ERRATA SHEET

The Following Corrections and Clarifications Apply to: Completion Report for Well ER-EC-14 Corrective Action Units 101 and 102: Central and Western Pahute Mesa

DOE Document Number: DOE/NV--1499

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This errata sheet was issued under cover letter from DOE on: April 18, 2013

In Appendix B, Page B-1-8, Table B-1-2 (page 2 of 2) the table's main header lists the wrong well, the well number should be ER-EC-14. Also, in the table's column headers, the two columns listing the sample numbers and the depth's at which the samples were taken, the dates are incorrect, the correct date for both columns should be 10-12-2012. This Errata Sheet and the attached corrected copy of Table B-1-2 will replace the incorrect table in the document.

Table B-1-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-EC-14
(Page 2 of 2)

Analyte	Analytical Method [a]	Detection Limit	10/12/2012 Sample Number 119-101212-2 Taken at Depth of 453.5 meters (1,488 feet)		10/12/2012 Sample Number 119-101212-3 (Duplicate) Taken at Depth of 453.5 meters (1,488 feet)	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level I (picocuries per liter)						
		MDC [e]	Result	Error	Result	Error
Tritium	EPA 906.0 [f]	350	60 U	210	-170 U	210
Gross Alpha	EPA 900.0 [f]	1.7	1.8 U	1.2	13.1	3.2
Gross Beta		2.5, 2.7	3.2 U	1.7	7.4	2.3
^{238}Pu	HASL 300 [g] / ASTM D3865-02 [h]	0.024, 0.015	0 U	0.032	0 U	0.02
$^{239/240}Pu$	HASL 300 [g] / ASTM D3865-02 [h]	0.024, 0.015	0 U	0.032	0.006 U	0.02
Gamma Spectroscopy	EPA 901.1 [g]	Varies by nuclide	ND	Varies by nuclide	ND	Varies by Nuclide
			10/12/2012 Sample Number 119-101212-3 Taken at Depth of 453.5 meters (1,488 feet)		10/12/2012 Sample Number 119-101212-4 (Duplicate) Taken at Depth of 453.5 meters (1,488 feet)	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (picocuries per liter)						
^{14}C	EERF C-01 [i]	400	80 UJ	240	30 UJ	240

Samples collected October 12, 2012

Source: N-I (2013)

a For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits. Analyses for samples 119-101212-1 and 119-101212-2 were performed by ALS Laboratory Group. Analyses for samples 119-101212-3 and 119-101212-4 were performed by ARS International.

b EPA (2012)

c EPA (1997)

d EPA (1983)

e MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 103-091112-1, the second with 103-091112-2.

f EPA (1980)

g U.S. Department of Energy (1997)

h ASTM (2002)

i EPA (1984)

ASTM = ASTM International

C = Carbon

CaCO3 = Calcium carbonate

Pu = Plutonium

EERF = Eastern Environmental Radiation Facility

SU = Standard unit

EPA = U.S. Environmental Protection Agency

SW = Solid waste

HASL = Health and Safety Laboratory

MDC = Minimum detectable concentration

J = Result is estimated

J- = Result is estimate bias low

ND = No gamma spectroscopy radionuclides detected above detection limit

U = Compound was analyzed for but was not detected ("non-detect")

UJ = Compound was non-detect, but result is bias low

DOE/NV--1499

Nevada
Environmental
Management
Operations

Completion Report for Well ER-EC-14

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

March 2013

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

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Completion Report for Well ER-EC-14

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

Prepared for:
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March 2013

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DOE/NV--1499

Completion Report for Well ER-EC-14

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

Approved by: _____ Date: 3/5/2013
Wilhelm R. Wilborn
Underground Test Area Activity Lead

Approved by: _____ Date: 3/5/2013
Robert F. Boehlecke
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Abstract

Well ER-EC-14 was drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office in support of the Nevada Environmental Management Operations Underground Test Area (UGTA) Activity at the Nevada National Security Site (NNSS; formerly Nevada Test Site), Nye County, Nevada. The well was drilled in September and October 2012, as part of the Central and Western Pahute Mesa Corrective Action Unit Phase II drilling program. The primary purpose of the well was to provide detailed hydrogeologic information for the Fortymile Canyon composite hydrostratigraphic unit in the Timber Mountain moat area, within the Timber Mountain caldera complex, that will help address uncertainties within the Pahute Mesa–Oasis Valley hydrostratigraphic framework model.

