusky yellow (5Y 6/4); mostly quartzo-feldspathic, lesser argillic; rare to minor pumice; rare felsic phenocrysts of feldspar; minor biotite; rare to minor lithic fragments.	
873.3–914.4 (2,865–3,000) TD	41.1 (135)	RSWC DA	899.8 (2,952) 914.4 (3,000)	**Bedded Tuff:** Grayish orange (10YR 7/4) to yellowish gray (5Y 7/2) to very pale orange (10YR 8/2); mostly quartzo-feldspathic, lesser argillic; minor to common pumice; rare to minor felsic phenocrysts of feldspar; common biotite; rare lithic fragments.	

a Lithologic samples collected from interval during drilling and logging operations and utilized for lithological interpretation. AC = auger cuttings; DA = drill cuttings that represent lithologic character of interval; PSWC = percussion-gun sidewall core; RSWC = rotary sidewall core. See Table 3-1 in this report for more information about sidewall samples. Note: The upper 3.0 to 6.1 m (10 to 20 ft) of most intervals contain cuttings from the overlying interval, particularly in the bottom half of the hole, due to drilling lag time.

b Depth of lithologic samples selected for laboratory analyses. Laboratory analyses include petrography (from polished thin sections), mineralogy (x-ray diffraction), and chemistry (x-ray fluorescence). See Table 3-2 in this report for a complete list of laboratory analyses.

c Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope, and incorporating observations from geophysical logs. Colors describe wet sample color unless otherwise noted.
Abundances for felsic phenocrysts, pumice fragments, and lithic fragments: **trace** = only one or two individuals observed; **rare** = ≤ 1%; **minor** = 5%; **common** = 10%; **abundant** = 15%; **very abundant** ≥ 20%.
Abundances for mafic minerals: **trace** = only one or two individuals observed; **rare** = ≤ 0.05%; **minor** = 0.2%; **common** = 0.5%; **abundant** = 1%; **very abundant** = ≥ 2%.

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Appendix D
Geophysical Logs Run in Well ER-EC-13

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Appendix D contains plots of selected geophysical log data for Well ER-EC-13. Table D-1 summarizes the logs presented. See Table 3-3 for more information.

Table D-1
Well ER-EC-13 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	Log Interval feet
Caliper	CA6-1 CA6-2	10/08/2010 10/18/2010	21.9–332.5 304.8–907.7	72–1,091 1,000–2,978
X-Multipole Array Acoustilog (sonic)	XMAC-1	10/19/2010	304.8–905.6	1,000–2,971
Gamma Ray	GR-1 GR-5	10/08/2010 10/18/2010	0–325.8 259.1–901.1	0–1,069 850–2,956
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2	10/08/2010 10/18/2010	0–325.8 259.1–901.1	0–1,069 850–2,956
High Definition Induction and R_t Explorer (resistivity)	HDIL-1 RTEX-1	10/09/2010 10/19/2010	21.9–331.0 331.6–905.3	72–1,086 1,088–2,970
Density	ZDL-1 ZDL-2	10/09/2010 10/19/2010	21.9–333.1 243.8–910.1	72–1,093 800–2,986
Compensated Neutron	CN-2	10/19/2010	243.8–910.1	800–2,986
Chemistry (pH and conductivity) Temperature	Chem-1 TL-2	10/21/2010	308.5–911.0	1,012–2,989
Heat Pulse Flow Log	HPFlow-1	10/21/2010	309.4–899.2	1,015–2,950

