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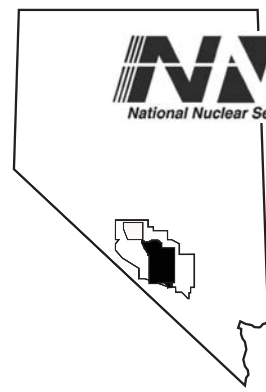

Completion Report for Well ER-EC-15

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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Completion Report for Well ER-EC-15

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

Prepared by:
Underground Test Area and Boreholes Programs and Operations
National Security Technologies, LLC
Las Vegas, Nevada

May 2011

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DOE/NV--1449

Completion Report for Well ER-EC-15

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

Approved by: [signature] Date: 5/10/2011

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

Approved by: [signature] Date: 5/11/11

Robert F. Boehlecke
Federal Project Director
Environmental Restoration Project

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Abstract

Well ER-EC-15 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 known as the Nevada Test Site), Nye County, Nevada. The well was drilled in October and November 2010, as part of the Pahute Mesa Phase II drilling program. The primary purpose of the well was to provide detailed hydrogeologic information in the Tertiary volcanic section in the area between Pahute Mesa and the Timber Mountain caldera complex that will help address uncertainties within the Pahute Mesa–Oasis Valley hydrostratigraphic model. In particular, the well was intended to help define the structural position and hydraulic parameters of volcanic aquifers potentially down-gradient from underground nuclear tests on Pahute Mesa. It may also be used as a long-term monitoring well.

The main 52.1-centimeter (cm) hole was drilled to a depth of 371.9 meters (m) and cased with 40.6-cm casing to 362.4 m. The hole diameter was then decreased to 37.5 cm, and the well was drilled to a total depth of 991.8 m. The completion casing string, set to the depth of 958.3 m, consists of 19.4- and 14.0-cm stainless-steel casing hanging from 19.4-cm carbon-steel casing. The 19.4-cm stainless-steel casing has one slotted interval open to the upper Paintbrush lava-flow aquifer. The 14.0-cm stainless-steel casing has two slotted intervals open to the Tiva Canyon and Topopah Spring aquifers.

Three piezometer strings were also installed in Well ER-EC-15 in the annulus between the completion string and the borehole wall. 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 string was landed at 530.6 m to monitor the upper Paintbrush lava-flow aquifer. The intermediate string was landed at 730.1 m to monitor the Tiva Canyon aquifer. The deep string was landed at 957.5 m to monitor the Topopah Spring aquifer, the deepest aquifer encountered in the well.

Data collected during and shortly after hole construction include composite drill cuttings samples collected every 3.0 m, 26 sidewall core samples, various geophysical logs, water quality (primarily tritium) measurements, and water level measurements. The well penetrated 14.0 m of younger alluvium and 977.8 m of Tertiary volcanic rock, including three rhyolite lava-flow aquifers and two welded ash-flow tuffs (all saturated except the upper lava-flow).

The water levels measured in the three piezometer strings on December 6, 2010, were as follows: 363.1-m depth in the upper Paintbrush lava-flow aquifer; 363.2-m depth in the underlying Tiva Canyon aquifer; and 363.1-m depth in the Topopah Spring aquifer. Groundwater temperatures within the borehole are higher than usual for the area, at 68.9 degrees Celsius. No tritium above

the minimum detection limit of the field instruments was detected in this hole during drilling. Measurements by a commercial laboratory indicated that tritium levels for discrete water samples collected at the depths of 725.4 and 947.9 m are below the minimum detectable concentration.

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List of Acronyms and Abbreviations

BA	Benham aquifer
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
FAWP	Field Activity Work Package
FFACO	Federal Facility Agreement and Consent Order
FMP	Fluid Management Plan
ft	foot (feet)
gpm	gallons per minute
HFM	hydrostratigraphic framework model
HSU	hydrostratigraphic unit
id	inside diameter
in.	inch(es)
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
Lpm	liters per minute
m	meter(s)
m^3	cubic meters
Ma	million years ago
MDC	minimum detectable concentration
NAD	North American Datum
NAIL	Nuclear Annular Investigation Log
NARA	National Archives and Records Administration
N-I	Navarro-Intera, LLC
NNES	Navarro Nevada Environmental Services, LLC
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC

List of Acronyms and Abbreviations (Continued)

NTMMSZ	northern Timber Mountain moat structural zone
NTS	Nevada Test Site
NTTR	Nevada Test and Training Range
od	outside diameter
pCi/L	picocuries per liter
PM–OV	Pahute Mesa–Oasis Valley
SCCC	Silent Canyon caldera complex
SNJV	Stoller-Navarro Joint Venture
TCA	Tiva Canyon aquifer
TD	total depth
TMCC	Timber Mountain caldera complex
TSA	Topopah Spring aquifer
TWG	Technical Working Group
UDI	United Drilling, Incorporated
UGT	underground nuclear test
UGTA	Underground Test Area
UPLFA	upper Paintbrush lava-flow aquifer
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
yd^3	cubic yards

1.0 Introduction

1.1 Project Description

Well ER-EC-15 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 known as the Nevada Test Site [NTS]), Nye County, Nevada. Well ER-EC-15 was the eighth well drilled as part of the Underground Test Area (UGTA) Sub-Project Phase II hydrogeologic investigation well-drilling program in the western Pahute Mesa area of Nye County, Nevada. It was drilled in the fall of 2010, and was the fourth well drilled in the second drilling campaign of the Phase II drilling program.

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 (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 of the 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-15 is located on the Nevada Test and Training Range (NTTR), approximately 3,292 meters (m) (10,800 feet [ft]) due west of the northwest boundary of the NNSS, and approximately 2,885 m (9,460 ft) southwest of the boundary at its closest approach (Figure 1-1). The well was drilled between the Silent Canyon and Timber Mountain caldera complexes (SCCC and TMCC, respectively) in an area known as the Bench (Figure 1-2). The primary purpose of drilling at this location was to obtain detailed hydrogeologic information in the

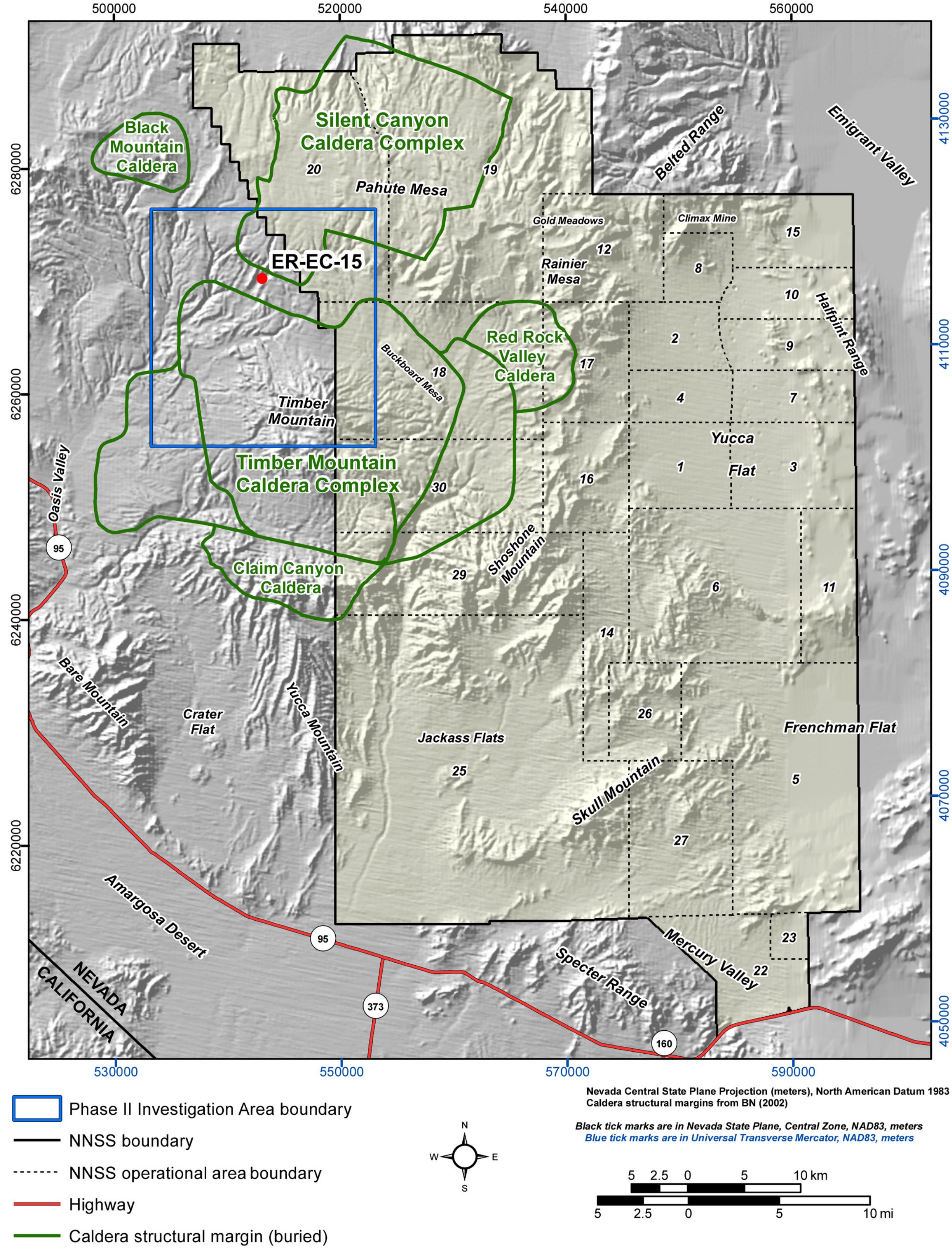


Figure 1-1
Reference Map Showing the Location of Well ER-EC-15

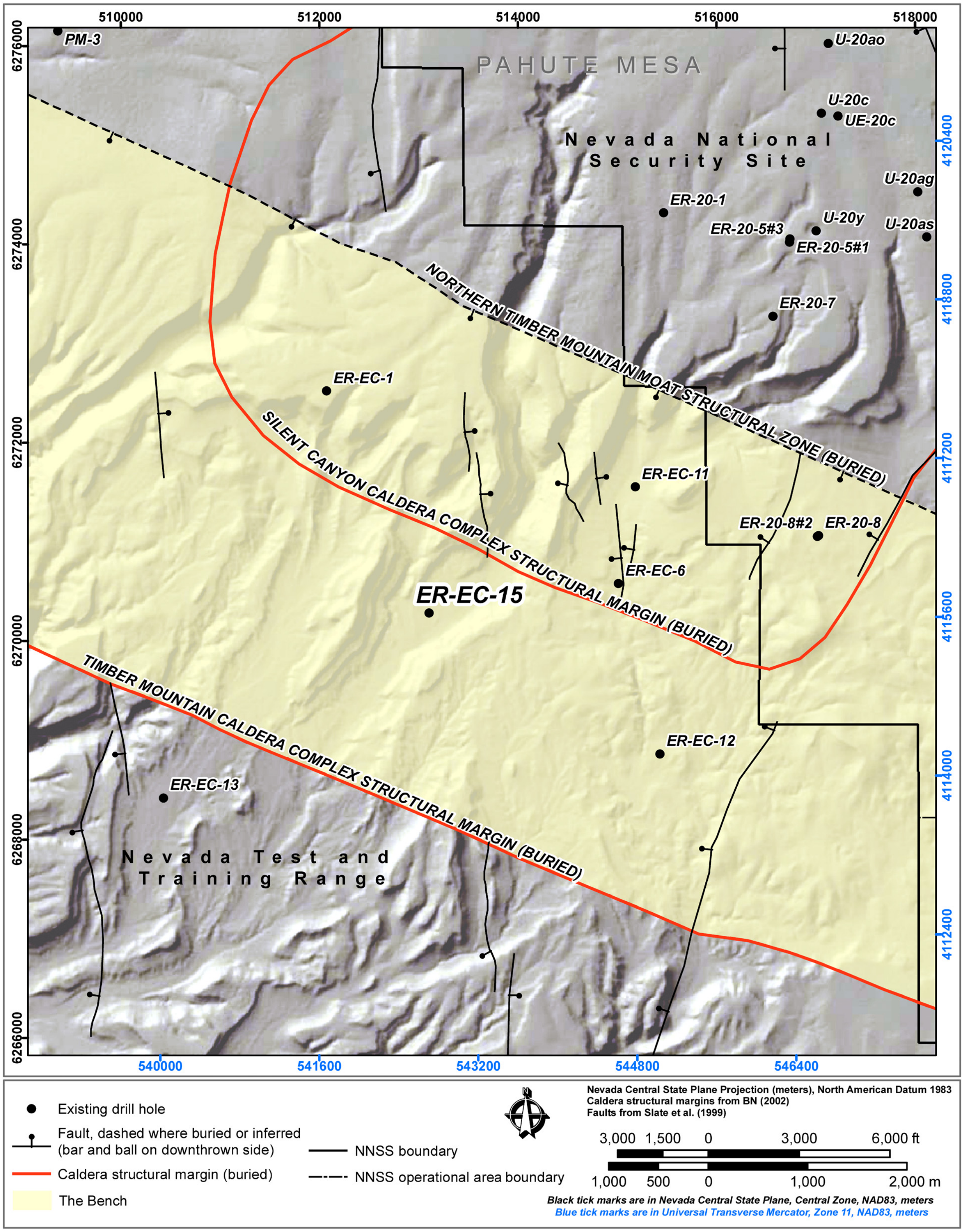


Figure 1-2
Shaded Relief Map of the Well ER-EC-15 Area, Showing the Location of the Bench

Tertiary volcanic section that will help address uncertainties within the Bench area of 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).

More specifically, the primary purpose of this well was to provide information that will help define the structural position and hydraulic parameters for the Benham aquifer (BA), Tiva Canyon aquifer (TCA), and Topopah Spring aquifer (TSA). The well was also expected to provide information regarding the nature and hydrologic character of the TMCC structural margin. A secondary purpose of this well was to further investigate migration of radionuclides from former testing areas on Pahute Mesa (SNJV, 2009a). Consequently, Well ER-EC-15 may be a favorable location for a long-term monitoring well.

1.2 Project Organization

The construction of Well ER-EC-15 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-15 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), Navarro-Interra, LLC (N-I; environmental contractor, formerly Navarro Nevada Environmental Services [NNES]), and National Security Technologies, LLC (NSTec; NNSS management and operating contractor). 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-15 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 assure that Well ER-EC-15 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)

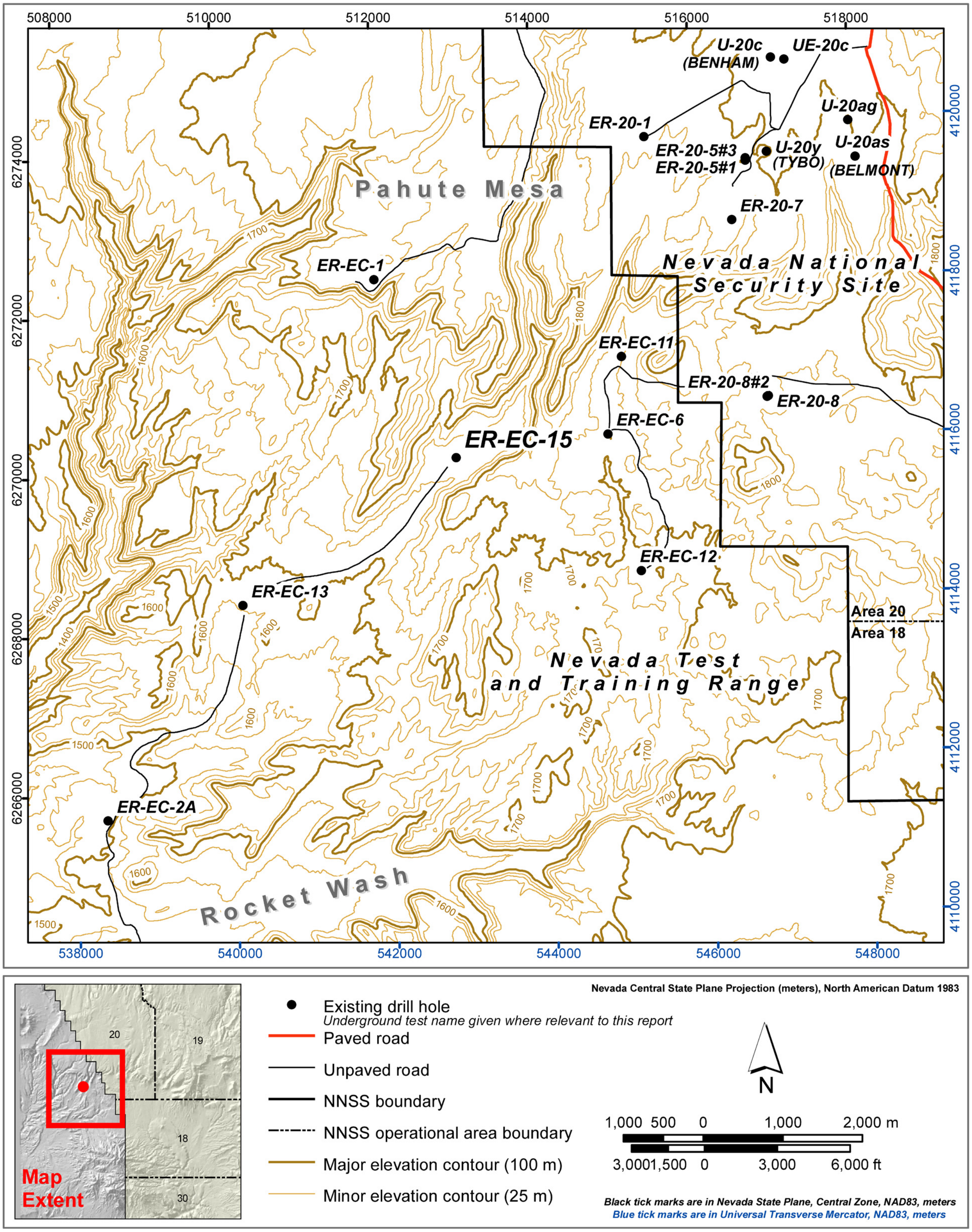


Figure 1-3
Topographic Map of the Well ER-EC-15 Area, Showing the Locations of Roads and Nearby Drill Holes

and *Addendum to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (NNES, 2010b) 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, Incorporated (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 packages (FAWPs) numbers D-003-001.10 and D-010-001.11 (NSTec, 2010a and 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, 2010b; NNES, 2010a) and the UGTA Project Health and Safety Plan, Revision 2 (NSTec, 2008).

This report presents construction data and summarizes scientific data gathered during the drilling of Well ER-EC-15. 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 completion of the PM–OV HFM [BN, 2002]) is compiled in the Phase II drilling criteria document (SNJV, 2009a) and the addendum to the criteria document (NNES, 2010b). 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-15 is located south of Pahute Mesa on the NTTR at an elevation of 1,635.3 m (5,365.0 ft). Wells drilled as part of the Phase I drilling program include Well ER-EC-6 (U.S. Department of Energy, Nevada Operations Office [DOE/NV], 2000a), which is located approximately 1,934 m (6,345 ft) to the east, and Well ER-EC-1 (DOE/NV, 2000b), which is located about 2,455 m (8,055 ft) to the northwest. Wells drilled as part of the Phase II drilling program in 2009 and 2010 include ER-EC-11 (NNSA/NSO, 2010b), which is located approximately 2,438 m (8,000 ft) to the northeast, Well ER-EC-12 (NNSA/NSO, 2011b), which is located about 2,725 m (8,940 ft) to the southeast, Wells ER-20-8 and ER-20-8#2 (NNSA/NSO, 2011a), which are located approximately 4,012 m (13,160 ft) to the east northeast, and Well ER-20-7 (NNSA/NSO, 2010a), which is located about 4,572 m (15,000 ft) to the northeast. The locations of these wells in relation to Well ER-EC-15 are shown in Figure 1-3. Additional information about Well ER-EC-15 is provided in Table 1-1.

Well ER-EC-15 is located in an area known as the Bench, a structural domain defined as the area between the northern Timber Mountain moat structural zone (NTMMSZ) and the structural margin of the TMCC (Figure 1-2). Well ER-EC-15 is located on volcanic terrain of the Bench between the buried Area 20 caldera structural margin and the TMCC structural margin. The surface topography in the vicinity is dissected by southwest draining canyons. Well ER-EC-15 is located within one of the larger canyons, a tributary to Rocket Wash. The canyon bottom in the vicinity of the wellhead is relatively flat and composed of younger alluvium.

The closest UGTs to Well ER-EC-15 are TYBO (U-20y) and BELMONT (U-20as) (Figure 1-3). Well ER-EC-15 was sited approximately 5,486 m (18,000 ft) south-southwest of the TYBO test location and approximately 6,248 m (20,500 ft) southwest of the BELMONT test location. The TYBO test was conducted below the water table, and BELMONT was conducted approximately 9 m (29 ft) above the water table (NNSA/NSO, 2009a). See Table 1-2 for information pertaining to nearby tests.

1.4 Objectives

The primary purpose for drilling Well ER-EC-15 was to obtain detailed hydrogeologic information from the shallow- to intermediate-depth Tertiary volcanic section in order to refine the understanding of the hydrogeology in the Bench area, between the NTMMSZ and the TMCC (NNSA/NSO, 2009a; NNES, 2010b). In particular, the well was intended to help define the structural position and hydraulic parameters of the BA, TCA, and TSA. The well was also

Table 1-1
Site Data Summary for Well ER-EC-15

Site Coordinates [a]	**Nevada State Plane (Central Zone) (NAD 27)** N 886,766.0 ft E 543,262.0 ft **Nevada State Plane (Central Zone) (NAD 83)** N 6,270,287.4 m E 513,106.7 m **UTM (Zone 11) (NAD 83)** N 4,115,624.0 m E 542,689.1 m **UTM (Zone 11) (NAD 27)** N 4,115,426.9 m E 542,769.4 m **Geographic (NAD 83)** (degrees, minutes, seconds) Latitude: 37˚ 11' 09.9" Longitude: 116˚ 31' 08.6" **Township and Range** [b] Southeast 1/4 of Northeast 1/4 of Section 5 Township 9 south, Range 49 east
Surface Elevation [c]	1,635.3 m (5,365.0 ft)
Drilled Depth	991.8 m (3,254 ft)
Fluid-Level Depth [c]	363.1 m (1,191.4 ft)
Fluid-Level Elevation	1,272.1 m (4,173.6 ft)
Surface Geology	Alluvium (young alluvial deposits [Qay])

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 were 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 December 6, 2010.

Table 1-2
Information for Underground Nuclear Tests Relevant to Well ER-EC-15

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

expected to provide information regarding the nature and hydrologic character of the structural margin of the TMCC. A secondary purpose of this well was to further investigate migration of radionuclides from former testing areas on Pahute Mesa. Radionuclides (thought to originate from the TYBO and BENHAM UGTs [DOE/NV, 1997]) have been detected at UGTA Wells ER-20-5 (DOE/NV, 1997), ER-20-7 (NNSA/NSO, 2010a), ER-20-8/ER-20-8#2 (NNSA/NSO, 2011a), and ER-EC-11 (NNSA/NSO, 2010b). The leading edge of this contaminant plume may be located just north of Well ER-EC-6 (DOE/NV, 2000a) (located east of Well ER-EC-15 [Figure 1-3]) where no radionuclides were detected. Well ER-EC-15 is expected to produce data that will improve modeling of flow and transport within the transport corridor down-gradient of CAUs 101 and 102, and may be a favorable location for a long-term monitoring well.

The objectives for Well ER-EC-15, as described in Appendix G of the drilling and completion criteria document for the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells and the addendum (SNJV, 2009a and NNES, 2010b respectively), are listed below, along with well-specific activities necessary to accomplish the objectives:

1. Characterize the hydrogeology to help reduce uncertainties within the Bench 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 intermediate-depth Tertiary volcanic section. The aquifers of interest are the BA, TCA, and TSA.
   - Refine the location of structural features such as the TMCC structural margin and infer what effect they may have on groundwater flow.
   - Provide detailed geology and configuration of aquifer units in the upper portion of the saturated section where contaminant transport is most likely.
2. Investigate radionuclide migration down-gradient from former testing areas in southwestern Pahute Mesa.
3. Obtain hydraulic properties such as detailed fracture data and hydrologic information for the BA, TCA, and TSA, to improve subsequent flow and transport modeling for the area between the former test areas at Pahute Mesa and the TMCC.

The following activities were 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 and investigate potential local groundwater flow down-gradient from the UGTs conducted in southwestern Pahute Mesa.

Additional data that will help characterize the hydrology of the Bench area will be obtained during later hydraulic testing at this well. Specific criteria for these later tests will be provided elsewhere (e.g., FAWPs and the well development and testing plan), but, ultimately, Well ER-EC-15 is expected to provide data for determination of horizontal and vertical conductivity and hydraulic properties of saturated hydrostratigraphic units (HSUs) penetrated.

The completed well will accommodate single-well hydraulic testing and could be a potential observation well (and possibly a pumping well) for future multiple-well aquifer tests.