The main 55.9-centimeter (cm) hole was drilled to a total depth of 325.5 meters (m) and cased with 40.6-cm casing to 308.1 m. The hole diameter was then decreased to 37.5 cm, and drilling continued to a total depth of 724.8 m. The completion casing string, set to the depth of 690.9 m, consists of 16.8-cm stainless-steel casing hanging from 19.4-cm carbon-steel casing. The stainless-steel casing has two slotted intervals open to the Rainier Mesa Tuff. Two piezometer strings were installed in Well ER-EC-14. Both piezometer strings, each with one slotted interval, consist of 6.0-cm carbon-steel tubing at the surface, then cross over to 7.3-cm stainless-steel tubing just above the water table. The shallow piezometer string was landed at 507.8 m, and the deep piezometer string was landed at 688.6 m. Both piezometer strings are set to monitor groundwater within moderately to densely welded Rainier Mesa Tuff.

Data collected during and shortly after hole construction include composite drill cuttings samples collected every 3.0 m, various geophysical logs, water quality (including tritium and other radionuclides) measurements, and water level measurements. The well penetrated 15.2 m of alluvium and 709.6 m of Tertiary volcanic rocks. The stratigraphy and general lithology were not as expected due to the position of Well ER-EC-14 relative to the buried caldera margins of the Timber Mountain caldera complex. The well is located inside the Rainier Mesa caldera, but outside the younger Ammonia Tanks caldera.

On November 5, 2012, a preliminary fluid level in the shallow piezometer string was measured at the depth of 311.8 m. This water level depth was taken before installation of the bridge plug (to be placed within the main completion casing to separate the two slotted zones). Well development, hydrologic testing, and sampling, will be conducted at a later date.

No tritium above levels detectable by field methods were encountered in this hole. All Fluid Management Plan (FMP) requirements for Well ER-EC-14 were met. Analysis of monitoring samples and FMP confirmatory samples indicated that fluids generated during drilling at Well ER-EC-14 met the FMP criteria for discharge to an unlined sump or designated infiltration area. All sanitary and hydrocarbon waste generated was properly handled and disposed of.

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List of Acronyms and Abbreviations

BN	Bechtel Nevada
CAIP	Corrective Action Decision Investigation Plan
CAU	Corrective Action Unit
cm	centimeter(s)
CFR	Code of Federal Regulations
DOE/NV	U.S. Department of Energy, Nevada Operations Office
EPA	Environmental Protection Agency
FAWP	Field Activity Work Package
FCCM	Fortymile Canyon composite unit
FMP	Fluid Management Plan
ft	foot (feet)
gal	gallon(s)
gpm	gallons per minute
HFM	hydrostratigraphic framework model
HSU	hydrostratigraphic unit
id	inside diameter
in.	inch(es)
km	kilometer(s)
LANL	Los Alamos National Laboratory
Lpm	liters per minute
LSC	liquid scintillation counter
m	meter(s)
m^3	cubic meters
Ma	million years ago
MDA	minimum detectable activity
mi	mile(s)
NAD	North American Datum
NAIL	nuclear annular investigation log
NARA	National Archives and Records Administration
NDEP	Nevada Division of Environmental Protection
N-I	Navarro-Intera, LLC
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office

List of Acronyms and Abbreviations (continued)

NNSA/NV	U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
NTTR	Nevada Test and Training Range
pCi/L	picocuries per liter
PM–OV	Pahute Mesa–Oasis Valley
RCT	radiological control technician
RMWTA	Rainier Mesa welded-tuff aquifer
SNJV	Stoller-Navarro Joint Venture
TD	total depth
THCM	Tannenbaum Hill composite unit
TMCC	Timber Mountain caldera complex
TMCM	Timber Mountain composite unit
TWG	Technical Working Group
UDI	United Drilling, Inc.
UGTA	Underground Test Area
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
yd^3	cubic yards

1.0 Introduction

1.1 Project Description

Well ER-EC-14 was drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) in support of the Nevada Environmental Management Operations Underground Test Area (UGTA) Activity at the Nevada National Security Site (NNSS; formerly Nevada Test Site). Well ER-EC-14 was the second well of the third drilling campaign as part of the Phase II hydrogeologic investigation well drilling program in the Central and Western Pahute Mesa area of Nye County, Nevada, and was constructed in the fall of 2012.

The Pahute Mesa Phase II drilling program is part of the Corrective Action Investigation Plan (CAIP) for the Central and Western Pahute Mesa Corrective Action Units (CAUs) 101 and 102, respectively (NNSA/NSO, 2009a). The CAIP is a requirement of the Federal Facility Agreement and Consent Order (1996, as amended), agreed to by the U.S. Department of Energy (DOE/NV), the Nevada Division of Environmental Protection (NDEP), and the U.S. Department of Defense.