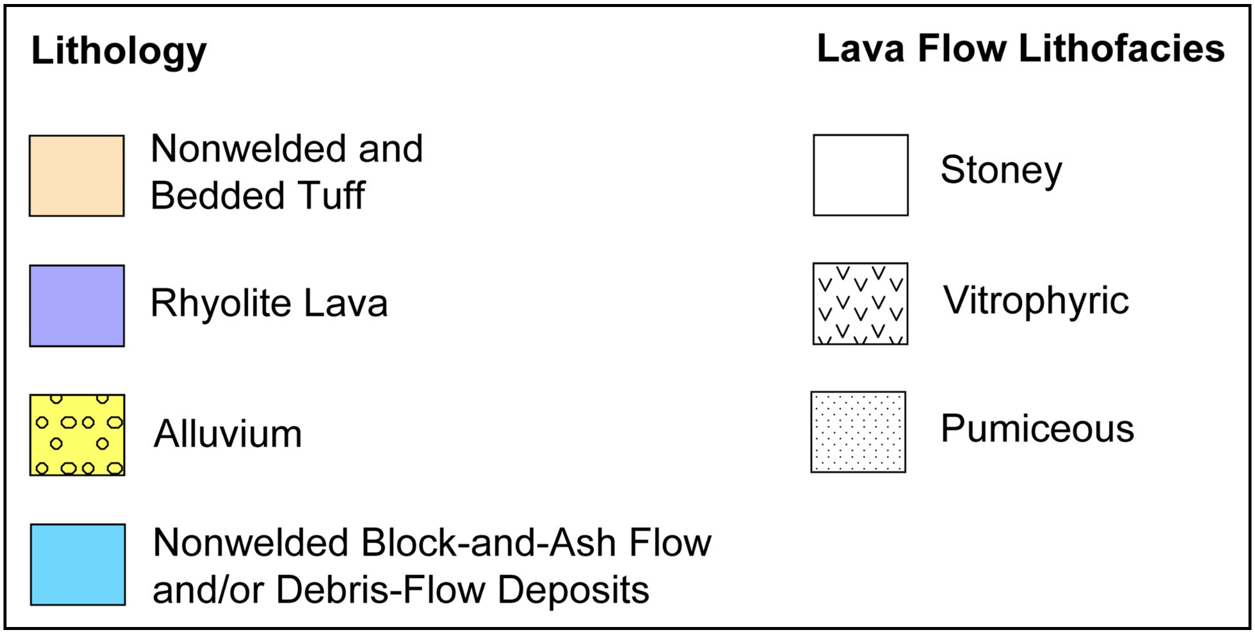