1.5 Project Summary

This section summarizes construction operations for Well ER-EC-15; the details are provided in Sections 2.0 through 7.0 of this report.

A 106.7-centimeter (cm) (42-inch [in.]) diameter surface conductor hole was constructed by drilling to a depth of 24.4 m (80 ft), and installing a string of 30-in. conductor casing to the depth of 23.8 m (78.0 ft). Drilling of the main hole with a 20½-in. tricone bit, using an air-foam in conventional circulation, began on November 5, 2010. The 52.1-cm (20.5-in.) diameter surface hole was drilled to a depth of 371.9 m (1,220 ft) and 16-in. surface casing was set at 362.4 m (1,189.0 ft). The hole diameter was decreased to 37.5 cm (14.75 in.) at the depth of 371.9 m (1,220 ft) and the total depth (TD) of 991.8 m (3,254 ft) and was reached on November 19, 2010. The top of the upper Paintbrush lava-flow aquifer (UPLFA) was encountered at 397.2 m (1,303 ft), the top of the TCA was encountered at 644.7 m (2,115 ft), and the top of the TSA was reached at 836.4 m (2,744 ft). The open-hole water level prior to installation of the completion string was measured at 363.3 m (1,192 ft) on November 19, 2010, during geophysical logging. On December 6, 2010, a water level of 363.1 m (1,191.4 ft) was measured in the shallow piezometer string. No tritium above the resolution of the field instruments was detected in this hole during drilling.

The completion casing string, set to the depth of 958.3 m (3,144.0 ft), consists of 7 ⅝- and 5½-in. stainless-steel casing hanging from 7⅝-in. carbon-steel casing via a crossover sub. The carbon-steel casing extends through the unsaturated zone to a point approximately 5.8 m (19 ft) above the water table. The 7 ⅝-in. stainless-steel casing has one slotted interval from 424.7 to 530.2 m (1,393.3 to 1,739.4 ft), allowing access to the UPLFA. The 5½-in. stainless-steel casing has two slotted intervals, one from 657.3 to 734.0 m (2,156.5 to 2,408.3 ft), and the other from 855.5 to 951.5 m (2,806.6 to 3,121.7 ft), allowing access to the TCA and TSA, respectively. These two zones are separated by an interval of cement within the annulus outside the completion casing. Bridge plugs were set at 565.4 and 749.8 m (1,855 and 2,460 ft) inside the completion casing to isolate the three aquifers.

Three piezometer strings were installed in Well ER-EC-15. All three strings are composed of 2⅞-in. stainless-steel tubing suspended from 2⅜-in. carbon-steel tubing. The shallow piezometer string was landed at 530.6 m (1,740.7 ft), and is slotted from 420.8 to 530.6 m (1,380.7 to 1,740.7 ft) for monitoring the UPLFA. The intermediate piezometer string was landed at 730.1 m (2,395.2 ft), and is slotted from 657.3 to 730.1 m (2,156.4 to 2,395.2 ft) for monitoring the TCA. The deep piezometer string was landed at 957.5 m (3,141.5 ft), and is slotted from 853.3 to 950.8 m (2,799.5 to 3,119.5 ft) for monitoring the TSA, the deepest aquifer encountered in the well. The three completion zones are separated by intervals of cement.

Composite drill cuttings were collected every 3.0 m (10 ft) from the depth of 24.4 m (80 ft) to TD, and 26 rotary sidewall core samples were recovered at various depths between 381.0 and 969.3 m (1,250 and 3,180 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. Except for a thin veneer of surficial alluvium, the well was drilled entirely within Tertiary volcanic rocks.

1.6 Contact Information

Inquiries concerning Well ER-EC-15 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 fluid management issues, geologic data collection, and completion information. The general drilling requirements for all the Pahute Mesa Phase II wells were provided in *Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2009a) and its addendum (NNES, 2010b). Specific requirements for Well ER-EC-15 were outlined in numbers D-003-001.10 and D-010-001.11 (NSTec, 2010a and 2010b). The layout of the drill site is shown in Figure 2-1. Figure 2-2 is a chart of the drilling and completion history for Well ER-EC-15. 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-15 began on October 18, 2010, when an NSTec crew set up the Auger II drill rig and augered a 106.7-cm (42-in.) diameter hole to 14.3 m (47 ft). On October 19, 2010, the NSTec crew completed drilling the conductor hole to a depth of 24.4 m (80 ft). A string of 30-in. conductor casing was set at the depth of 23.8 m (78.0 ft). The bottom of the conductor casing was cemented in place on October 20, 2010, using 3.5 cubic meters (m^3) (4.6 cubic yards [yd^3]) of 75/25 Type II cement (see cement composition in Appendix A-3). On October 21, 2010, 16.3 m^3 (21.3 yd^3) of Type II neat cement was pumped into the annulus between the casing and the formation to seal the annulus from the depth of 24.4 m (80.0 ft) to ground level.

The UDI crews arrived on October 28, 2010, and began rigging up the Wilson Mogul 42B drill rig. They finished rigging up on November 3, 2010, and began drilling from the top of cement inside the 30-in. casing at 21.5 m (70.5 ft) on November 5, 2010. The drill crew worked through the cement at the bottom of the 30-in. casing with a center-punch assembly consisting of a 20½-in. tricone bit mounted 3.8 m (12.5 ft) below a 26-in. hole opener. The drilling fluid was an air/water/soap mix in conventional circulation. The hole opener was removed when the hole reached the depth of 28.3 m (93 ft).

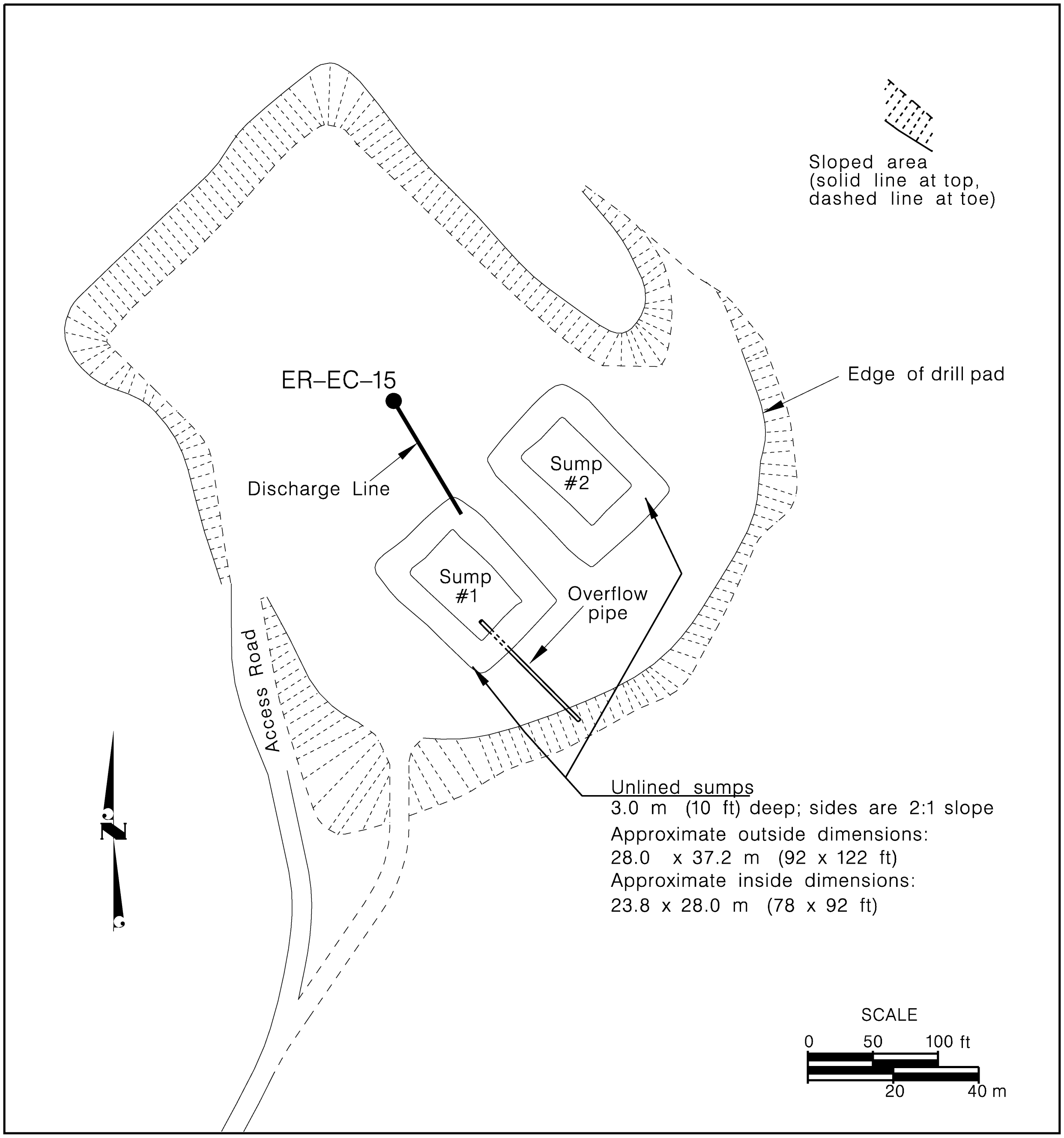
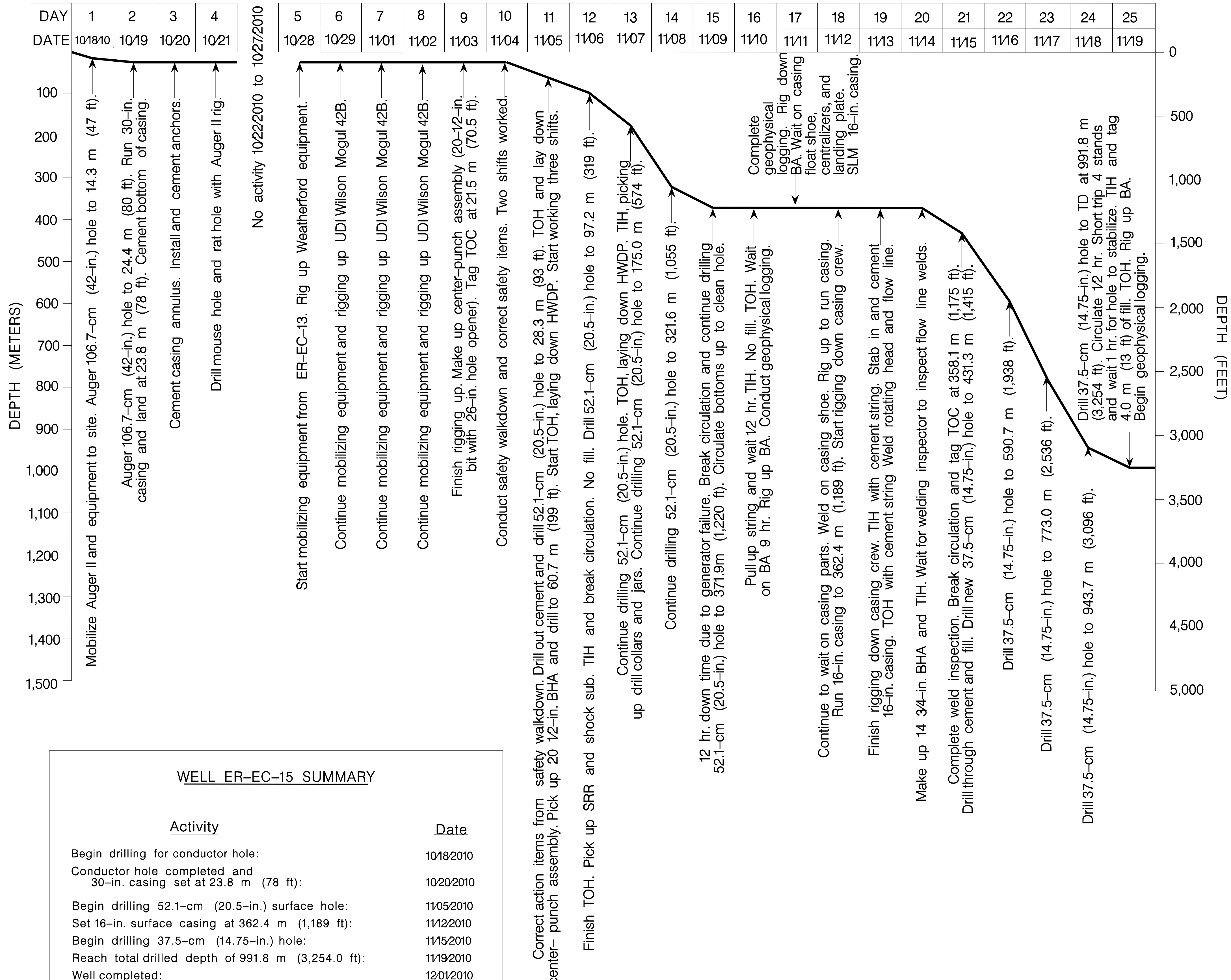


Figure 2-1
Drill Site Configuration for Well ER-EC-15

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)
HWDP	heavy–weight drill pipe
hr	hour(s)
in.	inch(es)
IPS	intermediate piezometer string
m	meter(s)
NAIL	nuclear annular investigation log
NSTec	National Security Technologies, LLC
RIH	run in hole
R–SWC	rotary sidewall core
SLM	steel line measurement
SPS	shallow piezometer string
SRR	side roller reamer
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.
WOC	waiting on cement



WELL ER–EC–15 SUMMARY

Activity	Date
Begin drilling for conductor hole:	10/18/2010
Conductor hole completed and 30–in. casing set at 23.8 m (78 ft):	10/20/2010
Begin drilling 52.1–cm (20.5–in.) surface hole:	11/05/2010
Set 16–in. surface casing at 362.4 m (1,189 ft):	11/12/2010
Begin drilling 37.5–cm (14.75–in.) hole:	11/15/2010
Reach total drilled depth of 991.8 m (3,254.0 ft):	11/19/2010
Well completed:	12/01/2010

FIGURE 2–2

WELL ER–EC–15
DRILLING AND COMPLETION
HISTORY
SHEET 1 OF 2

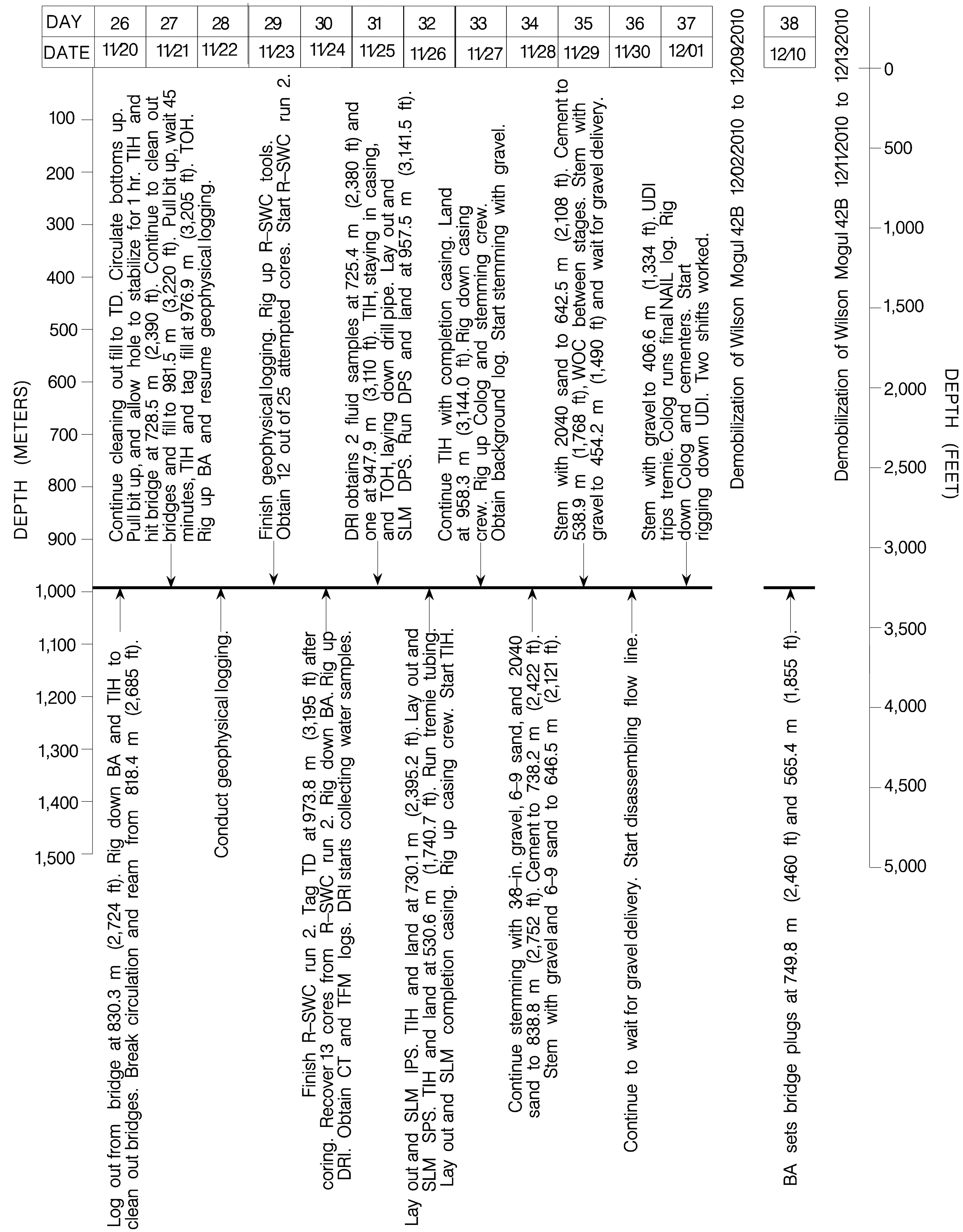


FIGURE 2–2

WELL ER–EC–15
DRILLING AND COMPLETION HISTORY

SHEET 2 OF 2

Table 2-1
Abridged Drill Hole Statistics for Well ER-EC-15

LOCATION DATA:

Coordinates:				
Nevada State Plane (Central Zone)	(NAD 27):	N 886,766.0 ft	E 543,262.0 ft
Nevada State Plane (Central Zone)	(NAD 83):	N 6,270,287.4 m	E 513,106.7 m
Universal Transverse Mercator (Zone 11)	(NAD 83):	N 4,115,624.0 m	E 542,689.1 m
Universal Transverse Mercator (Zone 11)	(NAD 27):	N 4,115,426.9 m	E 542,769.4 m

Surface Elevation [a]: 1,635.3 m (5,365 ft)

DRILLING DATA:

Spud Date: 11/05/2010 (main hole drilling with Wilson Mogul 42B rig)

Total Depth (TD): 991.8 m (3,254 ft)

Date TD Reached: 11/19/2010

Date Well Completed: 12/01/2010 (date completion string was cemented in place)

Hole Diameter: 106.7 cm (42 in.) from surface to 24.4 m (80.0 ft); 52.1 cm (20.5 in.) from 24.4 to 371.9 m (80 to 1,220 ft); 37.5 cm (14.75 in.) from 371.9 m (1,220 ft) to TD of 991.8 m (3,254 ft).

Drilling Techniques: Drill 106.7-cm (42-in.) hole from surface to 24.4 m (80.0 ft) with dry-hole auger. Center-punch with 20½-in. tricone bit mounted below a 26-in. hole opener to 28.3 m (93 ft); rotary drill with 20½-in. tricone bit, using air-foam in direct circulation from 28.3 to 371.9 m (93 to 1,220 ft); rotary drill with 14¾-in. tricone bit, using air-foam and polymer (when necessary) in direct circulation to TD of 991.8 m (3,254 ft).

CASING DATA: 30-in. conductor casing to 23.8 m (78.0 ft); 16-in. surface casing 0 to 362.4 m (0 to 1,189.0 ft); 7⅝-in. casing to 530.2 m (1,739.4 ft); cross-over sub at 530.2 to 530.7 m (1,739.4 to 1,741.3 ft); 5½-in. casing 530.7 to 958.3 m (1,741.3 to 3,144.0 ft).

WELL COMPLETION DATA [b]:

A string of 7⅝-in. and 5½-in. stainless-steel casing hangs from 7⅝-in. epoxy-coated carbon-steel casing via a crossover sub. The carbon-steel casing is positioned in the unsaturated zone to a point approximately 5.8 m (19 ft) above the water table. The 7⅝-in. outside diameter casing has an inside diameter (id) of 17.701 cm (6.969 in.). The 5½-in. casing has an id of 12.819 cm (5.047 in.). The completion string was landed at 958.3 m (3,144.0 ft). The 5½-in. casing has two slotted intervals, and the 7⅝-in. stainless-steel casing has one. Three 2⅞-in. piezometer strings (id of 5.994 cm [2.36 in.]) were also installed. The three stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing (id of 5.067 cm [1.995 in.]), connected via crossover subs. The shallow piezometer string was landed at 530.6 m (1,740.7 ft); the intermediate piezometer string was landed at 730.1 m (2,395.2 ft); and the deep piezometer string was landed at 957.5 m (3,141.5 ft). Bridge plugs were set at 565.4 and 749.8 m (1,855 and 2,460 ft) to isolate the three completion zones.

Depth of Slotted Section:		
	7⅝-in. completion casing (UPLFA):	424.7 to 530.2 m (1,393.3 to 1,739.4 ft)
	5½-in. completion casing (TCA):	657.3 to 734.0 m (2,156.5 to 2,408.3 ft)
	5½-in. completion casing (TSA):	855.5 to 951.5 m (2,806.6 to 3,121.7 ft)
	Shallow 2⅞-in. piezometer string (UPLFA):	420.8 to 530.6 m (1,380.7 to 1,740.7 ft)
	Intermediate 2⅞-in. piezometer string (TCA):	657.3 to 730.1 m (2,156.4 to 2,395.2 ft)
	Deep 2⅞-in. piezometer string (TSA):	853.3 to 950.8 m (2,799.5 to 3,119.5 ft)

Depth of Sand Packs: 642.5 to 652.0 m (2,108 to 2,139 ft)
838.8 to 848.6 m (2,752 to 2,784 ft)

Depth of Gravel Packs: 406.6 to 538.9 m (1,334 to 1,768 ft)
652.0 to 739.7 m (2,139 to 2,427 ft)
848.6 to 972.0 m (2,784 to 3,189 ft)

Depth of Pump: Not installed at time of completion

Water Depth [c]: Fluid-level depths measured 12/06/2010: 363.1 m (1,191.4 ft) in the shallow piezometer string; 363.2 m (1,191.5 ft) in the intermediate piezometer string; and 363.1 m (1,191.4 ft) in the deep piezometer string.

DRILLING CONTRACTOR: United Drilling, Inc.

GEOPHYSICAL LOGS BY: Baker Atlas, Desert Research Institute, Colog

SURVEYING CONTRACTOR: National Security Technologies, LLC

a Elevation of ground at wellhead, relative to mean sea level. National Geodetic Vertical Datum, 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. UPLFA = upper Paintbrush lava-flow aquifer; TCA - Tiva Canyon aquifer; TSA = Topopah Spring aquifer

c Fluid level tags by Navarro-Intera, LLC.

Drilling of the surface hole continued with a 20½-in. rotary tricone bit and air-foam in conventional circulation. Drilling continued uneventfully with no fill reported after pipe connections, though below 249.0 m (817 ft) returns were sporadic. Drilling was stopped for 12 hours on November 9, 2010, to repair generators for the radiological control technicians' station.

The first observation of water in the drilling effluent was reported at the depth of 356.3 m (1,169 ft) on November 9, 2010. When drilling had reached the depth of 371.9 m (1,220 ft), the decision was made to suspend drilling and conduct open-hole logging in the unsaturated zone, prior to installation of the surface casing. UDI then pulled the drill string up a short distance, waited 30 minutes, and then checked for fill. No fill was encountered and the crew removed the drill string in preparation for geophysical logging and the installation of surface casing. Geophysical logging began on November 10, 2010. The Baker Atlas logging crew completed the required geophysical logs, then rigged down and departed the location on November 11, 2010.

After logging operations were complete, the casing subcontractor began installing a string of 16-in. casing. Resistance due to a "tight hole" was encountered at 137.2 m (450 ft) and fill was encountered at 363.0 m (1,191 ft). The casing was set at 362.4 m (1,189 ft) on November 12, 2010. The bottom of the casing was cemented with 9.9 m^3 (13 yd^3) of Type II neat cement on November 13, 2010. The top of cement in the annulus is estimated to be at the depth of 278.0 m (912 ft), based on geophysical log data.

After installation of the casing, on November 14, 2010, the drill crew lowered a bottom-hole assembly with a 14¾-in. bit into the hole. After the flow line was welded onto the surface casing at the well head, operations at the rig site were stopped briefly until the new flow line configuration could be inspected. Operations resumed on November 15, 2010, when drilling of a 37.5-cm (14.75-in.) hole began. The crew drilled through cement inside the 16-in. casing from 358.1 to 362.7 m (1,175 to 1,190 ft) and through fill material to 371.9 m (1,220 ft).