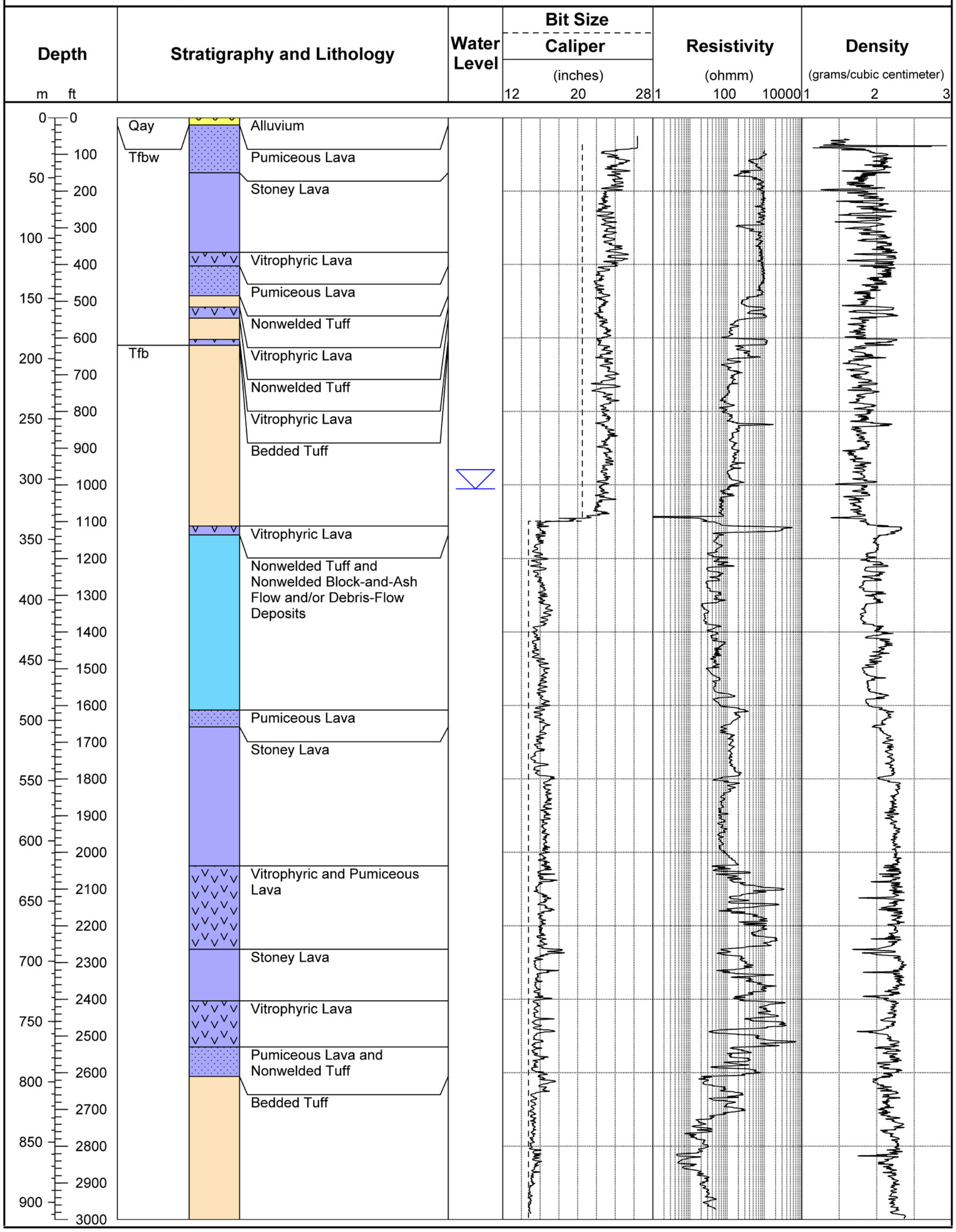


Figure D-1
Legend for Lithology Symbols Used on Log Plots

Well ER-EC-13

Logging Company: Baker Atlas
Date Logged: October 8, 9, 18, and 19, 2010
Drilled Depth: 914.4 m (3,000 ft)
Date TD Reached: October 18, 2010
Drill Method: Rotary/Air foam

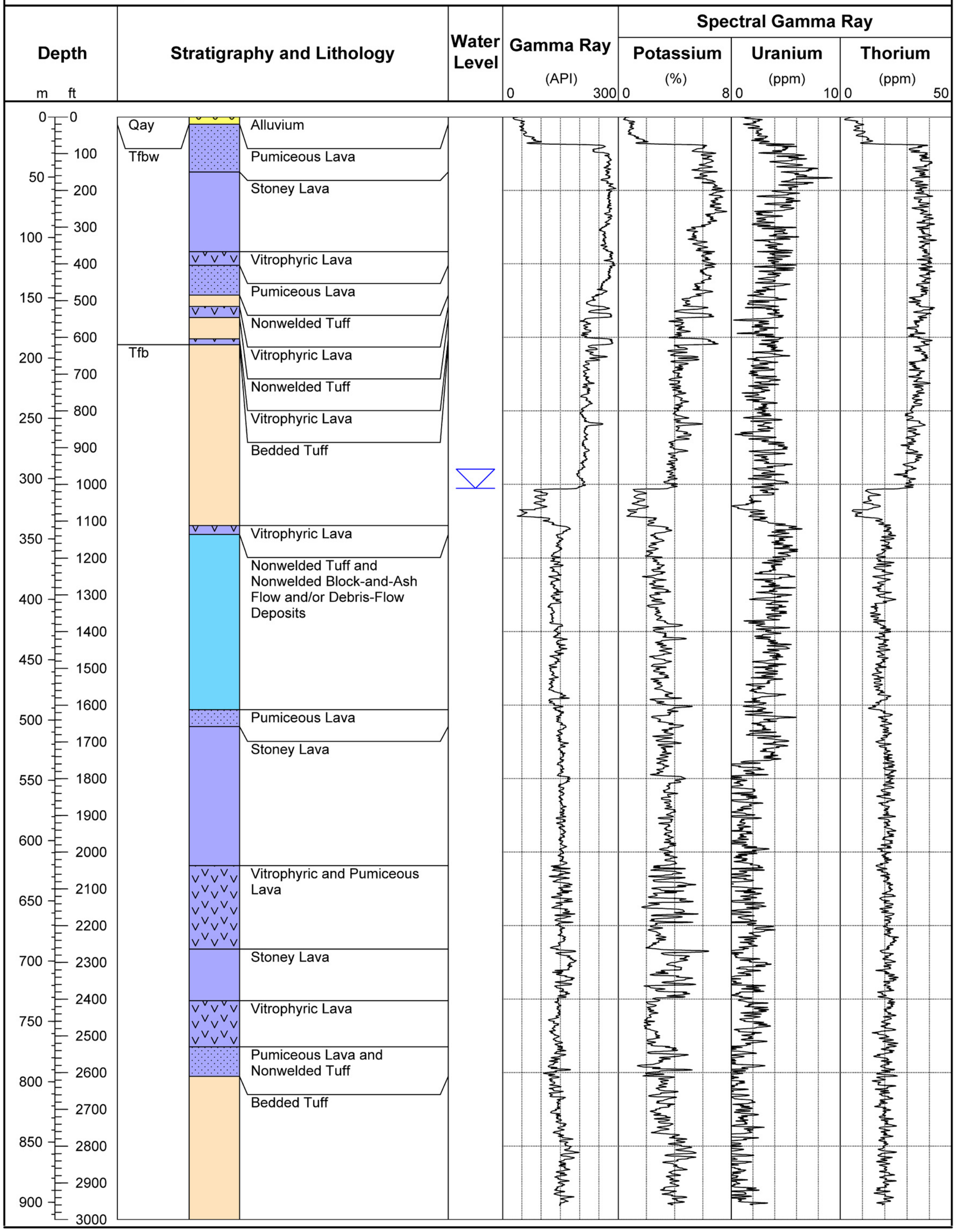
Surface Elevation: 1,577.4 m (5,175.1 ft)
Coordinates (UTM [NAD 83]): 4,113,750.2 m
540,021.9 m
Water Level: 308.0 m (1,010.6 ft) on November 5, 2010



Well ER-EC-13

Logging Company: Baker Atlas
Date Logged: October 8 and 18, 2010
Drilled Depth: 914.4 m (3,000 ft)
Date TD Reached: October 18, 2010
Drill Method: Rotary/Air foam