Drilling continued into the formation with the 14¾-in. tricone bit and air-foam in conventional circulation. The drilling fluid was an air/water/soap mix with a polymer additive when needed. Drilling to the TD of 991.8 m (3,254 ft) continued without any delays. Between 568 to 2,082 liters per minute (Lpm) (150 to 550 gallons per minute [gpm]) of water was produced during most of the time the hole was being drilled below the water table.

Between approximately 847.3 and 924.8 m (2,780 and 3,034 ft) circulation was intermittent. High pressure discharges occurred every 10 to 15 minutes, occasionally bringing up fist-sized rocks. Between the surges, 3.0 m (10 ft) was sometimes drilled with no discharge. N-I estimated that the hole was producing between 1,893 and 2,082 Lpm (500 and 550 gpm) of water through this interval. During the surges, pressure in the stand pipe was measured at 3.1 to 3.4 megapascals (450 to 500 pounds per square inch). After the connection at 924.8 m (3,034 ft), water production decreased, and, although the hole continued surging, the maximum stand pipe pressure was 2.1 megapascals (310 pounds per square inch), and returns became constant for the remainder of drilling.

On November 19, 2010, the TD of 991.8 m (3,254 ft) was reached. The drill crew circulated fluid to clean out the hole, pulled the drill pipe up off bottom a short distance and waited an hour, and then checked for fill. They measured 4.0 m (13 ft) of fill, then removed the drill string from the hole in preparation for geophysical logging.

Geophysical logging began that same day. While running the temperature/gamma ray tools down the borehole, Baker Atlas encountered an obstruction at approximately 830.3 m (2,724 ft); tight spots were also encountered at the depths of 729.7 and 759.0 m (2,394 and 2,490 ft). Baker Atlas logged as they pulled up from the depth of 830.3 m (2,724 ft) with the six-arm caliper, orientation, spectral gamma ray, and gamma ray tools, then rigged down.

On November 20, 2010, the drill crew ran the drill string back into the borehole to attempt to clean out the bridge (obstacle consisting of fill material). After breaking through a bridge at 729.4 m (2,393 ft) and attempting to wash through another bridge at 818.4 m (2,685 ft) without circulation, they picked up the kelly and circulated air-foam in the borehole. The drill crew reamed through tight spots and drilled through bridges and fill back to the original TD of 991.8 m (3,254 ft). They circulated fluid to clean out the hole, and pulled the bit up. After waiting one hour for the hole to stabilize, the UDI crew ran the drill string back down and hit a bridge at 728.5 m (2,390 ft). They cleaned out bridges and fill as they worked the drill string back to 981.5 m (3,220 ft), then pulled up 10 stands of drill pipe, waited 45 minutes, and ran back in, tagging fill at 976.9 m (3,205 ft), approximately 14.9 m (49 ft) above the original drilled TD. UDI then pulled the drill string from the borehole and the Baker Atlas geophysical logging crew again rigged up to run logs.

Geophysical logging and rotary sidewall sampling operations were conducted by Baker Atlas crews on November 21–24, 2010. During the logging operations, Baker Atlas recorded water level depths between 363.0 and 364.5 m (1,191.0 and 1,196.0 ft). Baker Atlas tagged fill at 973.8 m (3,195 ft) after collection of the rotary sidewall cores, and pulled out of the hole in preparation for logging and water sampling by DRI personnel. DRI operations were completed on November 25, 2010.

The drill crew installed three 2⅞-in. piezometer strings on November 25–26, 2010, each with one slotted interval. The deep piezometer string was set at 957.5 m (3,141.5 ft), the intermediate piezometer string was set at 730.1 m (2,395.2 ft), and the shallow piezometer string was set at 530.6 m (1,740.7 ft). A casing subcontractor inserted the completion casing string, which has three slotted intervals, landing it on November 27, 2010, at a depth of 958.3 m (3,144 ft). The annulus around production casing and the three piezometer strings was packed with sand and gravel, and cemented. Stemming operations were completed on December 1, 2010. See Section 7.0 for details about the completion operations.

The drillers started demobilizing the rig and drilling equipment on December 1, 2010, and crews worked one shift per day after that, until demobilization was completed on December 9, 2010. Two bridge plugs that isolate the three slotted intervals in the completion casing string were installed at 565.4 m (1,855 ft) and 749.8 m (2,460 ft) by Baker Atlas on December 10, 2010.

The inclination of the borehole was determined from borehole orientation logs run by Baker Atlas during each logging operation (November 10 and 21, 2010). The changes in borehole orientation visible on the borehole orientation plots are relatively gentle and generally correspond to formation changes or changes in drilling parameters. The borehole follows a gentle northeasterly path. The average borehole inclination is 2.6 degrees, and the greatest deviation is 4.1 degrees. At TD the borehole is approximately 41.2 m (135.2 ft) northeast of the collar location, on a bearing of 51.1 degrees. At the lowest logged depth of 974.1 m (3,196.0 ft) the true vertical depth is calculated to be 973.0 m (3,192.3 ft), a difference of 1.1 m (3.7 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-15 are listed in Appendix A-3.

2.3 Drilling Problems

Throughout most of the hole, a slight but consistent “wobble” in the borehole path caused an oscillating pattern on geophysical log plots. Similar oscillation has been observed in geophysical logs from previous UGTA wells (DOE/NV, 2000a and 2000b; NNSA/NSO, 2010a), and its cause is unknown. On November 17, 2010, drillers turned off the automatic driller, a device used to keep weight on the bit within the desired range, and drilled manually from 513.3 to 544.1 m (1,684 to 1,785 ft) in an attempt to determine if the automatic driller was the cause of the repetitive borehole wall grooving. However, later examination of the geophysical logs revealed that the oscillation was still present through the manually drilled interval.

Pressurization of the borehole followed by rapid unloading of the hole led to intermittent returns below 847.3 m (2,780 ft). This caused the loss of cuttings samples from several intervals and, in places, contamination of cuttings with excessive caved material from higher in the hole.

After TD was reached, excessive sloughing of the borehole wall led to the deposition of fill and bridges that obstructed attempts at geophysical logging. Initial attempts to clear the bridges without breaking circulation failed, and the drill crew was forced to break circulation and drill through the bridges and fill twice. Over 36 hours were spent cleaning out the borehole to allow geophysical logging, and 19.8 m (65 ft) of fill was left in the bottom of the borehole.

2.4 Fluid Management

The drilling effluent was monitored during drilling according to the methods prescribed in the UGTA Project FMP (NNSA/NSO, 2009b) and the associated state-approved, well-specific, fluid management strategy letter (NNES, 2010c). The air-foam/polymer drilling 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 UGTA Well ER-EC-8, located to the southwest in Rocket Wash near its intersection with Thirsty Canyon. Lithium bromide was added to the drilling 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 drilling fluid returns.

Radionuclides exceeding fluid quality objectives were not expected at Well ER-EC-15 based on Phase I flow and transport modeling (SNJV, 2006, 2007, and 2009b). To manage the anticipated water production, two unlined sumps (sump #1 and sump #2) were constructed prior to drilling (Figure 2-1).

Samples of drilling effluent were collected hourly during drilling by N-I personnel and analyzed on site by radiological control technicians for the presence of tritium. As detailed in the N-I data report (N-I, 2011) and summarized in Appendix B of this report, the onsite drilling fluid monitoring results indicated that tritium activity levels were generally below 1,600 picocuries per liter (pCi/L) (minimum detection limit of the field instruments) and all were well within drinking water standards. Tritium activity levels above 1,600 pCi/L were measured on three samples. Two of these measurements were attributed to chemoluminescence, a common problem in field analyses. After these samples were re-run, the tritium activity levels were well below 1,600 pCi/L. The other sample, collected at 374.9 m (1,230 ft) while drilling through the cement, showed a slightly elevated tritium activity level of 2,150 pCi/L, but is believed to be due to a chemical interaction between the cement and the scintillation cocktail used in the analysis. That sample was not recounted.

No lead monitoring of discharge fluids was performed. Lead monitoring is not initiated until discharge fluids exceed the UGTA fluid management criteria for tritium (200,000 pCi/L), as specified in the Well ER-EC-15 fluid management strategy letter (NNES, 2010c) approved by the Nevada Division of Environmental Protection. N-I personnel checked all down-hole equipment for lead prior to use in the borehole. The lead analyses were below 2 micrograms per liter (2 parts per billion) (N-I, 2011).

All fluid quality objectives were met, as shown on the fluid management reporting form (Appendix B). The form in Table B-1 lists volumes of solids (drill cuttings) and fluids produced during well-construction operations (vadose-zone drilling and saturated-zone drilling; 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.

3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-EC-15 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology along the predicted groundwater flow path through the Bench area was one of the primary objectives of Well ER-EC-15, 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-15 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, 2010a).

3.2 Drill Cuttings

Two samples, at the depths of 18.3 and 24.4 m (60 and 80 ft), were collected by NSTec geologists during construction of the conductor hole. N-I personnel collected composite drill cuttings samples at 3.0-m (10-ft) intervals during drilling of the main hole below 24.4 m (80 ft). Triplicate samples, each consisting of approximately 550 cubic centimeters of material, were collected from 312 intervals to 990.6 m (3,250 ft). Samples are missing from five intervals due to intermittent and temporary poor drilling fluid returns:

- 381.0 to 384.0 m (1,250 to 1,260 ft)
- 899.2 to 902.2 m (2,950 to 2,960 ft)
- 905.3 to 908.3 m (2,970 to 2,980 ft)
- 911.4 to 917.4 m (2,990 to 3,010 ft)
- 990.6 to 991.8 m (3,250 to 3,254 ft)

The cuttings 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-15 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, geophysical logs, and the quality and quantity of drill cuttings, with consideration of borehole conditions determined from caliper logs. Baker Atlas used a rotary sidewall coring tool to obtain samples from the borehole wall between the depths of 381.0 and 969.3 m (1,250 and 3,180 ft). At Well ER-EC-15, only the rotary sidewall coring tool was employed because 1) the percussion-gun sidewall method has had a poor sample recovery record in the last several UGTA wells in the Pahute Mesa area, and 2) many of the intended sampling points at Well ER-EC-15 were of harder lithologies (e.g., lava and welded ash-flow tuff), in which the rotary sidewall coring tool has had a higher success rate.

A total of 26 cores were recovered, though there were many attempts where the core barrel did not reach the borehole wall due to washouts. Table 3-1 summarizes the results of sidewall coring operations at Well ER-EC-15.

3.4 Sample Analysis

Eight sidewall cores and seventeen samples of drill cuttings from various depths in Well ER-EC-15 were submitted to Comprehensive Volcanic Petrographics, LLC, for petrographic analysis. A split of the same sidewall cores and drill cuttings from the same 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 the cuttings and core samples and geophysical logs. The primary purpose of these analytical data is to confirm stratigraphic identification and to characterize mineral alteration. In addition, the data provide detailed information on mineralogic composition for 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 during drilling: in the unsaturated zone prior to installation of the 16-in. casing at 371.9 m (1,220 ft), and in the saturated zone after the TD

Table 3-1
Rotary Core Sidewall Samples from Well ER-EC-15

Core Depth [a]		Recovery [b, c] centimeters (inches)	Stratigraphic Unit	Lithology
meters	feet			
381.0	1,250	1.27 (0.50)	rhyolite of Fluorspar Canyon	Bedded tuff, zeolitic
381.0	1,250	tool stalled [d]	rhyolite of Fluorspar Canyon	Bedded tuff, zeolitic
393.2	1,290	3.68 (1.45)	hornblende-bearing rhyolite of ER-EC-15	Pumiceous lava, zeolitic
405.4	1,330	3.81 (1.50)	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, vitric
432.8	1,420	1.02 (0.40)	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, devitrified
453.8	1,489	Washout	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, devitrified
453.8	1,489	2.54 (1.0) [d]	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, devitrified
454.2	1,490	Washout	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, devitrified
454.2	1,490	Washout [d]	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, devitrified
472.4	1,550	3.43 (1.35)	hornblende-bearing rhyolite of ER-EC-15	Rhyolite lava, devitrified
515.1	1,690	3.18 (1.25)	hornblende-bearing rhyolite of ER-EC-15	Vitrophyric lava
536.4	1,760	3.56 (1.40)	Paintbrush Tuff, undifferentiated	Bedded tuff, zeolitic
554.4	1,819	2.29 (0.90)	rhyolite of Benham	Pumiceous lava, zeolitic
554.7	1,820	Washout	rhyolite of Benham	Pumiceous lava, zeolitic
554.7	1,820	Washout [d]	rhyolite of Benham	Pumiceous lava, zeolitic
563.9	1,850	3.68 (1.45)	rhyolite of Benham	Flow Breccia, vitric
579.1	1,900	2.16 (0.85)	rhyolite of Benham	Flow Breccia, vitric
624.8	2,050	3.68 (1.45)	Paintbrush Tuff, undifferentiated	Bedded tuff, zeolitic
640.1	2,100	3.05 (1.20)	Paintbrush Tuff, undifferentiated	Bedded tuff, zeolitic
640.1	2,100	Washout [d]	Paintbrush Tuff, undifferentiated	Bedded tuff, zeolitic
652.3	2,140	1.78 (0.70)	Tiva Canyon Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic
682.8	2,240	2.54 (1.00)	Tiva Canyon Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic
713.2	2,340	3.05 (1.20)	Tiva Canyon Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic

Table 3-1
Rotary Core Sidewall Samples from Well ER-EC-15 (continued)

Core Depth [a]		Recovery [b, c] centimeters (inches)	Stratigraphic Unit	Lithology
meters	feet			
721.8	2,368	2.29 (0.90)	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
722.1	2,369	Washout	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
722.4	2,370	Washout	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
722.4	2,370	Washout [d]	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
722.4	2,370	Washout [e]	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
722.4	2,370	Washout [f]	Tiva Canyon Tuff	Ash-flow tuff, vitrophyric
807.7	2,650	3.81 (1.50)	Topopah Spring Tuff	Ash-flow tuff, nonwelded, quartzo-feldspathic
868.4	2,849	1.27 (0.50)	Topopah Spring Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic
868.7	2,850	Washout	Topopah Spring Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic
899.2	2,950	1.78 (0.70)	Topopah Spring Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic
923.5	3,030	2.92 (1.15)	Topopah Spring Tuff	Ash-flow tuff, moderately welded, quartzo-feldspathic
935.4	3,069	0.99 (0.39)	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
935.7	3,070	2.29 (0.90)	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
947.9	3,110	3.94 (1.55)	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
956.5	3,138	2.29 (0.90)	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
956.8	3,139	Washout	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
957.1	3,140	Washout	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
957.1	3,140	Washout	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic
969.3	3,180	2.79 (1.10)	mafic-poor Calico Hills Formation	Bedded tuff, quartzo-feldspathic

a All depths are drilled depths.
b Rotary sidewall coring tool core diameter: 25.4 millimeters (1 in.)
c Shaded rows indicate samples attempted but not recovered.
d Second attempt
e Third attempt
f Fourth attempt

Table 3-2
Rock Samples from Well ER-EC-15 Selected for Petrographic, Mineralogic, and Chemical Analysis [a]

Depth [b, c]		Sample Identifier [d]
meters	feet	
39.6	130	EREC/15–130D
246.9	810	EREC/15–810D
292.6	960	EREC/15–960D
350.5	1,150	EREC/15–1,150D
393.2	1,290	EREC/15–1,290RS
405.4	1,330	EREC/15–1,330RS
442.0	1,450	EREC/15–1,450D
487.7	1,600	EREC/15–1,600D
518.2	1,700	EREC/15–1,700D
551.7	1,810	EREC/15–1,810D
563.9	1,850	EREC/15–1,850RS
606.6	1,990	EREC/15–1,990D
624.8	2,050	EREC/15–2,050RS
640.1	2,100	EREC/15–2,100RS
673.6	2,210	EREC/15–2,210D
728.5	2,390	EREC/15–2,390D
737.6	2,420	EREC/15–2,420D
771.1	2,530	EREC/15–2,530D
789.4	2,590	EREC/15–2,590D
807.7	2,650	EREC/15–2,650RS
823.0	2,700	EREC/15–2,700D
871.7	2,860	EREC/15–2,860D
923.5	3,030	EREC/15–3,030RS
947.9	3,110	EREC/15–3,110RS
990.6	3,250	EREC/15–3,250D

a Mineralogic analysis by x-ray diffraction; chemical analysis by x-ray fluorescence.
b All depths are drilled depths.
c Depths for petrographic, mineralogic, and chemical analyses represent base of 3.0-m (10-ft) sample interval for drill cuttings samples.
d “D” in sample identifier indicates drill cuttings sample. “RS” indicates rotary sidewall core sample.

was reached at 991.8 m (3,254 ft). The overall quality of the geophysical log data collected was good, but several of the log signatures were affected by the borehole "wobble" described in Section 2.3. This primarily affects the density and neutron porosity logs. A complete listing of the logs, dates run, depths, and service companies is provided in Table 3-3. Note that a gamma ray log is typically included with each logging run for depth control. Electronic and paper versions of the logs are stored at NSTec offices 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 log data are provided in Appendix D.

Table 3-3
Well ER-EC-15 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	11/19/2010 11/21/2010	TL-1 / GR-4 L-2 / GR-6	830.3 (2,724) 976.0 (3,202)	259.7 (852) 259.7 (852)
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	11/10/2010 11/19/2010 11/21/2010	CA6-1 / ORIT-1 / GR-1 CA6-2 / ORIT-2 / GR-5 CA6-3 / ORIT-3 / GR-7	369.1 (1,211) 826.6 (2,712) 972.9 (3,192)	23.8 (78) 362.4 (1,189) 362.4 (1,189)
* Gamma Ray / * Digital Spectralog	Stratigraphy, mineralogy, and natural and man-made radiation determination	BA	11/10/2010 11/19/2010 11/21/2010	SGR-1 / GR-1 SGR-2 / GR-5 SGR-3 / GR-7	361.5 (1,186) 817.5 (2,682) 962.9 (3,159)	0 (0) 362.4 (1,189) 306.0 (1,004)
* High Definition Induction / Gamma Ray / Spontaneous Potential	Lithologic determination; saturation of formations; stratigraphic and depth correlation	BA	11/10/2010	HDIL-1 / GR-2 / SP-1	367.0 (1,204)	23.8 (78)
* Compensated Z-Densilog / * Compensated Neutron / Gamma Ray / Caliper	Stratigraphic and lithologic determination; identification of welding, alteration, rock porosity, and water content	BA	11/11/2010 11/22/2010	ZDL-1 / CN-1 / GR-3 ZDL-2 / CN-2 / GR-9	370.0 (1,214) 973.8 (3,195)	23.8 (78) 274.3 (900)
Circumferential Borehole Imaging / Gamma Ray	Structural analysis, including fracture characterization; recognition of lithologic features	BA	11/23/2010	CBIL-1 / GR-12	973.2 (3,193)	363.2 (1,191.5)
* X-Multipole Array Acoustilog/ Gamma Ray	Primary matrix porosity	BA	11/22/2010	XMAC-1 / GR-10	970.0 (3,182.5)	367.6 (1,206)
Resistivity Imaging / Gamma Ray	Saturated zone: lithologic characterization, bedding dip, fracture and void analysis	BA	11/22/2010	STAR-1 / GR-11	973.7 (3,194.5)	371.9 (1,220)
* R_t Explorer / Gamma Ray / Spontaneous Potential	Lithologic determinations, identification of alteration, recognition of welding; distinguishing low versus high porosity	BA	11/22/2010	RTEX-1 / GR-8 / SP-2	969.6 (3,181)	364.2 (1,195)
Rotary Sidewall Coring Tool / Gamma Ray	Geologic samples	BA	11/23/2010	RCOR-1 / GR-13	969.3 (3,180)	381.0 (1,250)

Table 3-3
Well ER-EC-15 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)
* Chemistry / * Temperature Log	Groundwater chemistry and temperature	DRI	11/24/2010	Chem-1 / TL-3	830.6 (2,725)	363.2 (1,191.5)
* Heat Pulse Flow Log	Groundwater flow rate and direction	DRI	11/24/2010	HPFlow-1	835.2 (2,740)	390.1 (1,280)

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

b BA = Baker Atlas; DRI = Desert Research Institute.

c Drilled depth

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

4.0 Geology and Hydrogeology

4.1 Introduction

This section describes the geology and hydrogeology of Well ER-EC-15. The basis for the discussions here is the detailed geologic characterization of Well ER-EC-15 presented as a detailed lithologic log in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, and drilling characteristics. Petrographic, mineralogic, and chemical analyses on select lithologic samples from Well ER-EC-15 were incorporated into the detailed lithologic log.

4.2 Geology

This section is divided into three discussions relating to the geology of Well ER-EC-15. Section 4.2.1 briefly describes the geologic setting of the Pahute Mesa and Bench areas and the Well ER-EC-15 site. The stratigraphic and lithologic units penetrated at the well are discussed 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 used in various figures in this report. See Figure 4-1 for a surface geologic map of the area surrounding the Well ER-EC-15 site.

4.2.1 Geologic Setting

Well ER-EC-15 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 the southern rim of Pahute Mesa, a high volcanic plateau composed of lava and tuff of generally rhyolitic composition. The volcanic rocks that compose Pahute Mesa bury the SCCC, which consists of two overlapping calderas—the Grouse Canyon caldera and the younger Area 20 caldera (Sawyer and Sargent, 1989). These calderas were formed by voluminous eruptions of ash-flow tuffs of generally rhyolitic composition, between approximately 13 and 14 Ma (Sawyer et al., 1994).

Table 4-1
Key to Stratigraphic Units of the Well ER-EC-15 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
Rocket Wash Tuff	Ttr
comendite of Ribbon Cliff	Ttc
Volcanics of Fortymile Canyon	**Tf**
rhyolite of Beatty Wash	Tfbw
Beatty Wash Formation	Tfb
Timber Mountain Group	**Tm**
Ammonia Tanks Tuff	Tma
mafic-rich Ammonia Tanks Tuff	Tmar
mafic-poor Ammonia Tanks Tuff	Tmap
debris-flow breccia	Tmax
bedded Ammonia Tanks Tuff	Tmab
rhyolite of Tannenbaum Hill	Tmat
landslide deposits	Tmatx
Rainier Mesa Tuff	Tmr
mafic-rich Rainier Mesa Tuff	Tmrr
mafic-poor Rainier Mesa Tuff	Tmrp
rhyolite of Fluorspar Canyon	Tmrf
Paintbrush Group	**Tp**
hornblende-bearing rhyolite of ER-EC-15	Tph
rhyolite of Benham	Tpb
rhyolite of Scrugham Peak	Tps
tuff of Pinyon Pass	Tpcy
crystal-poor tuff of Pinyon Pass	Tpcyp
Tiva Canyon Tuff	Tpc
Pahute Mesa lobe of Tiva Canyon Tuff	Tpcm
crystal-poor Tiva Canyon Tuff	Tpcp
rhyolite of Delirium Canyon	Tpd
Topopah Spring Tuff	Tpt
Pahute Mesa lobe of Topopah Spring Tuff	Tptm
Calico Hills Formation	**Th**
mafic-poor Calico Hills Formation	Thp
mafic-rich Calico Hills Formation	Thr

Table 4-1
Key to Stratigraphic Units of the Well ER-EC-15 Area (continued)

Stratigraphic Unit	Map Symbol
Crater Flat Group	**Tc**
rhyolite of Inlet	Tci
rhyolite of Jorum	Tcpj
rhyolite of Sled	Tcps
rhyolite of Kearsarge	Tcpk
Bullfrog Tuff	Tcb
debris-flow breccia	Tcbx
Belted Range Group	**Tb**
Dead Horse Flat Formation	Tbd
Grouse Canyon Tuff	Tbg
pre-Grouse Canyon caldera units	**To**
Paleozoic sedimentary rocks	**Pz**

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
Tannenbaum Hill lava-flow aquifer	THLFA
Tannenbaum Hill composite unit	THCM
Timber Mountain composite unit	TMCM
Fluorspar Canyon confining unit	FCCU
upper Paintbrush lava-flow aquifer	UPLFA
post-Benham Paintbrush confining unit	PBPCU
Benham aquifer	BA
upper Paintbrush confining unit	UPCU
Tiva Canyon aquifer	TCA
lower Paintbrush confining unit	LPCU
Topopah Spring aquifer	TSA
Calico Hills confining unit	CHCU
Crater Flat composite unit	CFCM
Crater Flat confining unit	CFCU
Bullfrog confining unit	BFCU
Belted Range aquifer	BRA
pre-Belted Range composite unit	PBRCM
lower carbonate aquifer	LCA

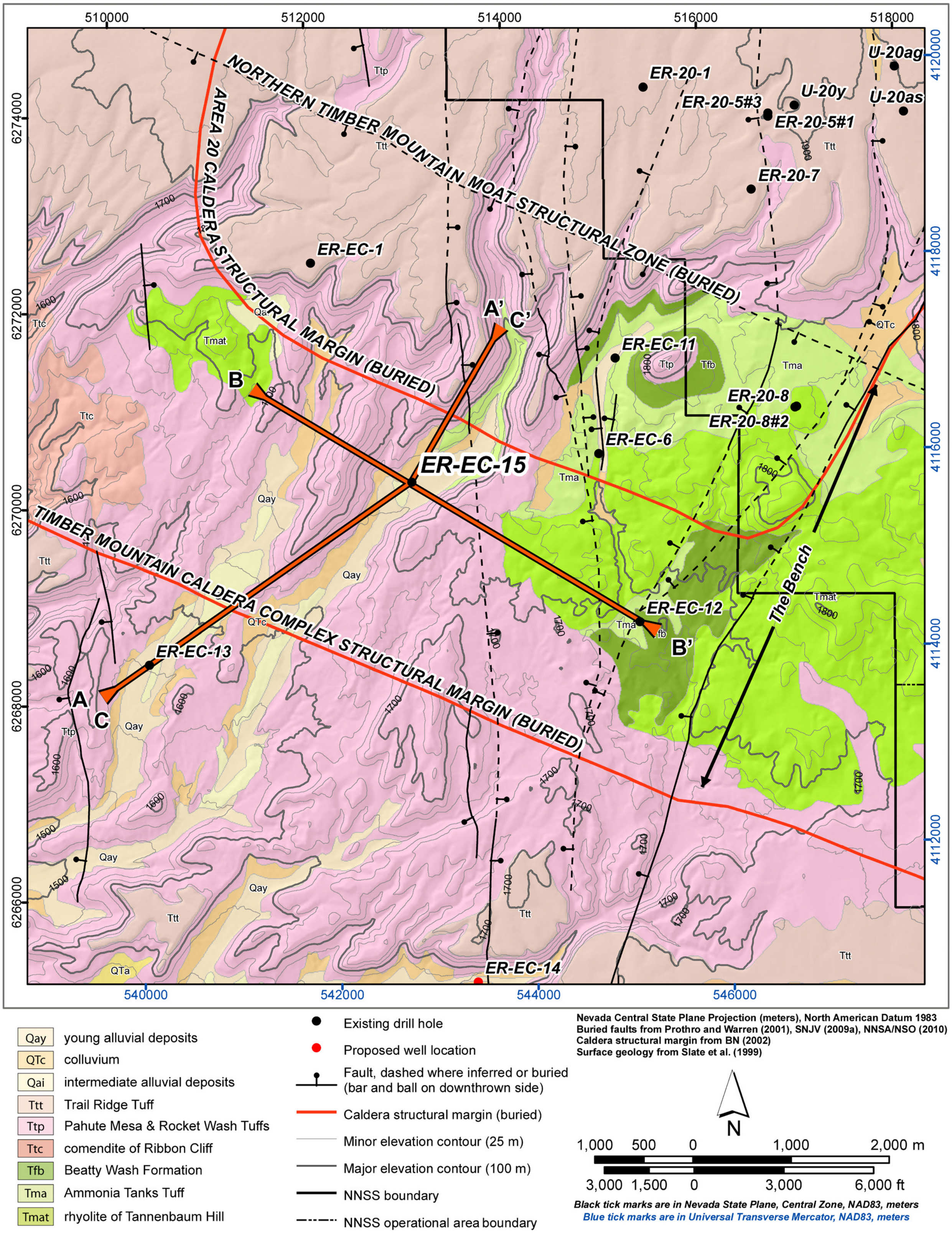


Figure 4-1
Surface Geologic Map of the Well ER-EC-15 Area

The TMCC, whose buried structural margin is located approximately 1,767.8 m (5,800 ft) southwest of Well ER-EC-15 (BN, 2002), formed as a result of the eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff, 11.6 and 11.45 Ma, respectively (Sawyer et al., 1994). At this location, the structural margin of the TMCC is interpreted to represent the northern structural boundaries of both the Rainier Mesa and Ammonia Tanks calderas (BN, 2002). The youngest volcanic units in the area are a series of ash-flow tuffs erupted from the Black Mountain caldera, located approximately 10 kilometers (6 miles) northwest of the well. These tuffs include the 9.4-Ma Rocket Wash Tuff and Pahute Mesa Tuff and the 9.3-Ma Trail Ridge Tuff (Slate et al., 1999).

The well site is constructed on young alluvial deposits in a canyon cut into Pahute Mesa and Rocket Wash Tuffs (Slate et al., 1999). Underlying the Pahute Mesa and Rocket Wash Tuffs in the canyon walls and the alluvium in the canyon floor, is a thick section of rhyolite lava that flowed onto a structural bench formed during the time period between the caldera-forming eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff. This structural bench, designated the Northwestern Timber Mountain Bench by Warren et al. (2000) but referred to as simply the Bench in this and other Phase II documents (SNJV, 2009a; NNES, 2010b; NNSA/NSO, 2010a; NNSA/NSO, 2010b), is bounded on the north by the NTMMSZ and on the south by the buried northern structural margin of the TMCC (Figure 4-1). The NTMMSZ is a west-northwest trending buried structural zone first recognized geophysically (Mankinen et al., 1999; Grauch et al., 1999), and subsequently confirmed by data from PM–OV Phase I drilling (DOE/NV, 2000a) and the recent Phase II drilling (e.g., Well ER-20-7 [NNSA/NSO, 2010a] and Well ER-EC-11 [NNSA/NSO, 2010b]). The NTMMSZ is a down-on-the-southwest fault (or fault zone) that displaces rock units as young as the Rainier Mesa Tuff by more than 300 m (1,000 ft). The NTMMSZ appears to be related to the formation of the TMCC, with major movement occurring between the eruptions of the Rainier Mesa Tuff and Ammonia Tanks Tuff (DOE/NV, 2000b).

Numerous normal faults have been mapped at the surface on Pahute Mesa (Slate et al., 1999). These faults generally strike in a northerly direction with the larger faults dipping west. Based on surface exposures, many of these faults appear to die out or become obscured south of Pahute Mesa (Slate et al., 1999). Initial results from Phase II drilling suggest that, like much of Pahute Mesa, the Bench is also dissected by generally north-striking normal faults, but these faults are poorly exposed and buried in many places by younger, post-fault deposits (NNSA/NSO, 2010a and 2010b; NNSA/NSO, 2011a and 2011b; this report). Several of these faults are interpreted to occur in the vicinity of Well ER-EC-15 (Figure 4-1). The nearest mapped surface faults are located about 1.1 kilometers (0.7 miles) northeast of Well ER-EC-15 (O'Conner et al., 1966).

4.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Well ER-EC-15 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 Figures 4-3 and 4-4. The determination of the volcanic stratigraphic and lithologic units penetrated by Well ER-EC-15 was aided by examination of, and correlation with, nearby Phase I Wells ER-EC-6 and ER-EC-1 (DOE/NV, 2000a; 2000b), located approximately 1,934 m (6,345 ft) east-northeast and 2,455 m (8,055 ft) north-northwest, respectively, from Well ER-EC-15 (Figure 1-3).

Drilling at Well ER-EC-15 began in young alluvial deposits which form the ground surface in the vicinity of the well site (Figure 4-1). Alluvium was encountered from the surface to the depth of 14.0 m (46 ft). This relatively thin veneer of alluvium overlies 25.6 m (84 ft) of zeolitic bedded tuff assigned to the Ammonia Tanks Tuff of the Timber Mountain Group, which was penetrated from 14.0 to 39.6 m (46 to 130 ft). The stratigraphic assignment of Ammonia Tanks Tuff is based on nearby surface exposures, the interval's stratigraphic position above rhyolite lava of the rhyolite of Tannenbaum Hill (see discussion below), and its mineralogic assemblage, which includes quartz phenocrysts, biotite, and sphene. The thin occurrence of the Ammonia Tanks Tuff at Well ER-EC-15 clearly indicates that the well is located outside the structural margins of the Ammonia Tanks caldera.

Below the Ammonia Tanks Tuff and within the depth interval 39.6 to 272.8 m (130 to 895 ft), the borehole penetrated 163.7 m (537 ft) of rhyolite lava overlying 69.5 m (228 ft) of bedded tuff, all assigned to the rhyolite of Tannenbaum Hill, which is also part of the Timber Mountain Group. The rhyolite lava was encountered from 39.6 to 203.3 m (130 to 667 ft), and is composed of a typical sequence of rhyolite lava-flow facies, including a pumiceous lava top, upper vitrophyric zone, thick stoney-lava interior, lower vitrophyric zone, and a basal flow breccia. Other features common to rhyolite lava were also observed, including perlitic structures, spherulites, and flow banding. As is characteristic of rhyolite lava, lithic and pumice fragments (i.e., pyroclasts) are absent. The underlying bedded tuff is zeolitic, and was encountered from 203.3 to 272.8 m (667 to 895 ft). The upper 14.6 m (48 ft) of this bedded sequence, which directly underlies the rhyolite lava, exhibits characteristics of both pumiceous lava and nonwelded tuff, and likely represents a sequence of precursor eruptions related to the overlying lava that are transitional in nature between pyroclastic and effusive deposits. The stratigraphic assignment of the rhyolite of Tannenbaum Hill is based on the lava-flow lithology, stratigraphic position above the rhyolite of Fluorspar Canyon (see discussion below), and mineralogic assemblage, including the presence of quartz phenocrysts and sphene.

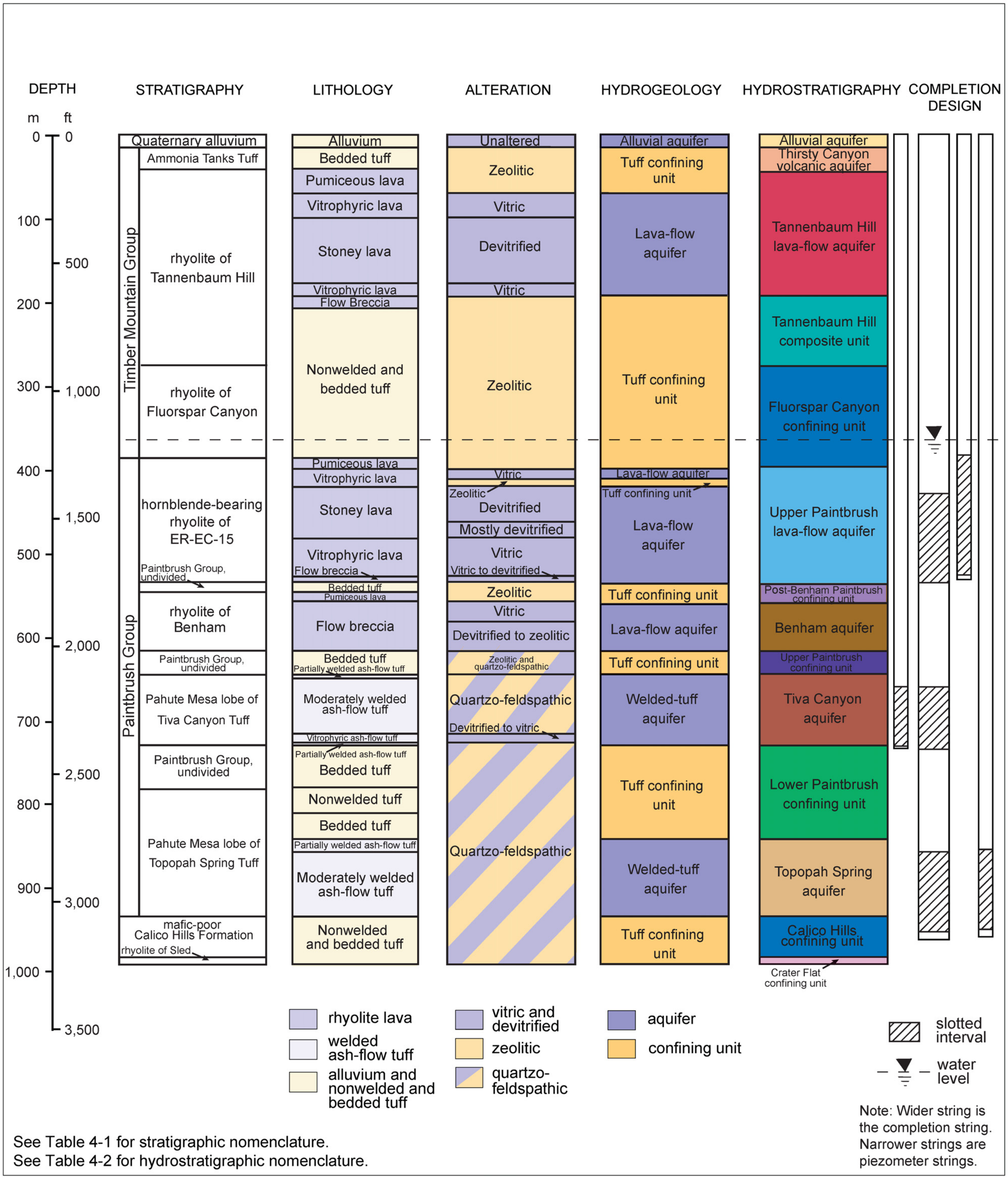


Figure 4-2
Geology and Hydrogeology of Well ER-EC-15

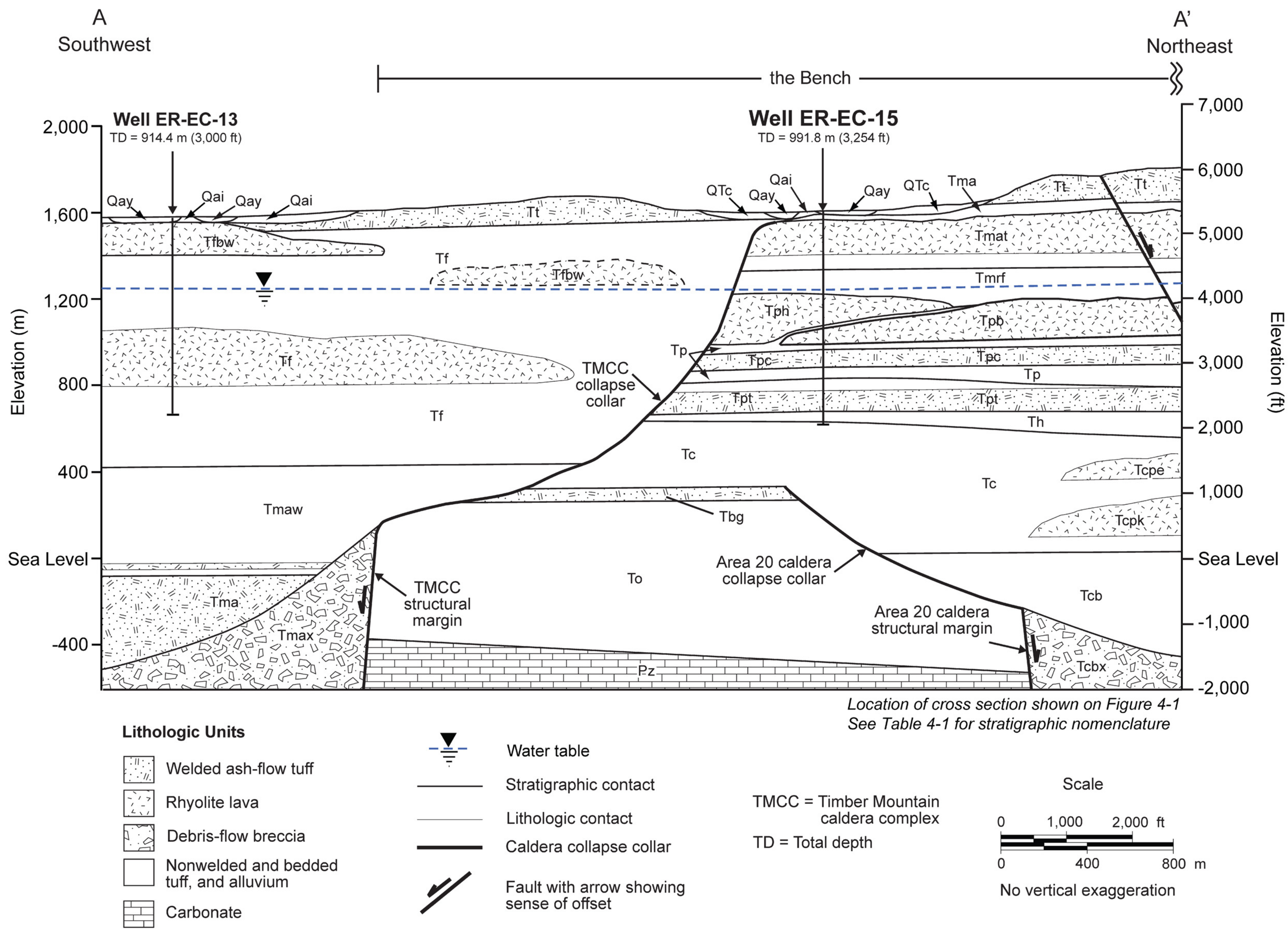


Figure 4-3
Southwest–Northeast Geologic Cross Section A–A' through Well ER-EC-15

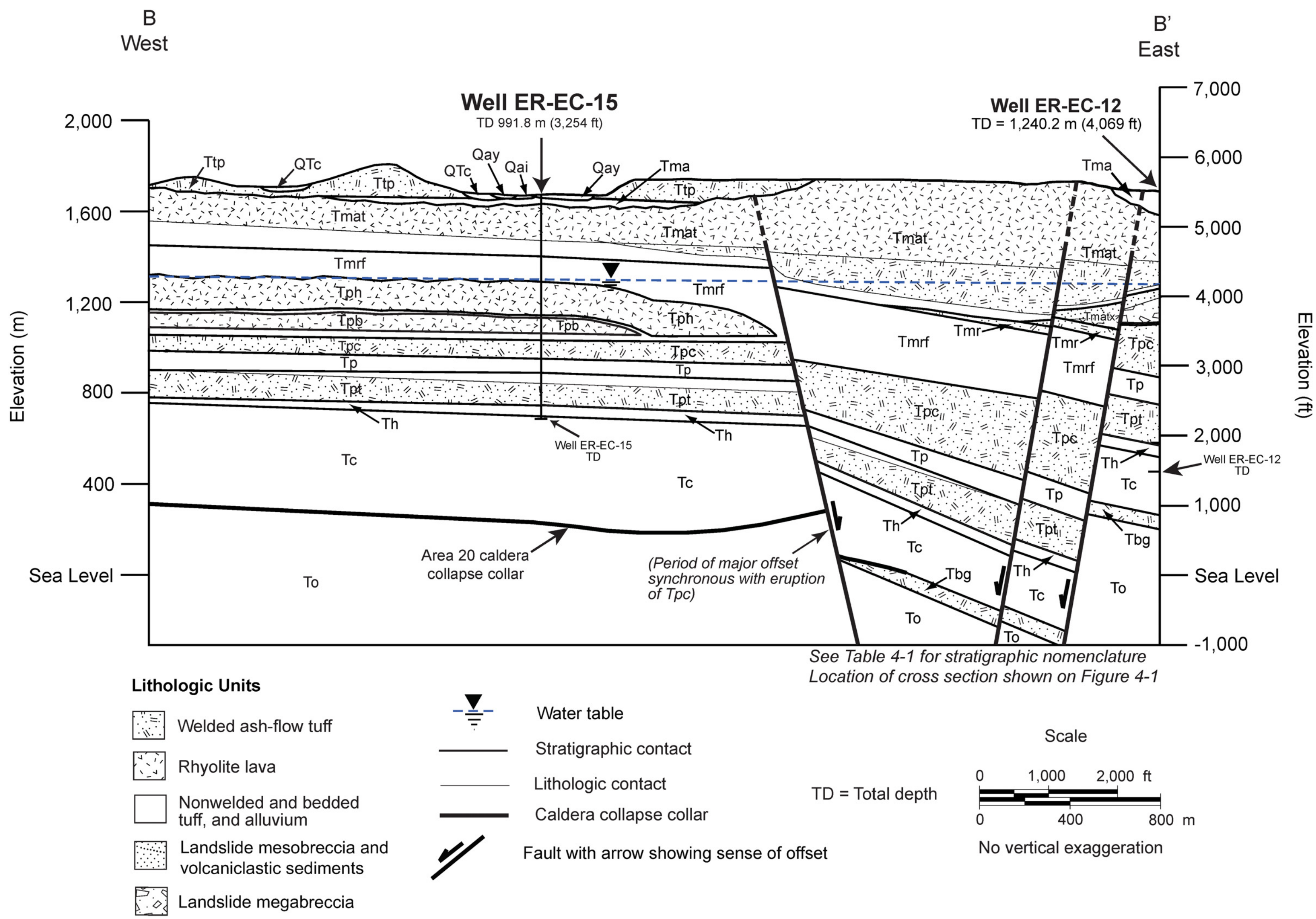


Figure 4-4
Northwest–Southeast Geologic Cross Section B–B’ through Well ER-EC-15

The rhyolite of Tannenbaum Hill was deposited onto the Bench during a time period between the caldera-forming eruptions of the Rainier Mesa and Ammonia Tanks Tuffs.

Below the rhyolite of Tannenbaum Hill, Well ER-EC-15 penetrated 113.1 m (371 ft) of zeolitic nonwelded and bedded tuff from 272.8 to 385.9 m (895 to 1,266 ft). This interval is assigned to the rhyolite of Fluorspar Canyon based on its thick nonwelded and bedded lithology, presence of quartz phenocrysts, absence of sphene, relatively low thorium content as observed on the spectral gamma ray log, and its stratigraphic position between the rhyolite of Tannenbaum Hill and Paintbrush Group (see discussions below). The rhyolite of Fluorspar Canyon, which forms the base of the Timber Mountain Group in the area, is a conspicuous stratigraphic marker horizon on the Bench. Its presence directly below the rhyolite of Tannenbaum Hill in Well ER EC-15 indicates that the Rainier Mesa Tuff is not present in the well, which in turn is a clear indication that the well lies outside of the Rainier Mesa caldera.

The next major stratigraphic interval in Well ER-EC-15 is the Paintbrush Group, consisting of a sequence of rhyolitic lava and tuff characterized by the almost complete absence of quartz phenocrysts (Slate et al., 1999). As is typical for most wells in the area, Well ER-EC-15 encountered lava and bedded tuff in the upper portion of the Paintbrush Group and welded ash-flow tuff and bedded tuff in the lower portion. The Paintbrush Group was erupted from calderas and related vents that are approximately spatially coincident with the TMCC, between 12.7 and 12.8 Ma (Sawyer et al., 1994).

The upper portion of the Paintbrush Group in Well ER-EC-15 consists of two rhyolite lava flows separated by 11.9 m (39 ft) of zeolitic bedded tuff that exhibits characteristics of both pumiceous lava and nonwelded tuff, and likely represents a sequence of local eruptions related to the over- and underlying lavas that are transitional in nature between pyroclastic and effusive deposits. The lower lava, which was penetrated from 545.6 to 614.2 m (1,790 to 2,015 ft), consists of 11.3 m (37 ft) of zeolitic pumiceous rhyolite lava overlying 57.3 m (188 ft) of mostly flow breccia. As is characteristic of rhyolite lava, lithic and pumice fragments (i.e., pyroclasts) are absent. The lava flow contains trace amounts of quartz, which is indicative of the rhyolite of Benham, a unit that has been encountered in almost all area wells to the north and east of Well ER-EC-15, including nearby Well ER-EC-6, where lava of the rhyolite of Benham is 179.5 m (589 ft) thick (DOE/NV, 2000a). Prior to the drilling of Well ER-EC-15, the rhyolite of Benham was thought to be the youngest (i.e., stratigraphically highest) and most westward-occurring Paintbrush Group lava flow in the area. The relatively thin occurrence of the rhyolite of Benham in Well ER-EC-15 and its composition, which consists almost entirely of flow breccia, suggest that the well likely encountered the flow near its distal edge.

The uppermost Paintbrush Group rhyolite lava flow in Well ER-EC-15 is 147.8 m (485 ft) thick and was penetrated from 385.9 to 533.7 m (1,266 to 1,751 ft). It consists of a typical sequence of rhyolite lava-flow facies, including a pumiceous lava top, upper vitrophyric zone, thick stoney-lava interior, lower vitrophyric zone, and a basal flow breccia. Other features common to rhyolite lava were also observed, including perlitic structures, spherulites, and flow banding. As is characteristic of rhyolite lava, lithic and pumice fragments (i.e., pyroclasts) are absent. However, this lava is conspicuously hornblende-bearing and lacks quartz, a mineralogic assemblage considerably different than that for the rhyolite of Benham. Thus, this rhyolite lava is informally assigned in this report as "hornblende-bearing rhyolite of ER-EC-15," with a map symbol of Tph.

Rhyolite lavas of the Paintbrush Group in the Pahute Mesa region include five separate and mineralogically distinct rhyolite lava-flow packages, four of which are well exposed along the south face of Pahute Mesa. These rhyolite lavas generally become progressively younger to the west as they on-lap each other. Previously, the rhyolite of Benham was considered to be the youngest and most westward-occurring of these Paintbrush Group lavas. However, the occurrence of hornblende-bearing rhyolite of ER-EC-15 above the rhyolite of Benham in Well ER-EC-15 indicates that the westward progression of Paintbrush Group effusive eruptions in the Pahute Mesa region continued after the emplacement of the rhyolite of Benham.