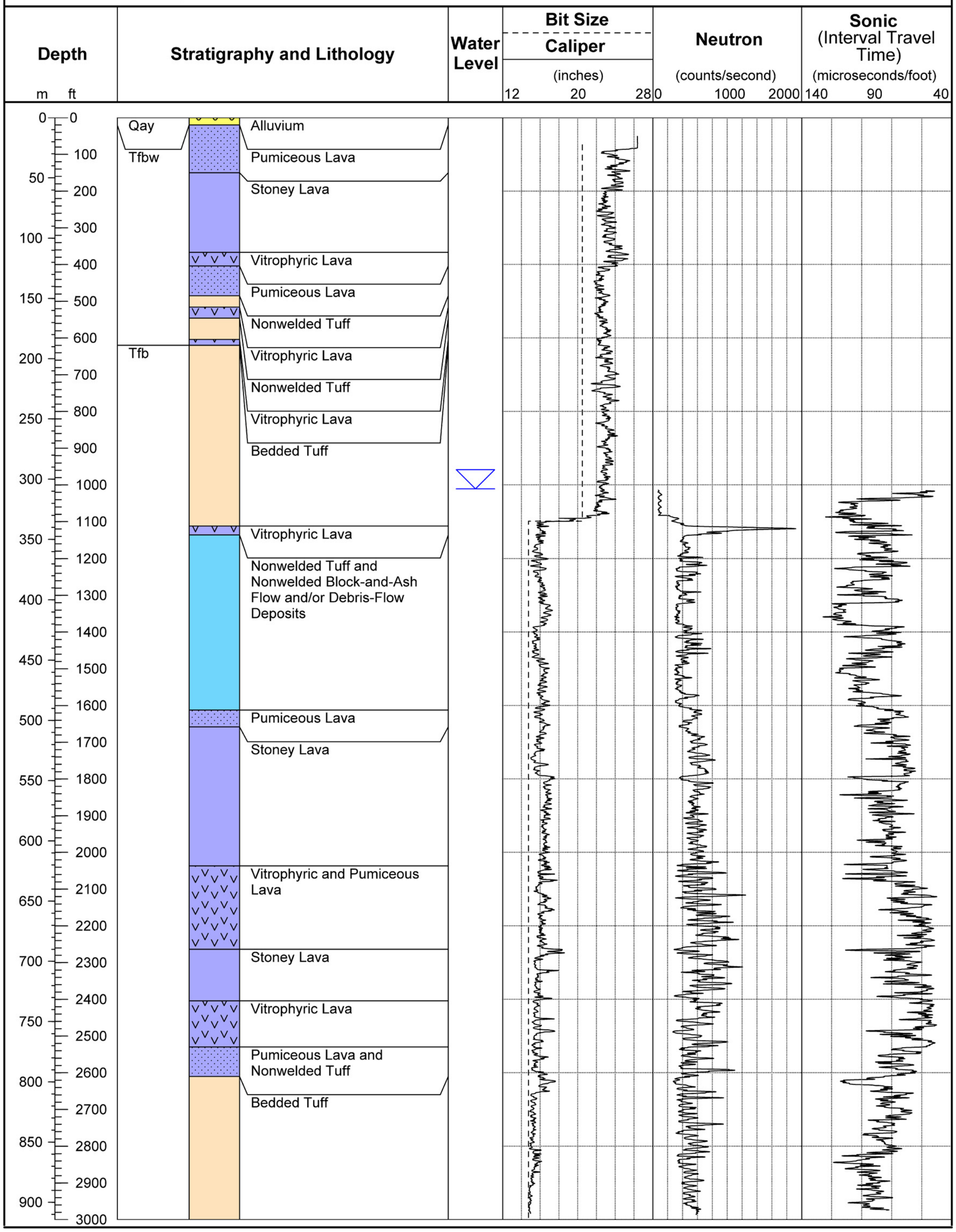
Surface Elevation: 1,577.4 m (5,175.1 ft)
Coordinates (UTM [NAD 83]): 4,113,750.2 m
540,021.9 m
Water Level: 308.0 m (1,010.6 ft) on November 5, 2010



Well ER-EC-13

Logging Company: Baker Atlas
Date Logged: October 8, 18, and 19, 2010
Drilled Depth: 914.4 m (3,000 ft)
Date TD Reached: October 18, 2010
Drill Method: Rotary/Air foam