A 30.5-m (100-ft) thick interval of zeolitic and quartzo-feldsapthic bedded tuff was penetrated below the rhyolite of Benham from 614.2 to 644.7 m (2,015 to 2,115 ft). This bedded tuff interval is broadly assigned as undivided Paintbrush Group, based on stratigraphic position and paucity of quartz. Although only broadly assigned, the interval likely includes the Paintbrush Group formation, tuff of Pinyon Pass.

Below the Paintbrush bedded tuffs, Well ER-EC-15 encountered ash-flow tuff of the Pahute Mesa lobe member of the Tiva Canyon Tuff, in the interval from 644.7 to 726.9 m (2,115 to 2,385 ft). A very thin, partially welded zone was encountered at the top of the Tiva Canyon Tuff, and below this partially welded zone the well penetrated 66.4 m (218 ft) of moderately welded ash-flow tuff that overlies 10.1 m (33 ft) of vitrophyric ash-flow tuff. The basal 2.7 m (9 ft) of the Tiva Canyon Tuff is partially welded to nonwelded. Lithophysae were observed in the borehole image log near the top and base of the moderately welded ash-flow tuff. The Tiva

Canyon Tuff was identified by its ash-flow tuff lithology, stratigraphic position between the rhyolite of Benham and the underlying Topopah Spring Tuff (see discussion below), and its mineralogic assemblage, which includes sphene and biotite, but no quartz phenocrysts. The Tiva Canyon Tuff was erupted 12.7 Ma from the Claim Canyon caldera, which is located south of the well site between Timber Mountain and Yucca Mountain (Sawyer et al., 1994). The northern portion of the Claim Canyon caldera, including its northern margin, is assumed to have been obliterated by the younger Timber Mountain caldera complex. The relatively thin occurrence of the unit in Well ER-EC-15 clearly indicates that the well location is outside of any source caldera for the Tiva Canyon Tuff.

Beneath the Tiva Canyon Tuff, the borehole penetrated 52.7 m (173 ft) of quartzo-feldspathic bedded tuff, from 726.9 to 779.7 m (2,385 to 2,558 ft). The position of these bedded tuffs between two Paintbrush Group ash-flow tuff units, the Tiva Canyon Tuff and the Topopah Spring Tuff (see discussion below), indicates that they also belong to the Paintbrush Group.

The borehole penetrated the Pahute Mesa lobe member of the Topopah Spring Tuff from 779.7 to 932.1 m (2,558 to 3,058 ft). This unit consists of 56.7 m (186 ft) of quartzo-feldspathic, nonwelded ash-flow tuff and bedded tuff in its upper portion above 836.4 m (2,744 ft), and 95.7 m (314 ft) of quartzo-feldspathic partially welded to moderately welded ash-flow tuff below 836.4 m (2,744 ft). The Topopah Spring Tuff was identified by its ash-flow tuff lithology, the presence of only trace amounts of quartz phenocrysts, and its stratigraphic position at the base of the Paintbrush Group section. The Topopah Spring Tuff was erupted 12.8 Ma from a caldera whose location is unknown (Sawyer, et al., 1995). The relatively thin occurrence of Topopah Spring Tuff in Well ER-EC-15 clearly indicates that the well lies outside of any source caldera for the unit.

Below the Topopah Spring Tuff, Well ER-EC-15 penetrated 49.4 m (162 ft) of quartzo-feldspathic bedded tuff, from 932.1 to 981.5 m (3,058 to 3,220 ft). The general scarcity of biotite, and an assemblage of felsic phenocrysts that includes quartz, indicate that the interval is best assigned to the mafic-poor Calico Hills Formation.

Well ER-EC-15 reached TD at 991.8 m (3,254 ft), within the rhyolite of Sled, a formation within the Crater Flat Group. The rhyolite of Sled encountered in Well ER-EC-15 consists of 10.4 m (34 ft) of quartzo-feldspathic bedded tuff. It is recognized mainly by its general paucity of quartz phenocrysts, particularly compared with the overlying mafic-poor Calico Hills Formation.

4.2.3 Alteration

The volcanic rocks penetrated at Well ER-EC-15 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.

Below the base of the alluvium at 14.0 m (46 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 and pumiceous lavas, 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., impervious matrix) that these rocks tend to retain their original glassy character well below the upper level of zeolitization. Below the depth of 640.1 m (2,100 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-15 is generally similar to that predicted prior to drilling (Figure 4-5). One significant difference, however, is the occurrence of an additional Paintbrush Group rhyolite lava above the rhyolite of Benham, and informally designated in this report as hornblende-bearing rhyolite of ER-EC-15. Prior to drilling Well ER-EC-15, the rhyolite of Benham was thought to be the youngest and most westward-occurring Paintbrush lava in the Pahute Mesa area.

Well ER-EC-15 was predicted to bottom in the Calico Hills Formation, after penetrating approximately 15.2 m (50 ft) of the formation. However, because the base of the Topopah Spring Tuff is slightly higher than predicted, and the fact that the well was drilled 16.5 m (54 ft) deeper than predicted, the well penetrated completely through the Calico Hills Formation and terminated in the rhyolite of Sled.

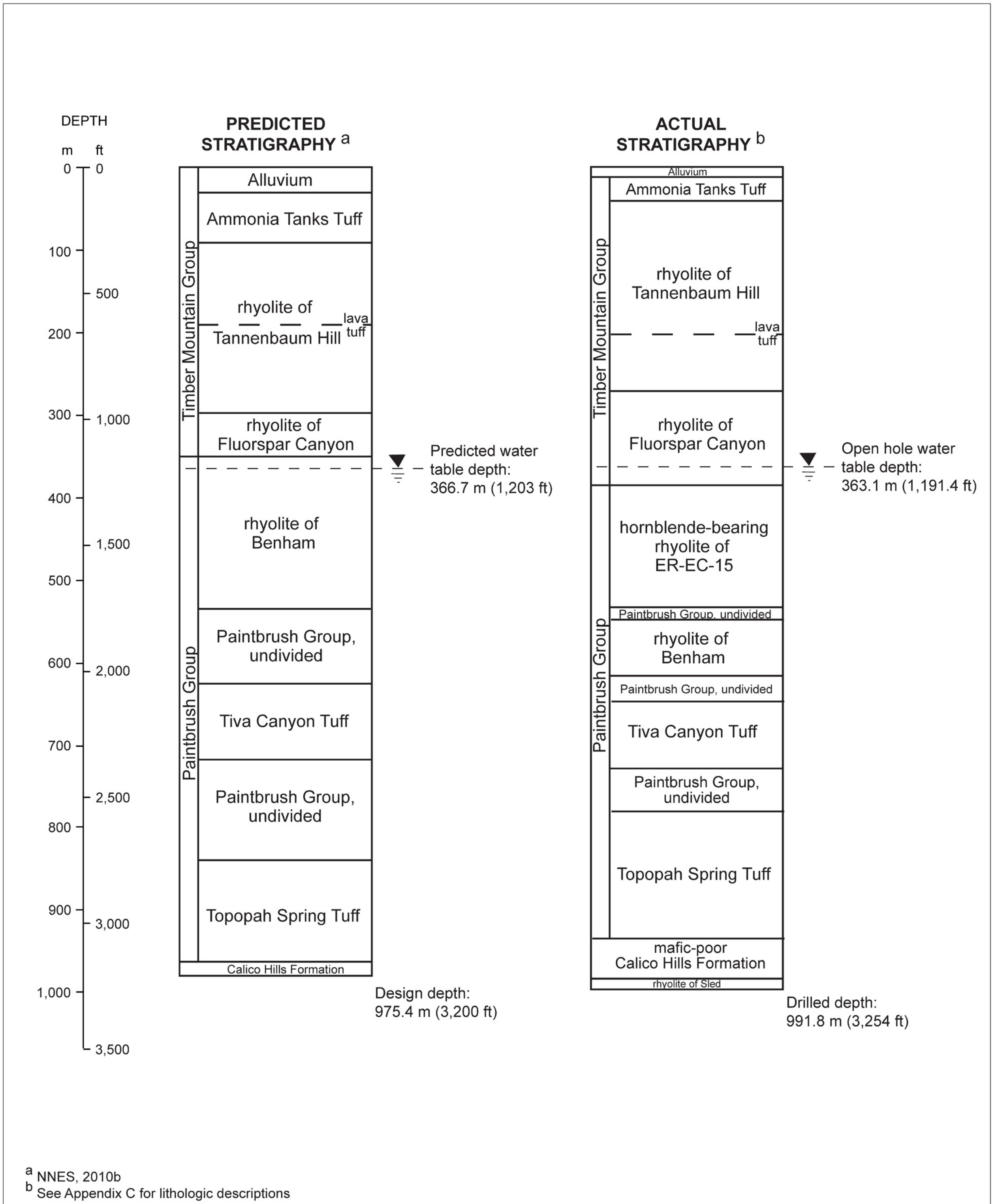


Figure 4-5
Predicted and Actual Stratigraphy at Well ER-EC-15

4.4 Hydrogeology

The saturated portion of Well ER-EC-15 consists of an alternating sequence of welded-tuff aquifers, lava-flow aquifers, and tuff confining units. In the upper portion of the saturated section, the hornblende-bearing rhyolite of ER-EC-15 and the rhyolite of Benham form two lava-flow aquifers separated by a relatively thin interval of tuff confining unit. The thick occurrence of the hornblende-bearing rhyolite of ER-EC-15 penetrated in the well indicates that the unit likely forms a significant aquifer in the western portion of the Bench. The relatively thin occurrence and flow-breccia character of the rhyolite of Benham in Well ER-EC-15 suggests that the well encountered this lava-flow aquifer near the southwestern limit of the flow.

Welded ash-flow tuffs of the Tiva Canyon Tuff and Topopah Spring Tuff form two distinct welded-tuff aquifers in the well, while the zeolitic bedded and nonwelded tuffs that occur between the two welded-tuff aquifers and below the welded Topopah Spring Tuff form tuff confining units. An interpretation of the possible distribution of the HSUs in the vicinity of Well ER-EC-15 is shown in cross section in Figure 4-6.

Prior to drilling, it was predicted that the water table would be encountered at a depth of 366.7 m (1,203 ft) and within lava-flow aquifer of the rhyolite of Benham. The actual water table depth, as measured in the shallow piezometer string on December 6, 2010, was 363.1 m (1,191.4 ft), and within the tuff confining unit formed by zeolitic tuffs of rhyolite of Fluorspar Canyon.

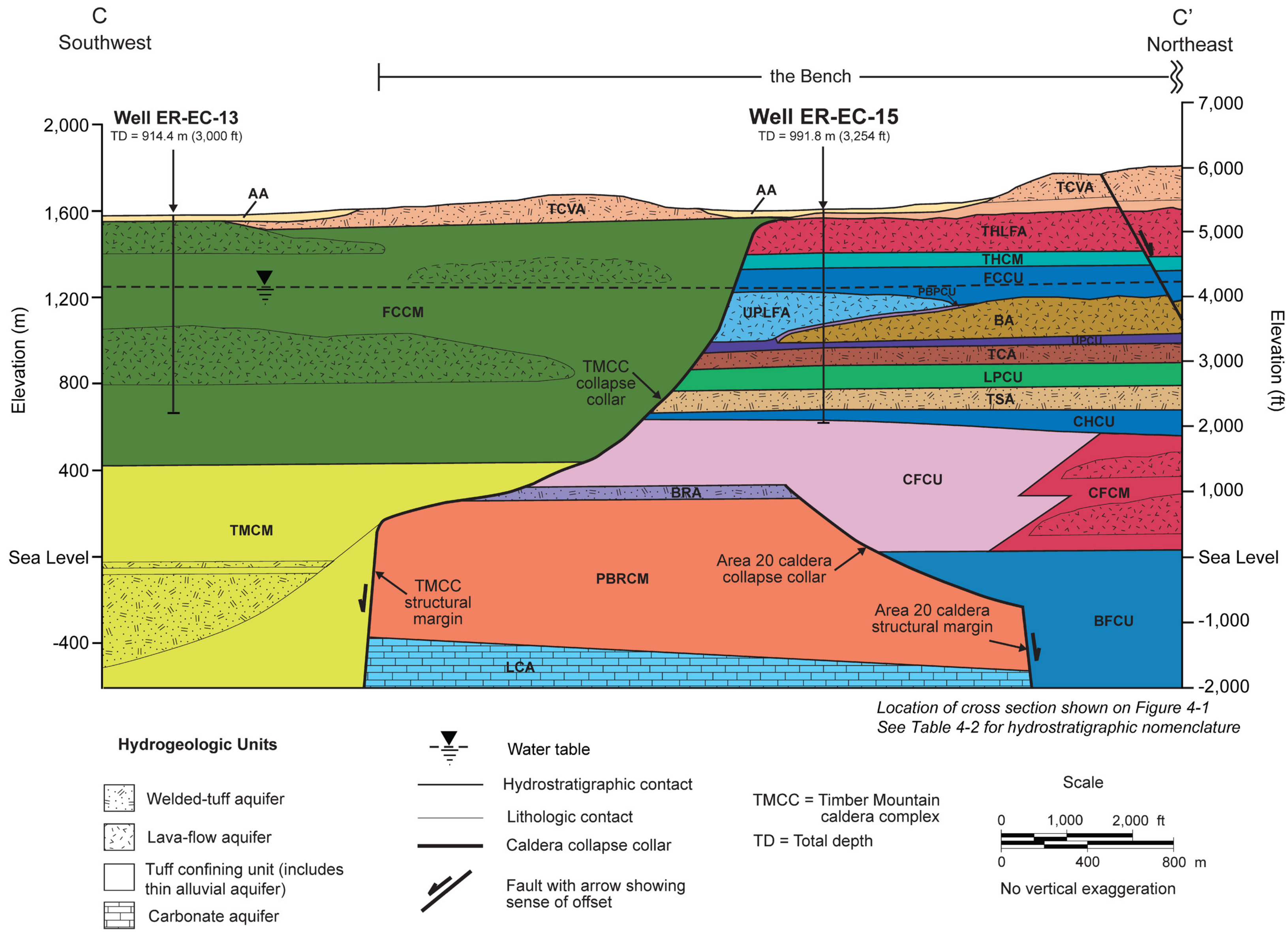


Figure 4-6
Southwest–Northeast Hydrostratigraphic Cross Section C–C' through Well ER-EC-15

5.0 Hydrology

5.1 Water-Level Information

Prior to drilling, the water level at Well ER-EC-15 was estimated to be within the Benham aquifer at a depth of 366.7 m (1,203 ft) below ground surface. During open-hole geophysical logging operations after the borehole reached TD (November 22, 2010), fluid level depths were measured by Baker Atlas and DRI. The measured fluid depth ranged from 363.0 to 364.5 m (1,191 to 1,196 ft), and averaged 363.3 m (1,192 ft). Approximately one month later, on December 6, 2010, water levels were measured by N-I in the three piezometer strings and in the main completion string. In the shallow piezometer string (accessing the UPLFA), the water level was 363.1 m (1,191.4 ft). In the intermediate piezometer string (accessing the TCA), the water level was 363.2 m (1,191.5 ft). In the deep piezometer (accessing the TSA), the water level was 363.1 m (1,191.4 ft). The water level in the main completion string was 363.1 m (1,191.4 ft).

The water temperature at Well ER-EC-15 is higher than typically encountered at the NNSS. The Baker Atlas differential temperature tool, run on November 21, 2010, two days after the drilling activities finished (and probably before the borehole had time to equilibrate) recorded a bottom-hole temperature of 64.1 degrees Celsius (147.3 degrees Fahrenheit) at the depth of 975.4 m (3,200 ft). The chemistry/temperature logging tool, run by DRI on November 24, 2010, recorded a maximum temperature of 68.9 degrees Celsius (156 degrees Fahrenheit) before the tool failed. Water level measurements given in this report are not temperature corrected.

5.2 Water Production

Water production was estimated during drilling of Well ER-EC-15 on the basis of dilution of a lithium-bromide tracer, as measured at the rig site by N-I field personnel. The first observation of water in returns was reported on November 9, 2010, at the approximate depth of 356.3 m (1,169 ft). Estimated water production ranged from approximately 38 to 1,135 Lpm (10 to 300 gpm) during drilling through the UPLFA, and increased to 1,325 Lpm (350 gpm) by time drilling reached base of the BA. Estimated water production through the TCA ranged from 1,325 to 1,514 Lpm (350 to 400 gpm). Estimated water production throughout most of the TSA averaged approximately 2,082 Lpm (550 gpm), but decreased to 946.3 Lpm (250 gpm) towards the bottom of the aquifer.

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 to characterize borehole fluid variability in UGTA wells, and may indicate inflow and outflow zones. DRI personnel ran their suite of logs shortly after TD was reached (see plot of log data in Appendix D, page D-6). The chemistry log measured temperature, electrical conductivity, and pH in the interval 363.2 to 830.6 m (1,191.5 to 2,725 ft) on November 24, 2010. The tool was run to a depth of 863.2 m (2,832 ft), but the electronics in the tool failed below 830.6 m (2,725 ft) due to high fluid temperatures in the borehole (up to 68.9 degrees Celsius [156 degrees Fahrenheit]). The pH readings made below the depth of 705.6 m (2,315 ft) are considered suspect.

DRI personnel measured the fluid flow rate and direction using their heat pulse flow log at six depths between 390.1 and 627.9 m (1,280 and 2,060 ft), within the hornblende-bearing rhyolite of ER-EC-15, rhyolite of Benham, and bedded Paintbrush tuffs, on November 24, 2010. DRI reported that the heat pulse flow log tool got hung up around 627.9 m (2,060 ft), and therefore data below that depth are considered invalid. The DRI flow log indicated upward flow of approximately 1.9 Lpm (0.5 gpm) from the lowest measurement point to 434.3 m (1,425 ft).

5.4 Groundwater Characterization Samples

Following geophysical logging on November 25, 2010, DRI collected depth-discrete groundwater characterization samples within the open borehole (pre-completion/pre-development) at the depths of 725.4 and 947.9 m (2,380 and 3,110 ft). The sample at 725.4 m (2,380 ft) included a duplicate sample. 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 metals, organic and inorganic constituents, tritium, gross alpha and beta, and plutonium. Tritium was not detected in these samples (N–I, 2011).

All of these samples were collected prior to completion and final development of the well. The analytical results should be used with care because water quality measurements may be affected by constituents of the drilling fluids, and thus not accurately reflect natural groundwater quality.

6.0 Precompletion and Open-Hole Development

Initial open-hole well development using the drill string to air-lift groundwater to remove residual cuttings and drilling fluids from the borehole is typically conducted immediately after the borehole has reached TD. However, during geophysical logging operations a bridge was encountered in the borehole and the drill crew had to run the drill string back into the hole and clean it out. The operations to clean out the borehole lasted longer than anticipated, but fluid in the borehole was circulated for 45 minutes before the drill string was again removed and geophysical logging operations continued.

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7.0 Well Completion

7.1 Introduction

Well completion refers to the installation in a borehole of one or more strings 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 insertion of 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-15 was presented in the addendum to the criteria document (NNES, 2010b) and in the NSTec FAWP (NSTec, 2010b). The original completion plans are summarized in Section 7.2.1 of this report, 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 design 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 following sections describe the well completion design and methods. 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 (presented in NNES, 2010b) was based on the assumption that Well ER-EC-15 would penetrate the water table near the top of the BA and reach TD just below the TSA within the Calico Hills confining unit. The primary goal of the proposed completion design was to provide groundwater production data from the BA, TCA, and TSA, and to provide access to groundwater for monitoring and sampling. The 16-in. casing was intended to extend to the depth of approximately 358.1 m (1,175 ft) to stabilize the unsaturated portion of the borehole and to isolate the near-surface units from the underlying BA, TCA, and TSA.