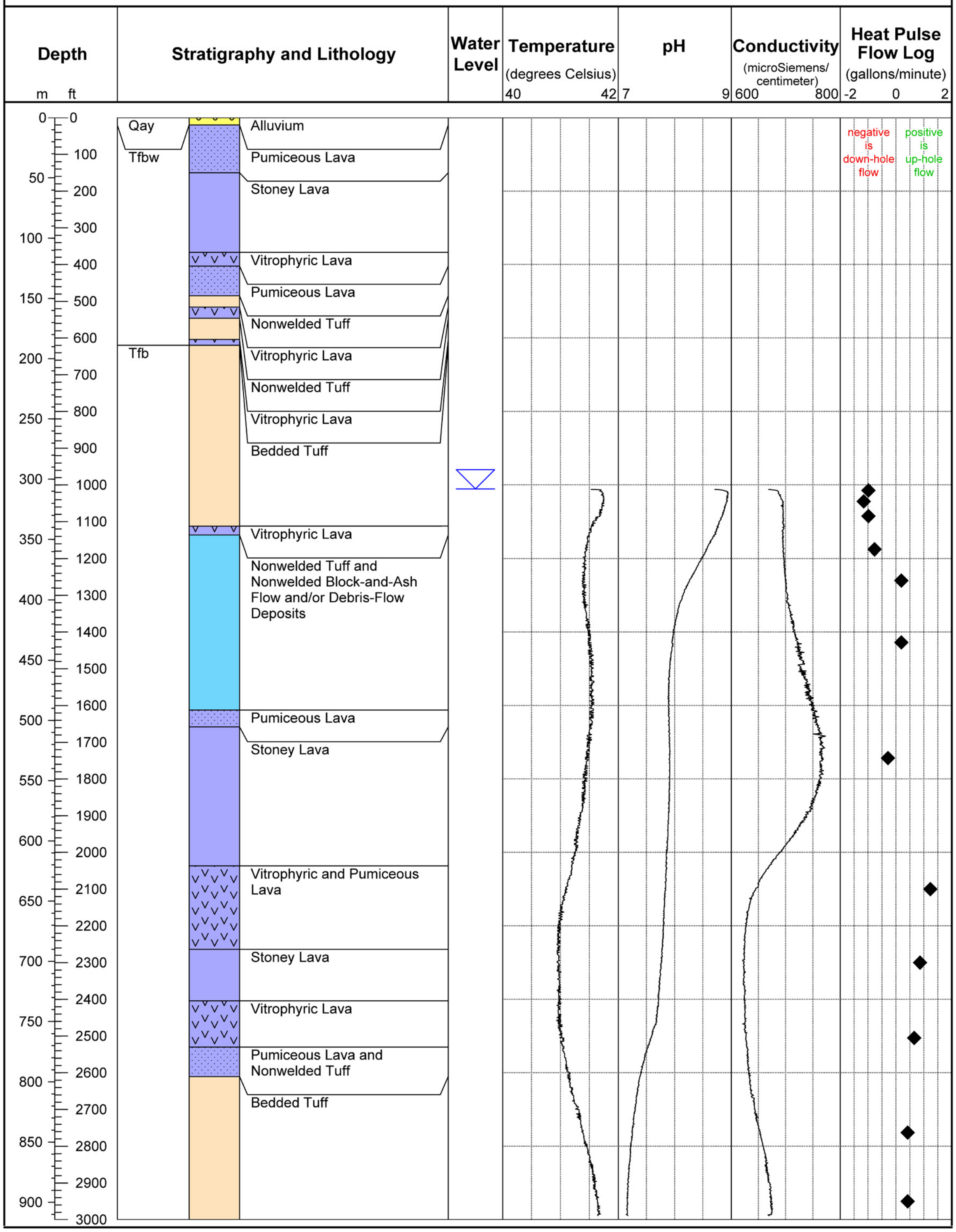
Surface Elevation: 1,577.4 m (5,175.1 ft)
Coordinates (UTM [NAD 83]): 4,113,750.2 m
540,021.9 m
Water Level: 308.0 m (1,010.6 ft) on November 5, 2010



Well ER-EC-13

Logging Company: Desert Research Institute
Date Logged: October 21, 2010
Drilled Depth: 914.4 m (3,000 ft)
Date TD Reached: October 18, 2010
Drill Method: Rotary/Air foam

Surface Elevation: 1,577.4 m (5,175.1 ft)
Coordinates (UTM [NAD 83]): 4,113,750.2 m
540,021.9 m
Water Level: 308.0 m (1,010.6 ft) on November 5, 2010



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