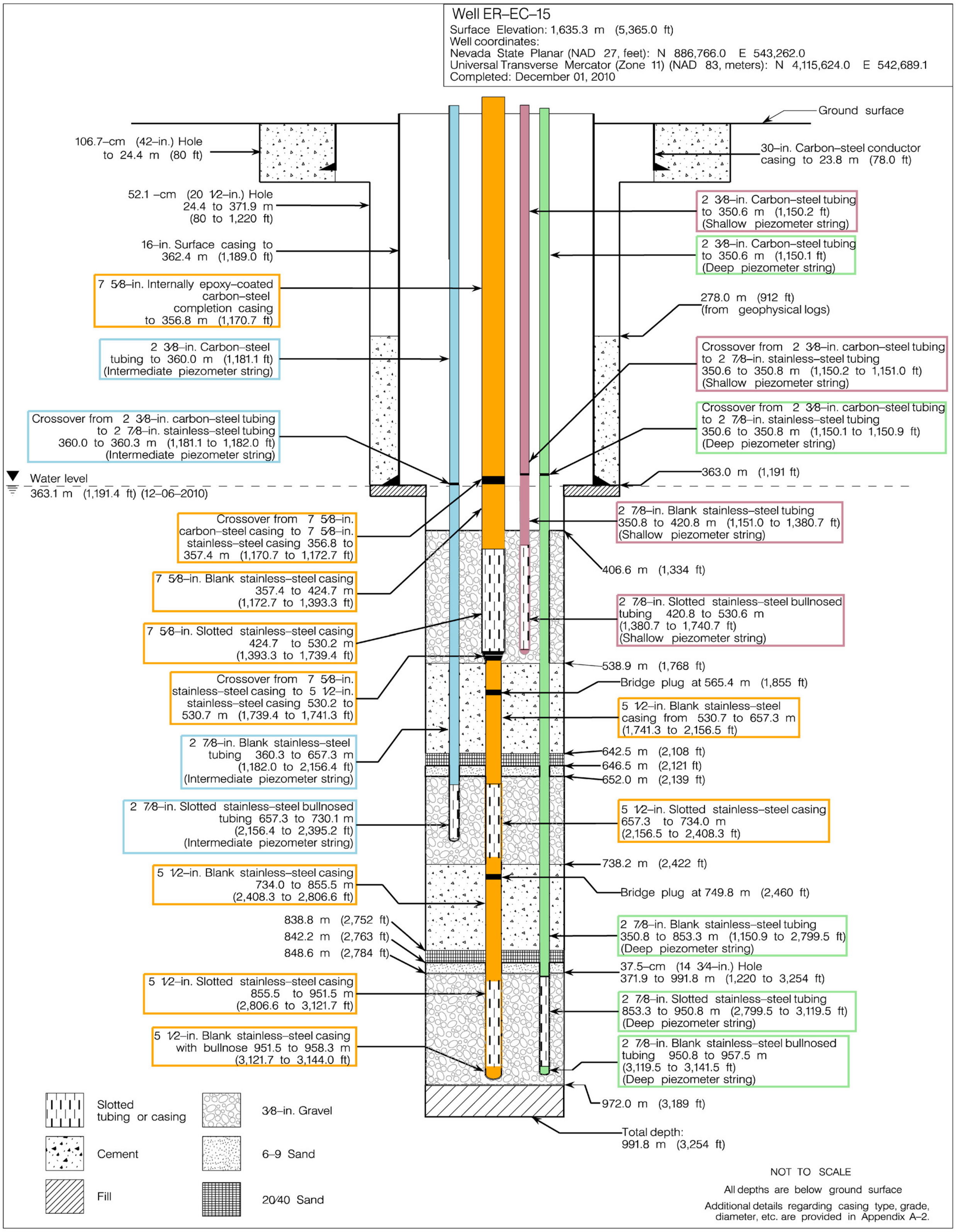

Figure 7-1
As-Built Completion Schematic for Well ER-EC-15

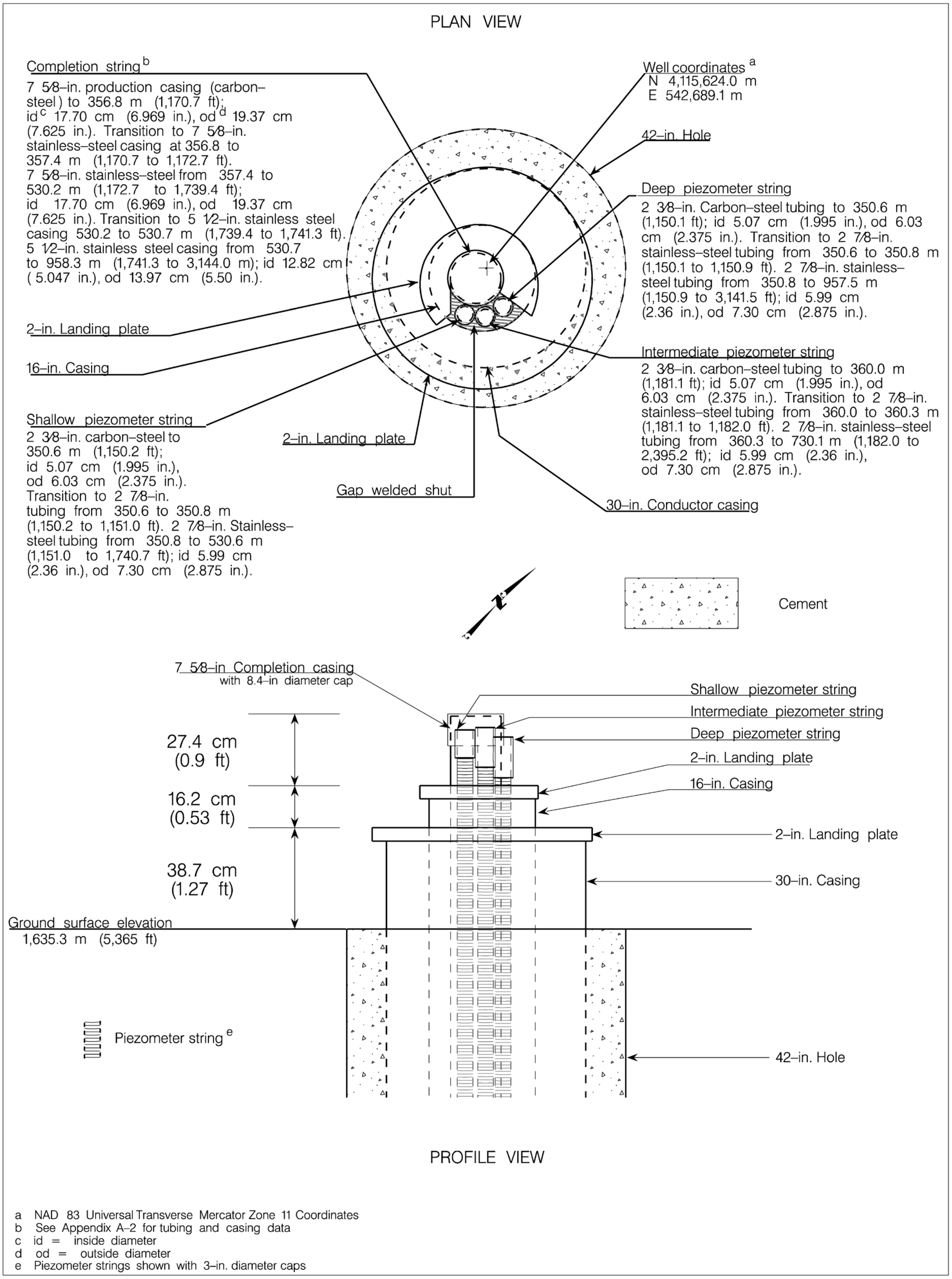

Figure 7-2
Wellhead Diagram for Well ER-EC-15

Table 7-1
Well ER-EC-15 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 crossover sub	0 to 350.8 (0 to 1,151.0)	**Blank**	None	None
	2⅞-in. stainless-steel tubing	350.8 to 530.6 (1,151.0 to 1,740.7)	**Blank** 350.8 to 420.8 (1,151.0 to 1,380.7)	None	**⅜–in. Washed Gravel** 406.6 to 538.9 (1,334 to 1,768)
			Slotted and bullnosed [a] 420.8 to 530.6 (1,380.7 to 1,740.7)	None	
Intermediate Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 360.3 (0 to 1,182.0)	**Blank**	None	None
	2⅞-in. stainless-steel tubing	360.3 to 730.1 (1,182.0 to 2,395.2)	**Blank** 360.3 to 657.3 (1,182.0 to 2,156.4)	**Type II Neat Cement** 538.9 to 642.5 (1,768 to 2,108)	**20/40 Sand** 642.5 to 646.5 (2,108 to 2,121) **6–9 Sand** 646.5 to 652.0 (2,121 to 2,139) **⅜–in. Washed Gravel** 652.0 to 739.7 (2,139 to 2,427)
			Slotted and bullnosed [a] 657.3 to 730.1 (2,156.4 to 2,395.2)	None	
Deep Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 350.8 (0 to 1,150.9)	**Blank**	None	None
	2⅞-in. stainless-steel tubing	350.8 to 957.5 (1,150.9 to 3,141.5)	**Blank** 350.8 to 853.3 (1,150.9 to 2,799.5)	**Type II Neat Cement** 739.7 to 838.8 (2,427 to 2,752)	**20/40 Sand** 838.8 to 842.2 (2,752 to 2,763) **6–9 Sand** 842.2 to 848.6 (2,763 to 2,784) **⅜–in. Washed Gravel** 848.6 to 972.0 (2,784 to 3,189)
			Slotted [a] 853.3 to 950.8 (2,799.5 to 3,119.5)	None	
			Blank and bullnosed 950.8 to 957.5 (3,119.5 to 3,141.5)	None	

Table 7-1
Well ER-EC-15 Completion String Construction Summary (continued)

String	Casing and Tubing	Configuration meters (feet)		Cement meters (feet)	Sand/Gravel meters (feet)
Completion Casing	7⅝-in. carbon-steel, internally epoxy-coated production casing and crossover sub with stainless-steel double pin	0 to 357.4 (0 to 1,172.7)	**Blank**	None	
	7⅝-in. stainless-steel production casing with crossover sub	357.4 to 530.7 (1,172.7 to 1,741.3)	**Blank** 357.4 to 424.7 (1,172.7 to 1,393.3)	None	Same as for Shallow Piezometer String
			Nine consecutive slotted joints [b] with crossover sub 424.7 to 530.7 (1,393.3 to 1,741.3)	None	
	5½-in. stainless-steel production casing	530.7 to 958.3 (1,741.3 to 3,144.0)	**Blank** 530.7 to 657.3 (1,741.3 to 2,156.5)	Same as for Intermediate Piezometer String	Same as for Intermediate Piezometer String
			12 consecutive slotted joints [c] 657.3 to 734.0 (2,156.5 to 2,408.3)	None	
			Blank 734.0 to 855.5 (2,408.3 to 2,806.6)	Same as for Deep Piezometer String	
			15 consecutive slotted joints [c] 855.5 to 951.5 (2,806.6 to 3,121.7)	None	Same as for Deep Piezometer String
			Blank and bullnosed 951.5 to 958.3 (3,121.7 to 3,144.0)		
Note: Bridge plugs set within production casing at 565.4 m (1,855 ft) and 749.8 m (2,460 ft) on December 10, 2010					

a Slots are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long, arranged in rows of 8, 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 rows of 18, on staggered 15.2-cm (6.0-in.) centers.

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

The well was planned to be completed with a string of 6⅝-in. production casing hung from a string of 7⅝-in. casing extending through the three target aquifers. This casing string was to be slotted and gravel-packed at each of the three target aquifers. Since three saturated aquifers were expected, two cement isolation intervals were planned to separate the three aquifers. The completion string was to consist of epoxy-coated carbon steel to within 13.1 m (43 ft) above the water table and stainless-steel casing below the water table.

Three piezometer tubes were to be positioned inside the 37.5-cm (14.75-in.) open hole, between the borehole wall and the well-completion string to monitor water levels during testing and for collecting water samples directly from the developed intervals for the BA, TCA, and TSA. The bottom portions of the tubing strings were to be slotted and positioned within the gravel packed intervals at approximately the same depths as the slotted intervals in the completion string. The tubing strings were to be separated by the same cement isolation intervals as in the completion string.

7.2.2 As-Built Completion Design

The final Well ER-EC-15 completion design was determined by the UGTA Well ER-EC-15 drilling advisory team after the TD of 991.8 m (3,254 ft) was reached. The team designed the completion on the basis of onsite evaluation of data such as lithology, water production, drilling data, and data from various geophysical logs.

The main completion string consists of a string of 7⅝-in. and 5½-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing and was set at the depth of 958.3 m (3,144.0 ft). The 7⅝-in. internally epoxy-coated carbon-steel casing and crossover sub extend from the surface to the depth of 357.4 m (1,172.7 ft), which is about 5.8 m (19 ft) above the water table. The stainless-steel 7⅝-in. casing is slotted in the interval 424.7 to 530.2 m (1,393.3 to 1,739.4 ft), and is open to the UPLFA. The stainless-steel 5½-in. casing, suspended from the 7⅝-in. stainless-steel casing, is slotted in the intervals 657.3 to 734.0 m (2,156.5 to 2,408.3 ft) and 855.5 to 951.5 m (2,806.6 to 3,121.7 ft), which are open to the TCA and TSA, respectively. The upper slotted section consists of 9 consecutive slotted joints, the middle slotted section consists of 12 consecutive slotted joints, and the lower slotted section consists of 15 consecutive slotted joints. The three slotted sections are separated by 126.5 m (415 ft) and 121.3 m (398 ft) of blank casing. The completion string was terminated with 6.4 m (21.0 ft) of blank stainless-steel casing with a 0.43-m (1.4-ft) long 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 slots on the 7⅝-in. stainless-steel casing are arranged in rows of 18, with rows staggered 20 degrees on 15.2-cm (6.0-in.) centers. The slots on the 5½-in. stainless-steel casing are arranged in rows of 12, with rows staggered 30 degrees on 15.2-cm (6.0-in.) centers. The three slotted sections of the casing string are gravel-packed. Cement isolation intervals separate the three aquifers.

Three 2⅞-in. piezometer strings were installed in Well ER-EC-15. The stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs, and each string is bullnosed. The shallow piezometer string was landed at 530.6 m (1,740.7 ft) for monitoring within the UPLFA, and is slotted from 420.8 to 530.6 m (1,380.7 to 1,740.7 ft). The intermediate piezometer string was landed at 730.1 m (2,395.2 ft) for monitoring within the TCA, and is slotted in the interval 657.3 to 730.1 m (2,156.4 to 2,395.2 ft). The deep piezometer string was landed at 957.5 m (3,141.5 ft) for monitoring within the TSA, and is slotted from 853.3 to 950.8 m (2,799.5 to 3,119.5 ft). The machine-cut openings in each slotted joint of the three 2⅞-in. tubing strings are 0.159 cm (0.0625 in.) wide and 5.72 cm (2.25 in.) long. The slots in each joint are arranged in rows of 8, with rows staggered 45 degrees on 10.2-cm (4.0-in.) centers. The slotted sections of the 2⅞-in. tubing strings were gravel packed and separated by cement.

On December 10, 2010, two bridge plugs were installed at 565.4 m (1,855 ft) and 749.8 m (2,460 ft) between the three slotted intervals in the 5½-in. completion string to isolate the three aquifers from each other.

7.2.3 Rationale for Differences between Planned and Actual Well Design

The proposed well completion design for Well ER-EC-15 (NNES, 2010b; NSTec, 2010b) was based on the expectation that the hole would penetrate the three primary aquifers typically present in the Bench area (the BA, TCA, and TSA). The actual geology encountered in Well ER-EC-15 is similar to that predicted, with the exception that an additional Paintbrush lava-flow aquifer was encountered above the BA. At the more southwesterly location of Well ER-EC-15, this younger lava (defined here as UPLFA) is dominant, while the BA likely pinches out south- and westward. Therefore the upper completion zone was in the UPLFA rather than in the BA as planned. Otherwise, only minor changes were made to the completion to better match the slotted intervals to the aquifers.

7.3 Well Completion Method

The main completion casing and three piezometers were installed after the final geophysical logging had been conducted. The UDI crew installed the three piezometer strings described above on November 25–26, 2010, then inserted a 2⅞-in. Hydril tremie line to be used as a conduit during emplacement of stemming materials (the tremie line was pulled up as stemming progressed). The casing crew then began running the main completion string on November 26, 2010, and landed the string at 958.3 m (3,144.0 ft) on November 27, 2010. Colog, Inc. ran a background Nuclear Annular Investigation Log (NAIL) tool in the 7⅝-in. and 5½-in. completion string prior to placement of stemming materials, and monitored the rise of stemming materials with the NAIL tool.

The three completion zones were gravel-packed and then isolated from each other with sand and cement barriers. First, a layer of ⅜-in. washed gravel 123.4 m (405 ft) thick was emplaced on top of fill at 972.0 m (3,189 ft) to surround the deep slotted intervals. Then a 6.4-m (21-ft) layer of 6–9 coarse silica sand and a 3.4-m (11-ft) layer of 20/40 fine silica sand were placed on the gravel to prevent cement from infiltrating the gravel pack. Type II neat cement was placed on top of the sand from 739.7 to 838.8 m (2,427 to 2,752 ft). Next, a layer of ⅜-in. washed gravel 87.8 m (288 ft) thick was emplaced around the middle completion zone. A 5.5-m (18-ft) layer of 6–9 coarse silica sand and 4.0-m (13-ft) layer of 20/40 fine silica sand were placed above the gravel that surrounds the middle completion zone, and a section of Type II neat cement was placed on the sand layers from 538.9 to 642.5 m (1,768 to 2,108 ft). The uppermost gravel layer, which is 132.3 m (434 ft) thick, was placed on the cement layer, and surrounds the upper completion zone. The borehole is open from the top of gravel to the surface (see Figure 7-1 and Table 7-1).

After stemming was complete, the tremie tubing string was pulled from the hole, and the UDI drill rig was rigged down in preparation for demobilizing. Hydrologic testing is planned as a separate effort, 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-15 was based on drilling to a planned TD of 975.4 m (3,200 ft) from the surface and installing one completion string and three piezometer strings. The well was drilled 16.5 m (54 ft) deeper than originally planned, to a TD of 991.8 m (3,254 ft). A single completion string with three slotted intervals, and three piezometer strings were installed as planned.

The baseline schedule for drilling and completing Well ER-EC-15 was 28 days (Figure 8-1). It took 26 days to construct Well ER-EC-15, starting with the drilling of the 52.1-cm (20.5-in.) surface hole. Few drilling problems were encountered, so the surface hole took two days fewer to drill than planned, and the main hole took five days fewer than planned. Ten days were planned for geophysical logging and completion, but due to difficulties with borehole sloughing, which necessitated using the drill rig to clean out the borehole several times, this work took thirteen days.

The cost analysis for Well ER-EC-15 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-15 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, the services of radiological control technicians, 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-15 was \$4,740,060. The actual cost was \$4,355,573, or 8.1 percent less than the planned cost. Cost savings were realized because the drill rig was released two days sooner than expected, despite difficulties with the borehole during geophysical logging and completion. Figure 8-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-EC-15.

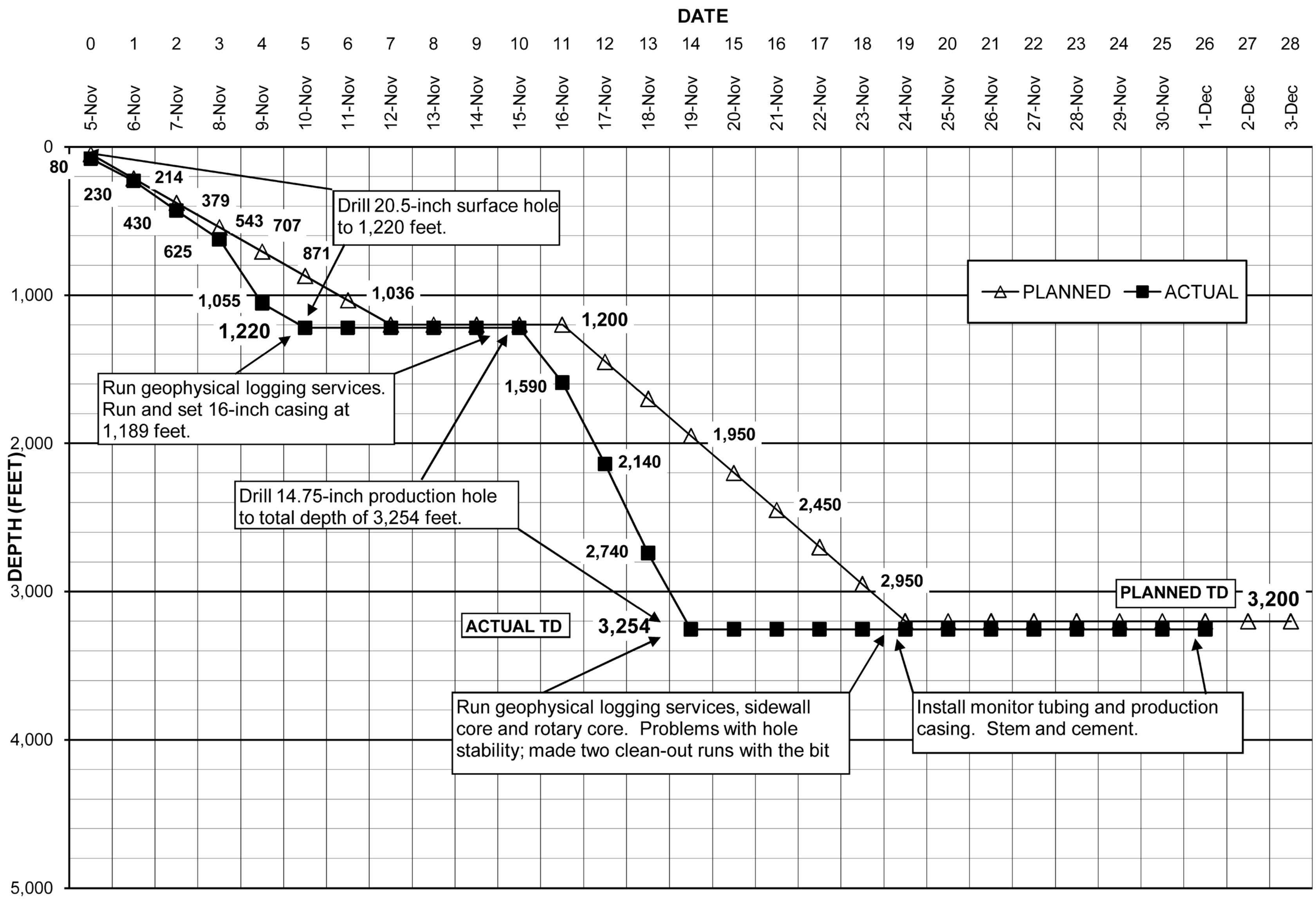

Figure 8-1
Planned and Actual Construction Progress for Well ER-EC-15

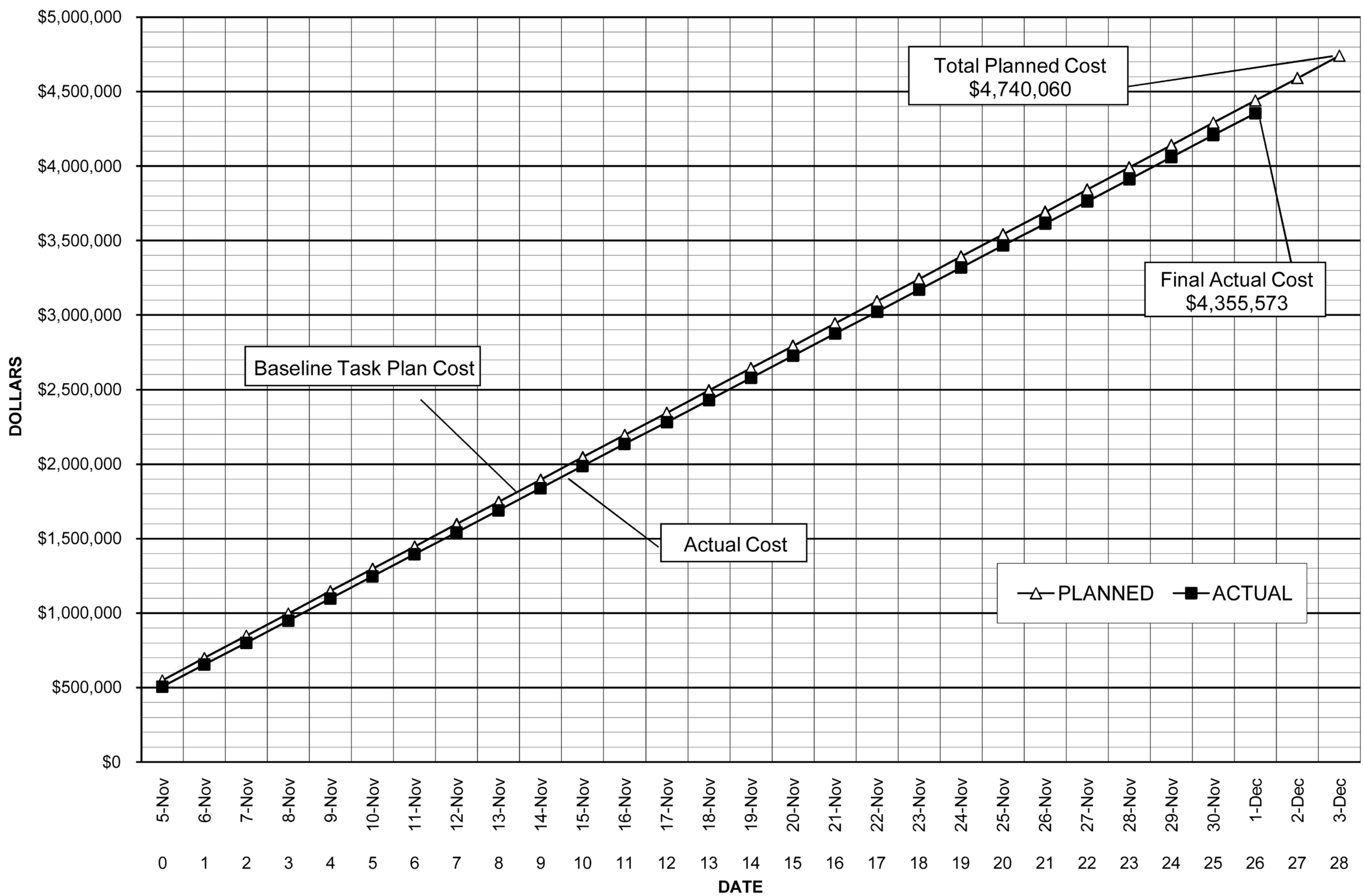

Figure 8-2
Planned and Actual Cost of Constructing Well ER-EC-15

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9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Main hole drilling at Well ER-EC-15 commenced on November 5, 2010, and concluded on November 19, 2010, at a total drilled depth of 991.8 m (3,254 ft). The borehole reached TD within altered, bedded tuffs of the Crater Flat Group (rhyolite of Sled). No major problems were encountered during drilling. Sloughing after TD was reached caused fill and bridges to block the borehole. Consequently, geophysical logging and well completion were delayed by over 36 hours while the hole was cleaned out.

The completion string consists of 5½-in. and 7⅝-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing. The carbon-steel casing extends to a depth that is 5.8 m (19 ft) above the water table. The 7⅝-in. stainless-steel casing is slotted in the interval 424.7 to 530.2 m (1,393.3 to1,739.4 ft) providing access to the UPLFA. The 5½-in. casing is slotted in the intervals 657.3 to 734.0 m (2,156.5 to 2,408.3 ft) and 855.5 to 951.5 m (2,806.6 to 3,121.7 ft), providing access to the TCA and TSA, respectively, for monitoring and sampling. The top slotted section consists of 9 consecutive stainless-steel slotted joints, the middle slotted section consists of 12 consecutive stainless-steel slotted joints, and the bottom slotted section consists of 15 consecutive stainless-steel slotted joints. The slotted intervals are gravel-packed and separated by cement. Two bridge plugs were placed within the main completion string at 565.4 m (1,855 ft) and 749.8 m (2,460 ft) on December 10, 2010, to isolate the three slotted intervals.

The well has three 2⅞-in. piezometer strings that access each of the three aquifers penetrated by the well. The three stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing, connected via crossover subs. The shallow piezometer string is slotted from 420.8 to 530.6 m (1,380.7 to 1,740.7 ft) for monitoring within the UPLFA. The intermediate piezometer string is slotted from 657.3 to 730.1 m (2,156.4 to 2,395.2 ft) for monitoring within the TCA. The deep piezometer string is slotted from 853.3 to 950.8 m (2,799.5 to 3,119.5 ft) for monitoring within the TSA.

Data collected during drilling of Well ER-EC-15 includes composite drill cuttings samples collected every 3.0 m (10 ft) from 24.4 to 990.6 m (80 to 3,250 ft). In addition, 26 sidewall core samples were collected in the interval 381.0 to 969.3 m (1,250 to 3,180 ft). Open-hole geophysical logging was conducted in the unsaturated zone before installation of the surface casing and in the lower portion after the TD of the well was reached. Some of these logs were used to aid in construction of the well, while others helped to verify the geology and determine the hydrologic characteristics of the rocks.

Well ER-EC-15 is collared in alluvium and penetrated Tertiary volcanic rocks through its entire depth below 14.0 m (46 ft). The volcanic rocks consist largely of rhyolite lava, bedded and nonwelded tuff, and nonwelded to vitrophyric ash-flow tuffs. Water levels were measured in the well on December 6, 2010. In the shallow piezometer string (measuring the UPLFA), the water level was 363.1 m (1,191.4 ft). In the intermediate piezometer string (measuring the TCA), the water level was 363.2 m (1,191.5). In the deep piezometer string (measuring the TSA), the water level was 363.1 m (1,191.4 ft). The elevation of the water level for the uppermost aquifer, the UPLFA, is 1,272.1 m (4,173.6 ft). The water temperature at Well ER-EC-15 is warmer than expected. The chemistry/temperature tool, run by DRI on November 24, 2010, recorded a maximum borehole fluid temperature of 68.9 degrees Celsius (156 degrees Fahrenheit) before failing due to the high temperature. Water-level measurements presented in this report are not corrected for temperature.

Tritium activity levels in the drilling fluid were below the minimum detection limit of the field instruments while drilling Well ER-EC-15. Laboratory measurements on drilling effluent samples taken during drilling in the three aquifers were also below the minimum detectable concentration. Data for samples of drilling effluent may not be representative of the groundwater. Valid groundwater data will not be available until the well is developed and properly sampled.

9.2 Recommendations

All the geologic and hydrologic data and interpretations from Well ER-EC-15 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. Updating the HFM will also allow better predictions for any future drilling, well development and testing, and aquifer testing.

The water level in Well ER-EC-15 should be monitored during the drilling and testing of nearby wells. Groundwater chemistry should be monitored on a routine basis to establish a baseline for the aquifers encountered and to learn more about possible groundwater flow systems. Specific geochemistry analyses might also help understand the anomalously high water temperatures in Well ER-EC-15. These data will also improve the understanding of aquifer connectivity. It is important that all completion zones in the well be tested and that all zones be monitored during pumping tests.

9.3 Lessons Learned

The efficiency of drilling and constructing wells to obtain hydrogeologic data in support of the UGTA Sub-Project continues to improve as experience is gained with each new well. Sometimes difficult drilling conditions are encountered and challenges are confronted. Several new lessons were learned during the construction of Well ER-EC-15, the fourth well in the 2010 Pahute Mesa Phase II drilling initiative, which built upon those learned during drilling in the 2009 and 2010 initiative:

- Harsh weather conditions may cause operational delays/inconveniences. For example, the sacks of gravel (for gravel packing completion intervals), which apparently contained a high moisture content, froze solid during a cold period. Gas heaters and mechanical impacts were required to break up the frozen gravel before feeding into the hopper.

- High borehole fluid temperatures (greater than 68.9 degrees Celsius [156 degrees Fahrenheit]) caused the DRI chemistry/temperature logging tool to fail. High bottom-hole temperatures were indicated by the more robust Baker Atlas Differential Temperature log. The DRI tool should be hardened to endure higher temperatures, or it should not be run where extreme temperatures are measured by the geophysical logging contractors.

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Appendix A
Drilling Data

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Appendix A-1
Drilling Parameter Log for Well ER-EC-15

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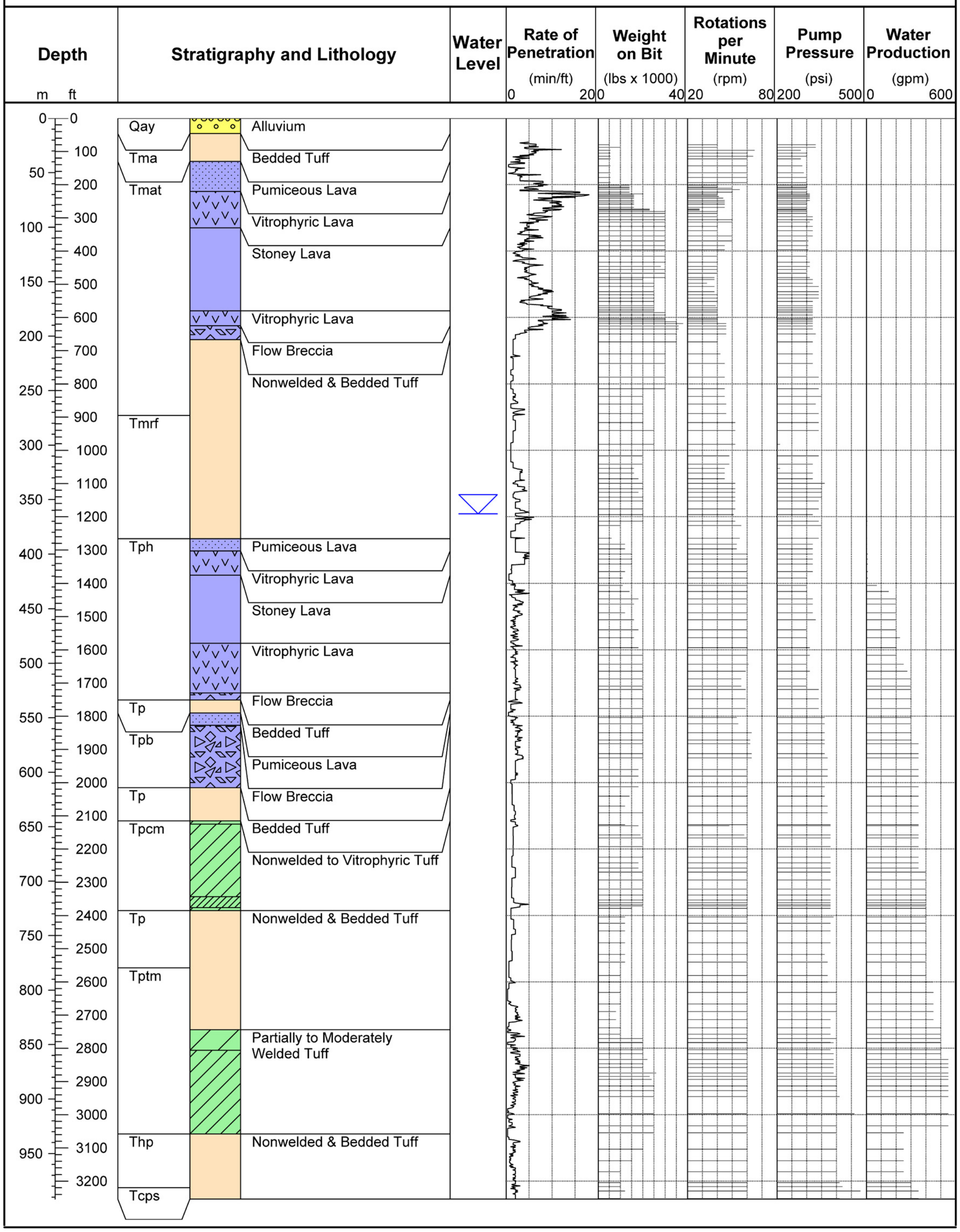
Well ER-EC-15

Logging Company: Baker Atlas
Drilled Depth: 991.8 m (3,254 ft)
Date TD Reached: November 19, 2010
Drill Method: Rotary/Air foam

Surface Elevation: 1,635.3 m (5,365.0 ft)
Coordinates (UTM [NAD 83]): N 4,115,624.0 m
E 542,689.1 m
Water Level: 363.1 m (1,191.4 ft) on December 6, 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-15

Table A-2-1
Tubing and Casing Data for Well ER-EC-15

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	0 to 23.8 (0 to 78.0)	Carbon Steel	B	76.20 (30)	73.66 (29)	1.270 (0.500)	157.8
Surface	0 to 362.4 (0 to 1,189.0)	Carbon Steel	K55	40.64 (16)	38.125 (15.010)	1.257 (0.495)	89.0
Completion Casing (with crossover)	0 to 357.4 (0 to 1,172.7	Epoxy-Coated Carbon-Steel	N80	19.368 (7.625)	17.701 (6.969)	0.833 (0.328)	26.4
Completion Casing (with crossover)	357.4 to 530.7 (1,172.7 to 1,741.3)	Stainless Steel	L304	19.368 (7.625)	17.701 (6.969)	0.833 (0.328	26.4
Completion Casing	530.7 to 958.3 (1,741.3 to 3,144.0)	Stainless Steel	L304	13.970 (5.50)	12.819 (5.047)	0.577 (0.227)	14.6
Shallow Piezometer String (with crossover)	0 to 350.8 (0 to 1,151.0)	Carbon Steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Shallow Piezometer String	350.8 to 530.6 (1,151.0 to 1,740.7)	Stainless Steel	SS	7.303 (2.875)	5.994 (2.36)	0.655 (0.258)	7.66
Intermediate Piezometer String (with crossover)	0 to 360.3 (0 to 1,182.0)	Carbon Steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Intermediate Piezometer String	360.3 to 730.1 (1,182.0 to 2,395.2)	Stainless Steel	SS	7.303 (2.875)	5.994 (2.36)	0.655 (0.258)	7.66
Deep Piezometer String (with crossover)	0 to 350.8 (0 to 1,150.9)	Carbon Steel	N80	6.033 (2.375)	5.067 (1.995)	0.483 (0.190)	4.7
Deep Piezometer	350.8 to 957.5 (1,150.9 to 3,141.5)	Stainless Steel	SS	7.303 (2.875)	5.994 (2.36)	0.655 (0.258)	7.66

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Appendix A-3
Well ER-EC-15 Drilling Fluids and Cement Composition

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Table A-3-1
Drilling Fluids Used in Well ER-EC-15

Typical Air-Foam/Polymer Mix
56.8 to 151.4 liters (15 to 40 gallons) Geofoam® [a] 0 to 3.8 liters (0 to 1 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-15 came from UGTA Well ER-EC-8.

2. A concentrated lithium bromide (LiBr) solution was added to all introduced fluids to make up a final concentration of approximately 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-15 Cement Composition

Cement Composition	30-inch Conductor Casing	16-inch Surface Casing	Completion Casing (5½- inch)
75 / 25 Type II (75% neat cement, 25% fly ash)	21.5 to 24.4 m [a] (70.5 to 80 ft) [b]	None	None
Type II neat	0 to 21.5 m (0 to 70.5 ft)	278.0 to 363.0 m (912 to 1,191 ft)	538.9 to 642.5 m (1,768 to 2,108 ft) 739.7 to 838.8 (2,427 to 2,752 ft)

a meter(s)
b foot (feet)

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Appendix B
Well ER-EC-15 Fluid Management Data

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Table B-1
Well ER-EC-15 Fluid Disposition Reporting Form

Site Identification: ER-EC-15
Site Location: Nevada Training and Tesing Range
Site Coordinates: N 4,115,426.9 m, E 542,769.5 m
Well Classification: ER Hydrogrologic Investigation Well
N-I Project No: UG11-430

Report Date: 03/04/2011
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	11/5/2010	11/9/2010	5	363.02	434.07	115.95	287.52	N/A	N/A	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	11/15/2010	11/19/2010	5	991.98	661.44	105.37	1,104.09	N/A	N/A	4,970	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			10	991.98	1095.51	221.32	1,391.61	N/A	N/A	4,970	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 12/11/2010: Sump #1 = 255 m^3 (16%) Sump #2 = 1,547 m^3 (100 %)

Current Average Tritium = -65 pCi/L, less than minimum detectable concentration

Notes: None

N-I Authorizing Signature/Date: [signature] 3-7-11

Table B-2
Analytical Results for Fluid Management Sample for Well ER-EC-15

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act (RCRA)* Metals (mg/L)							
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
ER-EC-15-112510-2	11/25/2010	Sample from Sump #1	Total	0.013 J+	0.012 J-	0.005 U	0.0021	0.0038	0.0037	0.01 U	0.000028 J-
			Dissolved	0.01 J+	0.00045 J-	0.005 U	0.00085	0.003 U	0.005 U	0.01 U	0.0002 U
ER-EC-15-112510-3	11/25/2010	Duplicate Sample from Sump #1	Total	0.012 J+	0.011 J-	0.005 U	0.0017	0.0045	0.005 U	0.01 U	0.0002 U
			Dissolved	0.01 J+	0.1 U	0.005 U	0.0012	0.003 U	0.0028	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-15-112510-2	11/25/2010	Sample from Sump #1	Result	10	2.5 U	4.1 U
			Error	190	1.9	2.2
			MDC	330	2.9	3.2
ER-EC-15-112510-3	11/25/2010	Duplicate Sample from Sump #1	Result	-140	2.5 U	2 U
			Error	190	1.9	2.0
			MDC	320	2.7	3.3
Nevada Drinking Water Standard				15	50	20,000

Analyses performed by ALS Laboratory Group.
Data provided by Navarro-Intera (N-I, 2011)

Notes: U = Compound analyzed for but not detected (“nondetect”).
J+ = Result estimated bias high 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-15

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Table C-1
Detailed Lithologic Log for Well ER-EC-15
Logged by Heather Huckins-Gang and Lance Prothro National Security Technologies, LLC, March 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)
0–14.0 (0–46)	14.0 (46)	None	None	**Alluvium:** Poorly consolidated sand and gravel derived from the erosion of nearby volcanic rocks.	young alluvial deposits (Qay)
14.0–39.6 (46–130)	25.6 (84)	AC DA	39.6 (130)	**Bedded Tuff:** Yellowish gray (5Y 8/1), very pale orange (10YR 7/4) to grayish orange (10YR 7/4), and light brown (5YR 6/4); zeolitic; common to abundant pumice with some corroded; minor to common felsic phenocrysts of feldspar and quartz, including dipyramidal quartz; common biotite; minor lithic fragments; sphene is present. Thin reworked tuff at base of interval.	Ammonia Tanks Tuff (Tma)
39.6–67.1 (130–220)	27.4 (90)	DA	None	**Pumiceous Rhyolite Lava:** Pale greenish yellow (10Y 8/2) to yellowish gray (5Y 7/2); zeolitic, vitric in places below 45.7 m (150 ft); minor felsic phenocrysts of feldspar and lesser quartz, feldspar phenocrysts up to 4 mm in size with biotite inter-growths; minor biotite; sphene is present; chalcedony-filled vesicles observed.	rhyolite of Tannenbaum Hill (Tmat)
67.1–100.6 (220–330)	33.5 (110)	DA	None	**Vitrophyric Rhyolite Lava:** Light olive gray (5Y 6/1) and grayish yellow (5Y 8/4); mostly vitric, partially devitrified below 73.2 m (240 ft); devitrification appears to be associated with spherulites; perlitic and spherulitic; minor felsic phenocrysts of feldspar and quartz; minor biotite; sphene is present.	
100.6–176.8 (330–580)	76.2 (250)	DA	None	**Stoney Rhyolite Lava:** Pale yellowish brown (10YR 6/2) to dark yellowish brown (10YR 4/2), mottled, also light brown (5YR 6/4) to white (N9); mostly devitrified, vitric (vitrophyric) in part below 152.4 m (500 ft); minor felsic phenocrysts of feldspar (including blue iridescent sanidine) and quartz; minor biotite; sphene is present; weakly spherulitic and flow banded.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
176.8–190.5 (580–625)	13.7 (45)	DA	None	**Vitrophyric Rhyolite Lava:** Dark gray (N3) to medium light gray (N6), dusky brown (5YR 2/2) to brownish gray (5YR 4/1); mostly vitric, lesser devitrified and silicic(?); perlitic and spherulitic; minor felsic phenocrysts of feldspar and quartz; minor biotite; sphene is present; flow banded and flow brecciated in places.	rhyolite of Tannenbaum Hill (Tmat)
190.5–203.3 (625–667)	12.8 (42)	DA	None	**Basal Flow Breccia:** Moderate reddish orange (10R 6/6) to pale reddish brown (10R 5/4) and dark yellowish orange (10YR 6/6), mostly zeolitic, lesser devitrified and vitric; perlitic where vitric, weakly pumiceous in part; minor to common felsic phenocrysts of feldspar and quartz; minor to common biotite.	
203.3–217.9 (667–715)	14.6 (48)	DA	None	**Bedded Tuff:** Grayish orange (10YR 7/4) to moderate greenish yellow (10Y 7/4); zeolitic; common to very abundant pumice; minor felsic phenocrysts of feldspar with biotite inclusions and lesser quartz; common biotite; no lithic fragments observed. Interval has characteristics of both pumiceous lava and nonwelded tuff, and likely represents a sequence of precursor eruptions related to the overlying lava that are transitional in nature between pyroclastic and effusive deposits.	
217.9–237.7 (715–780)	19.8 (65)	DA	None	**Bedded Tuff**: Grayish orange (10YR 7/4), zeolitic; rare to common pumice; minor felsic phenocrysts of feldspar and quartz, including dipyramidal quartz; minor biotite; minor lithic fragments; altered and dissolved sphene is present.	
237.7–272.8 (780–895)	35.1 (115)	DA	246.9 (810)	**Bedded Tuff:** Grayish orange (10YR 7/4) to grayish orange pink (5YR 7/2); zeolitic; abundant pumice; minor felsic phenocrysts of feldspar and quartz, including dipyramidal quartz; common to abundant biotite; rare to abundant lithic fragments; sphene observed in thin section.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
272.8–306.3 (895–1,005)	33.5 (110)	DA	292.6 (960)	**Nonwelded Tuff:** Light brown (5YR 6/4); zeolitic; very abundant pumice; minor felsic phenocrysts of feldspar and quartz; minor biotite; rare lithic fragments.	rhyolite of Fluorspar Canyon (Tmrf)
306.3–336.8 (1,005–1,105)	30.5 (100)	DA	None	**Nonwelded Tuff:** Pale reddish brown (10R 5/4) to moderate reddish orange (10R 6/6); zeolitic; abundant pumice; minor felsic phenocrysts of feldspar and quartz; minor biotite; minor lithic fragments.	
336.8–385.9 (1,105–1,266)	49.1 (161)	DA RSWC	350.5 (1,150)	**Bedded Tuff:** Very pale orange (10YR 8/2) to grayish orange pink (10R 8/2), grayish yellow (5Y 8/4), grayish orange (10YR 7/4), and moderate reddish orange (10R 6/6); zeolitic; rare to abundant pumice; rare to minor felsic phenocrysts of feldspar and quartz; rare to minor biotite; minor lithic fragments.	
385.9–397.2 (1,266–1,303)	11.3 (37)	DA RSWC	393.2 (1,290)	**Pumiceous Rhyolite Lava:** Moderate yellow (5Y 7/6) to dusky yellow (5Y 6/4); zeolitic; rare to minor feldspar phenocrysts; rare mafic minerals of biotite and lesser hornblende; sphene is present. Upper contact is sharp and dips 39 degrees to the north-northeast based, on the borehole image log. Image log also shows that the interval is flow brecciated in places.	hornblende-bearing rhyolite of ER-EC-15 (Tph) [d]
397.2–419.1 (1,303–1,375)	21.9 (72)	DA RSWC	405.4 (1,330)	**Vitrophyric Rhyolite Lava:** Moderate olive brown (5Y 4/4), and moderate yellow (5Y 7/6) to dusky yellow (5Y 6/4), becoming grayish yellow (5Y 8/4) to white (N9) near base of interval; mostly vitric, lesser devitrified and silicic, mostly zeolitic below 411.5 m (1,350 ft); perlitic; minor feldspar phenocrysts; minor mafic minerals of biotite and hornblende; sphene is present; thin veins of opaline silica are present. Upper contact is sharp and dips 22 degrees to the northwest, based on the borehole image log. Basal contact is approximate due to borehole washout from 417.6 to 426.7 m (1,370 to 1,400 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)
419.1–461.8 (1,375–1,515)	42.7 (140)	DA RSWC	442.0 (1,450)	**Stoney Rhyolite Lava:** Pale brown (5YR 5/2) and light gray (N7), mottled; devitrified; rare feldspar phenocrysts; minor mafic minerals of hornblende and lesser biotite; spherulitic and flow banded. Upper contact is approximate due to borehole washout from 417.6 to 426.7 m (1,370 to 1,400 ft).	hornblende-bearing rhyolite of ER-EC-15 (Tph) [d]
461.8–481.6 (1,515–1,580)	19.8 (65)	DA RSWC	None	**Stoney Rhyolite Lava:** Medium gray (N5) to medium light gray (N6), also brownish black (5YR 2/1) to dark greenish gray (5GY 4/1), mostly devitrified, lesser vitric (vitrophyric from 467.0 to 469.4 m [1,532 to 1,540 ft] and 476.1 to 478.5 m [1,562 to 1,570 ft]), zeolitic, and silicic; perlitic; minor feldspar phenocrysts; common mafic minerals of hornblende and biotite; flow brecciated in places; small crystal-lined versicles observed. Interval likely represents a transition zone between the stoney interior and the lower vitrophyre. Upper contact is sharp and dips 45 degrees to the northwest, based on the borehole image log.	
481.6–527.3 (1,580–1,730)	45.7 (150)	DA RSWC	487.7 (1,600) 518.2 (1,700)	**Vitrophyric Rhyolite Lava:** Olive black (5Y 2/1) to light olive gray (5Y 5/2), also grayish olive green (5GY 3/2) to dusky yellow green (5GY 5/2), also pale yellowish brown (10YR 6/2) and moderate brown (5YR 4/4); mostly vitric, particularly in the upper and lower portions of interval, becoming partially devitrified in middle portion; perlitic; minor feldspar phenocrysts; minor mafic minerals of hornblende and biotite; sphene is present.	
527.3–533.7 (1,730–1,751)	6.4 (21)	DA RSWC	None	**Basal Flow Breccia:** Pale reddish brown (10R 5/4) and grayish orange (10YR 7/4); vitric to devitrified, lesser zeolitic; perlitic where vitric, pumiceous in part; rare to minor feldspar phenocrysts; minor mafic minerals of biotite and hornblende; sphene is present. Brecciated character of the interval is clearly visible on 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)
533.7–545.6 (1,751–1,790)	11.9 (39)	DA	None	**Bedded Tuff:** Moderate yellow (5Y 7/6) to grayish yellow (5Y 8/4) with irregular bands of light brownish gray (5YR 6/1); zeolitic; common to very abundant pumice; minor to common feldspar phenocrysts; common biotite; rare lithic fragments; sphene is present. Interval has characteristics of both pumiceous lava and nonwelded tuff, although much of the interval is clearly pyroclastic. The interval likely represents a sequence of eruptions closely associated with the over- and underlying lavas, and that are transitional in nature between pyroclastic and effusive deposits.	Paintbrush Group, undivided (Tp)
545.6–556.9 (1,790–1,827)	11.3 (37)	DA RSWC	551.7 (1,810)	**Pumiceous Lava:** Yellowish gray (5Y 7/2) to moderate yellow (5Y 7/6); zeolitic; minor felsic phenocrysts of feldspar and much less quartz; common to abundant biotite; sphene is present; flow brecciated in part.	rhyolite of Benham (Tpb)
556.9–614.2 (1,827–2,015)	57.3 (188)	DA RSWC	563.9 (1,850) 606.6 (1,990)	**Flow Breccia:** Olive gray (5Y 3/2) to olive black (5Y 2/1), dusky yellow (5Y 6/4) to moderate yellow (5Y 7/6), and pale brown (5YR 5/2) to grayish brown (5YR 3/2); mostly vitric (including vitrophyric), lesser zeolitic and devitrified above 591.3 m (1,940 ft), becoming mostly devitrified and zeolitic and much less vitric below 591.3 m (1,940 ft); conspicuously perlitic where vitric; minor feldspar phenocrysts (quartz observed in thin section); common to abundant biotite; sphene is present. Interval likely includes some zones of non-brecciated lava. Upper contact is sharp and dips 65 degrees to the east-southeast.	
614.2–644.7 (2,015–2,115)	30.5 (100)	DA RSWC	624.8 (2,050) 640.1 (2,100)	**Bedded Tuff**: Grayish orange (10YR 7/4) to yellowish gray (5Y 7/2), also pale brown (5YR 5/2) to moderate brown (5YR 4/4); zeolitic and quartzo-feldspathic, weakly calcareous; rare to minor pumice; minor altered and dissolved feldspar phenocrysts (quartz observed in thin section at 640.1 m [2,100 ft]); common to abundant biotite; rare to minor lithic fragments.	Paintbrush Group, undivided (Tp)

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
644.7–647.7 (2,115–2,125)	3.0 (10)	DA	None	**Partially Welded Ash-Flow Tuff**: Medium light gray (N6); devitrified to quartzo-feldspathic; minor pumice; rare to minor typically dissolved feldspar phenocrysts; minor to common biotite; rare lithic fragments.	Pahute Mesa lobe of Tiva Canyon Tuff (Tpcm)
647.7–714.1 (2,125–2,343)	66.4 (218)	DA RSWC	673.6 (2,210)	**Moderately Welded Ash-Flow Tuff**: Grayish red (10R 4/2); quartzo-feldspathic; minor to common pumice; minor to common altered and dissolved feldspar phenocrysts, feldspar phenocrysts generally decrease in abundance towards base of interval; minor to common bronze-colored biotite in upper portion of interval, becoming mostly minor in abundance and more altered lower; rare lithic fragments; sphene is present. Lithophysal from 671.5 to 676.0 m (2,203 to 2,218 ft) and from 711.7 to 713.5 m (2,335 to 2,341 ft), based on the borehole image log.	
714.1–724.2 (2,343–2,376)	10.1 (33)	DA RSWC	728.5 (2,390) [e]	**Vitrophyric Ash-Flow Tuff:** Moderate reddish brown (5YR 3/2) to grayish red (10R 4/2), much less olive black (5Y 2/1) and moderate yellowish brown (10YR 5/4); mostly devitrified, lesser vitric, silicified in places; perlitic where vitric; minor feldspar phenocrysts, some altered; minor biotite; rare lithic fragments; sphene is present. Upper portion of interval from 714.1 to 718.7 m (2,343 to 2,358 ft) may be a zone of alteration associated with a fault. Base of interval is sharp and dips 27 degrees to the south, based on the borehole image log.	
724.2–726.9 (2,376–2,385)	2.7 (9)	DB4	None	**Partially Welded to Nonwelded Ash-Flow Tuff:** Grayish red (10R 4/2) to dark reddish brown (10R 3/4); quartzo-feldspathic; rare pumice; minor dissolved and altered feldspar phenocrysts; rare, mostly pseudomorphic, biotite; rare lithic fragments; a few silica-filled veins observed. Depth of lower contact is approximate due to borehole washout from 726.6 to 729.1 m (2,384 to 2,392 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)
726.9–779.7 (2,385–2,558)	52.7 (173)	DA	737.6 (2,420) 771.1 (2,530)	**Bedded Tuff:** Grayish yellow (5Y 8/4) to very pale orange (10YR 8/2), moderate yellow (5Y 7/6) to yellowish gray (5Y 7/2), and pale reddish brown (10R 5/4); quartzo-feldspathic (minor argillic alteration observed in thin section); common pumice; rare dissolved and altered feldspar phenocrysts (quartz phenocrysts observed in thin section); minor biotite; common lithic fragments.	Paintbrush Group, undivided (Tp)
779.7–809.2 (2,558–2,655)	29.6 (97)	DA RSWC	789.4 (2,590) 807.7 (2,650)	**Nonwelded Tuff:** Light brownish gray (5YR 6/1) to light gray (N7); quartzo-feldspathic (minor argillic alteration observed in thin section); common to abundant pumice; minor dissolved and altered feldspar phenocrysts; common biotite; rare lithic fragments.	Pahute Mesa lobe of Topopah Spring Tuff (Tptm)
809.2–836.4 (2,655–2,744)	27.1 (89)	DA	823.0 (2,700)	**Bedded Tuff:** Very light gray (N8), pale red (10R 6/2) to grayish red (10R 4/2), and very pale orange (10YR 8/2) to pale reddish brown (10R 5/4); quartzo-feldspathic; minor to very abundant pumice; minor to common dissolved and altered feldspar phenocrysts; common biotite; rare to common lithic fragments.	
836.4–855.3 (2,744–2,806)	18.9 (62)	DA	None	**Partially Welded Ash-Flow Tuff:** Grayish red (10R4/2); quartzo-feldspathic; minor pumice; minor felsic phenocrysts of dissolved and altered feldspar and much less quartz; minor biotite; minor lithic fragments; a few small silica-filled veins observed.	

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
855.3–932.1 (2,806–3,058)	76.8 (252)	DA DB4 RSWC	871.7 (2,860) 923.5 (3,030)	**Moderately Welded Ash-Flow Tuff:** Grayish red (10R 4/2) to moderate brown (5YR 3/4); quartzo-feldspathic; minor pumice; common dissolved and altered feldspar phenocrysts; minor biotite; rare lithic fragments; very weakly spherulitic. Resistivity log indicates that the degree of welding decreases below 927.2 m (3,042 ft). Possible fault, or fault zone, at approximately 914.4 m (3,000 ft) based on loss of circulation while drilling, borehole enlargement, and the occurrence of breccia fragments and secondary(?) sectile mineral alteration (kaolinite[?]), and associated welded tuff that appears sheared.	Pahute Mesa lobe of Topopah Spring Tuff (Tptm)
932.1–981.5 (3,058–3,220)	49.4 (162)	DA RSWC	947.9 (3,110)	**Nonwelded and Bedded Tuffs:** Pale red (10R 6/2), light brownish gray (5YR 6/1) to greenish gray (5GY 6/1), pale brown (5YR 5/2) to moderate brown (5YR 4/4), grayish orange pink (5YR 7/2), and yellowish gray (5Y 8/1); quartzo-feldspathic, also pyritic; common to abundant pumice; rare to minor felsic phenocrysts of quartz and dissolved and altered feldspar; rare biotite and biotite pseudomorphs(?); minor to abundant lithic fragments. Lower contact is approximate due to lack of geophysical log coverage across basal portion of interval.	mafic-poor Calico Hills Formation (Thp)
981.5–991.8 (3,220–3,254) (TD)	10.4 (34)	DA	990.6 (3,250)	**Bedded Tuff:** Brownish gray (5YR 5/1) and greenish gray (5GY 6/1); quartzo-feldspathic; minor pumice; rare dissolved and altered feldspar phenocrysts, trace of quartz phenocrysts; rare biotite pseudomorphs(?); rare lithic fragments. Upper contact is approximate due to lack of geophysical log coverage across interval.	rhyolite of Sled (Tcps)

NOTES:

a Lithologic samples collected from interval during drilling and logging operations and utilized for lithologic interpretation. **AC =** auger cuttings; **DA** = drill cuttings that represent lithologic character of interval; **DB4** = cuttings that are intimate mixtures of units; generally less than 50% of drill cuttings represent lithologic character of interval; **RSWC** = rotary sidewall core. See Table 3-1 in this report for more information about sidewall samples.

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 samples analyzed.

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%.

d Informal stratigraphic assignment for this report (see Section 4.2.2 for more information).

e Sample is representative of the indicated interval rather than the interval corresponding with the depth due to drilling lag time.

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Appendix D
Geophysical Logs Run in Well ER-EC-15

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Appendix D contains plots of selected geophysical logs run in Well ER-EC-15. Table D-1 summarizes the logs presented. See Table 3-3 for more information.

Table D-1
Well ER-EC-15 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval	
			meters	feet
Caliper	CA6-1 CA6-3	11/10/2010 11/21/2010	23.8–369.1 362.4–972.9	78–1,211 1,189–3,192
X-Multipole Array Acoustilog (sonic)	XMAC-1	11/22/2010	367.6–970.0	1,206–3,182.5
Gamma Ray	GR-1 GR-7	11/10/2010 11/21/2010	0–361.5 306.0–962.9	0–1,186 1,004–3,159
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-3	11/10/2010 11/21/2010	0–361.5 306.0–962.9	0–1,186 1,004–3,159
High Definition Induction and R_t Explorer (resistivity)	HDIL-1 RTEX-1	11/10/2010 11/22/2010	23.8–367.0 364.2–969.6	78–1,204 1,195–3,181
Density	ZDL-1 ZDL-2	11/11/2010 11/22/2010	23.8–370.0 274.3–973.8	78–1,214 900–3,195
Compensated Neutron	CN-2	11/22/2010	274.3–973.8	900–3,195
Chemistry (pH and conductivity) Temperature	Chem-1 TL-3	11/24/2010	363.2–830.6	1,191.5–2,725
Heat Pulse Flow Log	HPFlow-1	11/24/2010	390.1–835.2	1,280–2,740

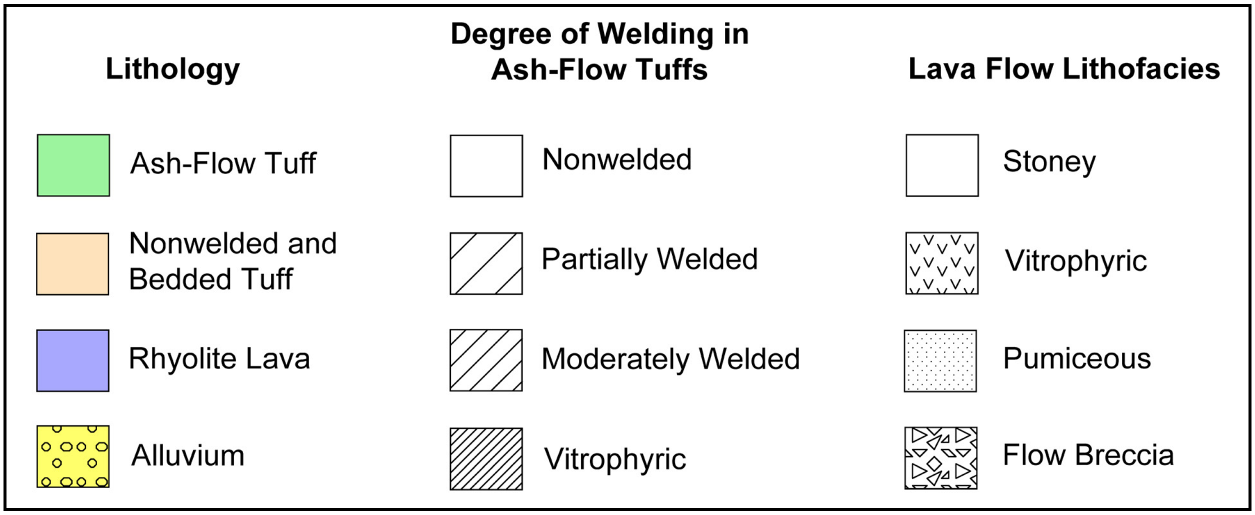
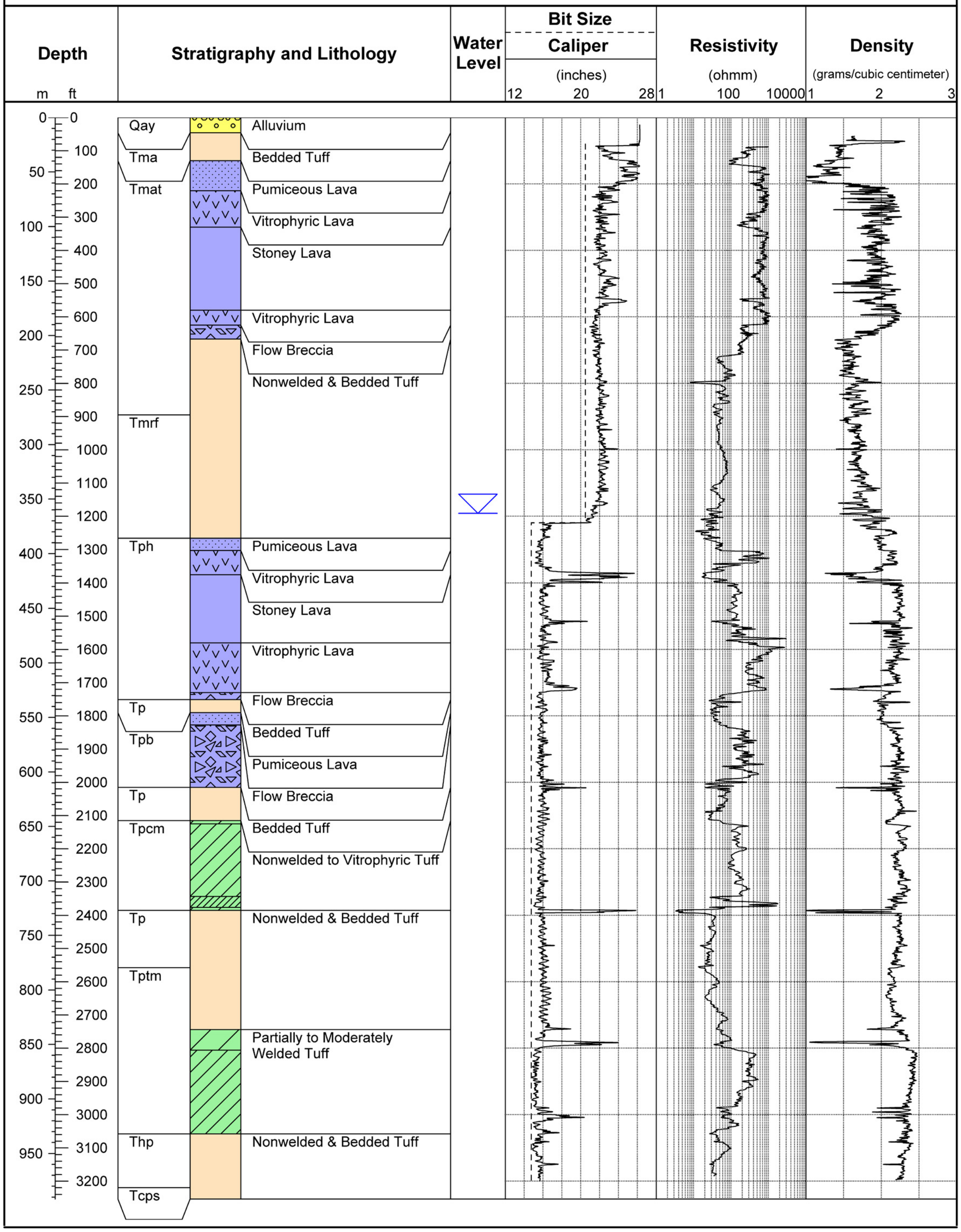


Figure D-1
Legend for Lithology Symbols Used on Log Plots

Well ER-EC-15

Logging Company: Baker Atlas
Date Logged: November 10, 11, 21, and 22, 2010
Drilled Depth: 991.8 m (3,254 ft)
Date TD Reached: November 19, 2010
Drill Method: Rotary/Air foam

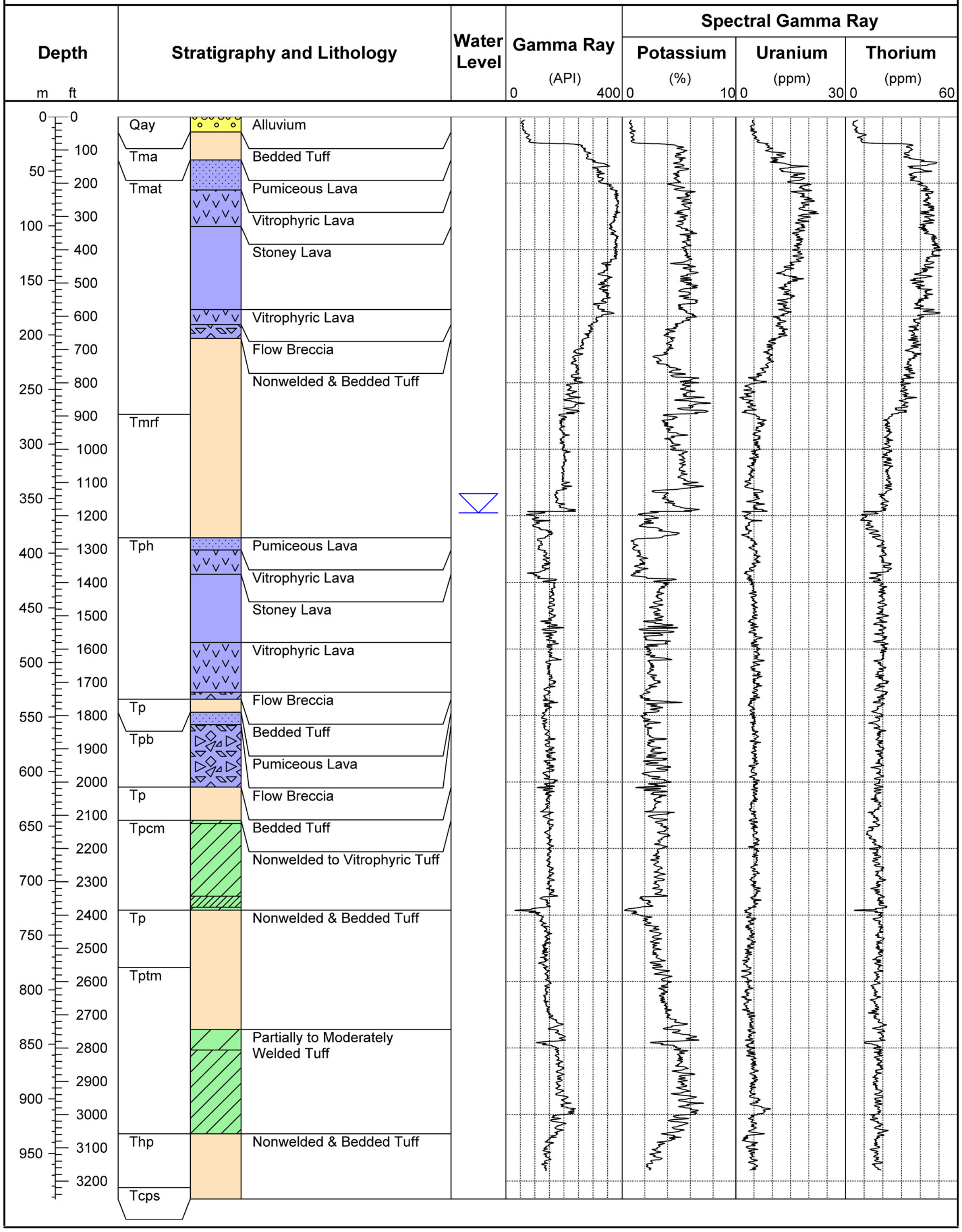
Surface Elevation: 1,635.3 m (5,365.0 ft)
Coordinates (UTM [NAD 83]): N 4,115,624.0 m
E 542,689.1 m
Water Level: 363.1 m (1,191.4 ft) on December 6, 2010



Well ER-EC-15

Logging Company: Baker Atlas
Date Logged: November 10 and 21, 2010
Drilled Depth: 991.8 m (3,254 ft)
Date TD Reached: November 19, 2010
Drill Method: Rotary/Air foam

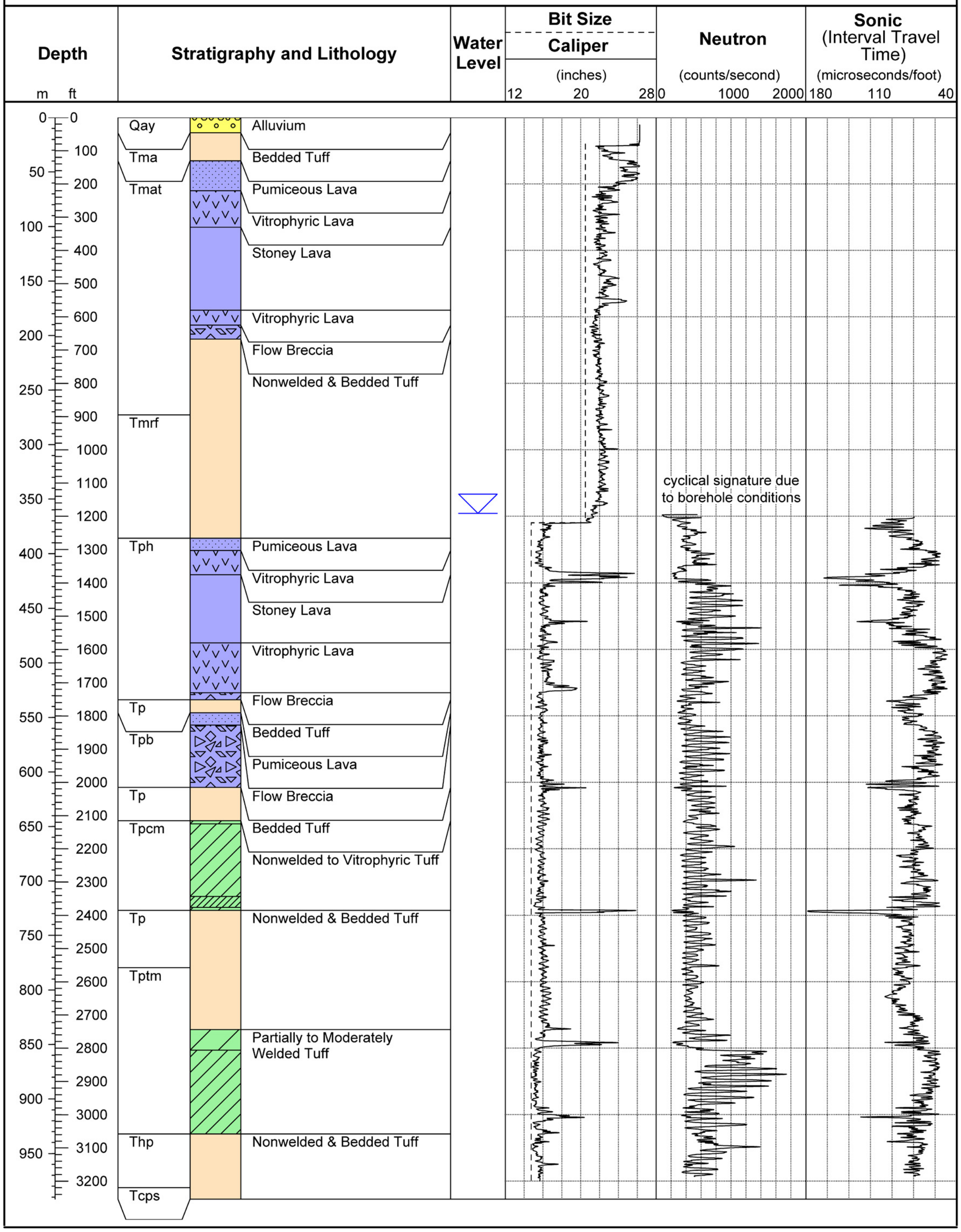
Surface Elevation: 1,635.3 m (5,365.0 ft)
Coordinates (UTM [NAD 83]): N 4,115,624.0 m
E 542,689.1 m
Water Level: 363.1 m (1,191.4 ft) on December 6, 2010



Well ER-EC-15

Logging Company: Baker Atlas
Date Logged: November 10, 21, and 22, 2010
Drilled Depth: 991.8 m (3,254 ft)
Date TD Reached: November 19, 2010
Drill Method: Rotary/Air foam

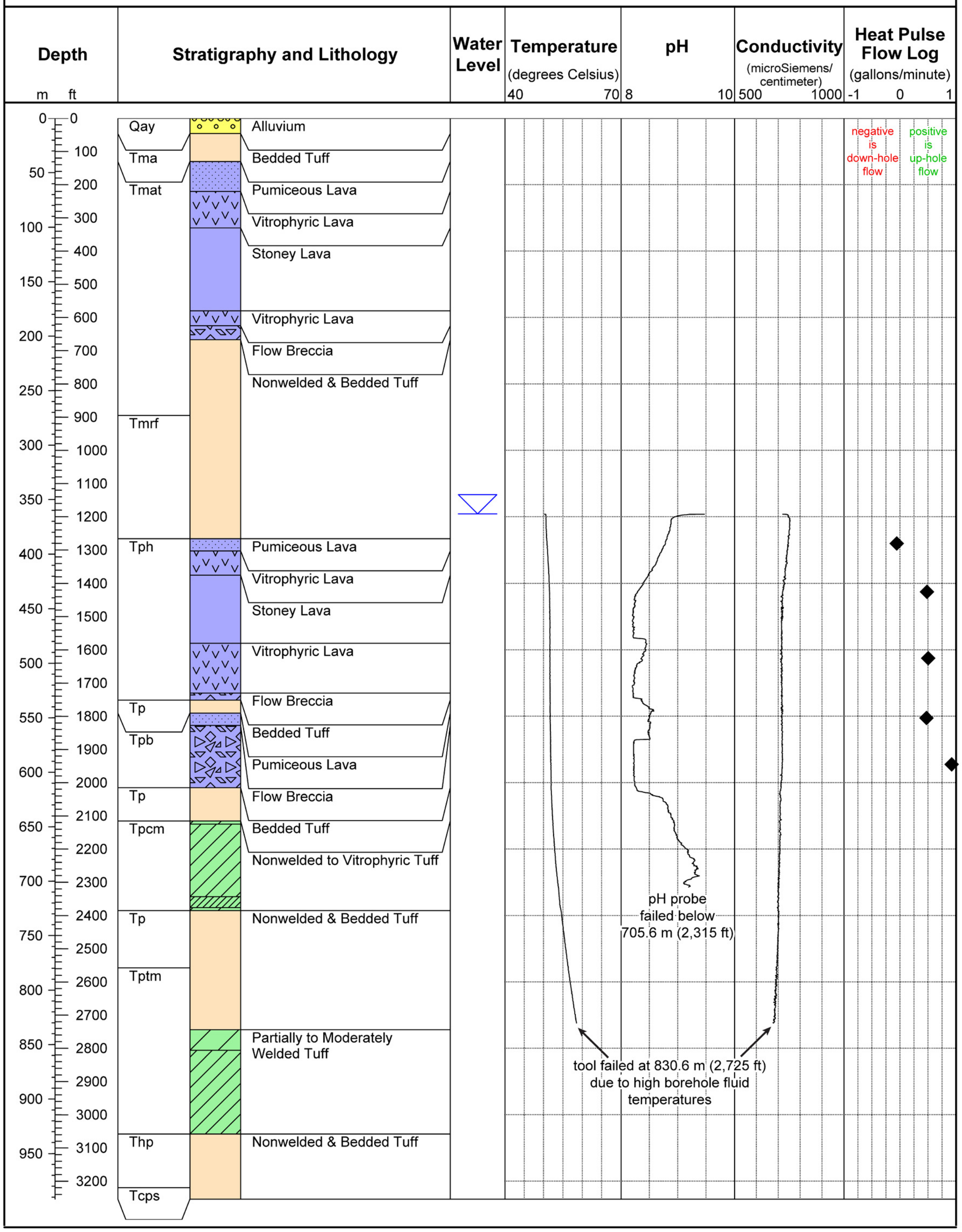
Surface Elevation: 1,635.3 m (5,365.0 ft)
Coordinates (UTM [NAD 83]): N 4,115,624.0 m
E 542,689.1 m
Water Level: 363.1 m (1,191.4 ft) on December 6, 2010



Well ER-EC-15

Logging Company: Desert Research Institute
Date Logged: November 24, 2010
Drilled Depth: 991.8 m (3,254 ft)
Date TD Reached: November 19, 2010
Drill Method: Rotary/Air foam

Surface Elevation: 1,635.3 m (5,365.0 ft)
Coordinates (UTM [NAD 83]): N 4,115,624.0 m
E 542,689.1 m
Water Level: 363.1 m (1,191.4 ft) on December 6, 2010



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