The Central and Western Pahute Mesa CAUs and the associated well drilling program are part of the UGTA Activity at the NNSS. Two goals of the UGTA Activity 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 Activity, scientists are developing computer models to forecast 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 reliable 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-14 is located on the Nevada Test and Training Range (NTTR), approximately 7 kilometers (km) (5 miles [mi]) south of the Area 20 underground test area (Figures 1-1 and 1-2). The primary purpose of Well ER-EC-14 was to provide detailed hydrogeologic information for volcanic aquifers in the shallow-to-intermediate-depth Tertiary volcanic section in the Timber Mountain caldera complex (TMCC) in the northern portion of the Timber Mountain moat area (Figure 1-3). Detailed hydrogeologic information about the Tertiary volcanic section obtained from this well will support Phase II efforts, including improving the

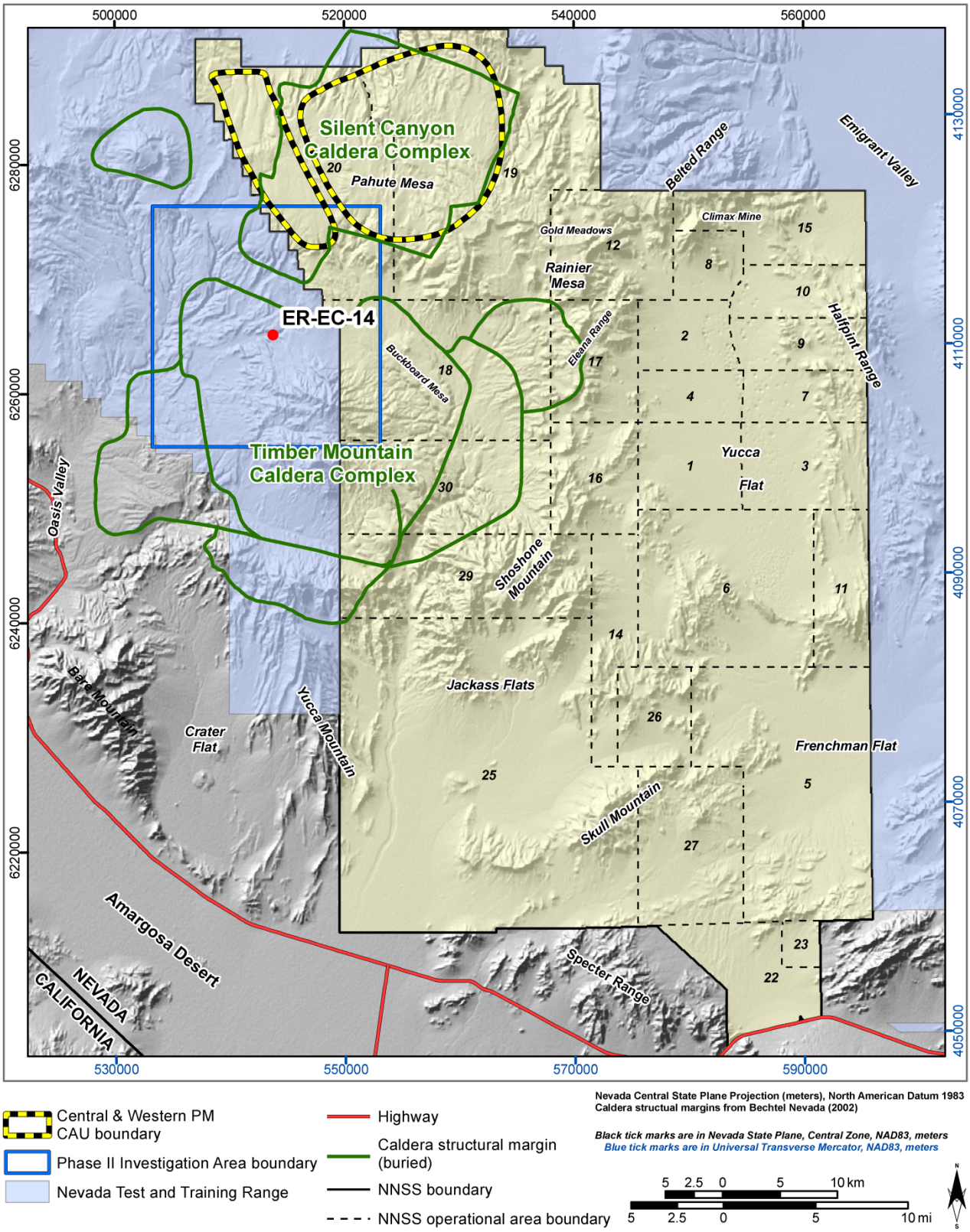


Figure 1-1
Reference Map Showing Location of Well ER-EC-14
on the Nevada Test and Training Range

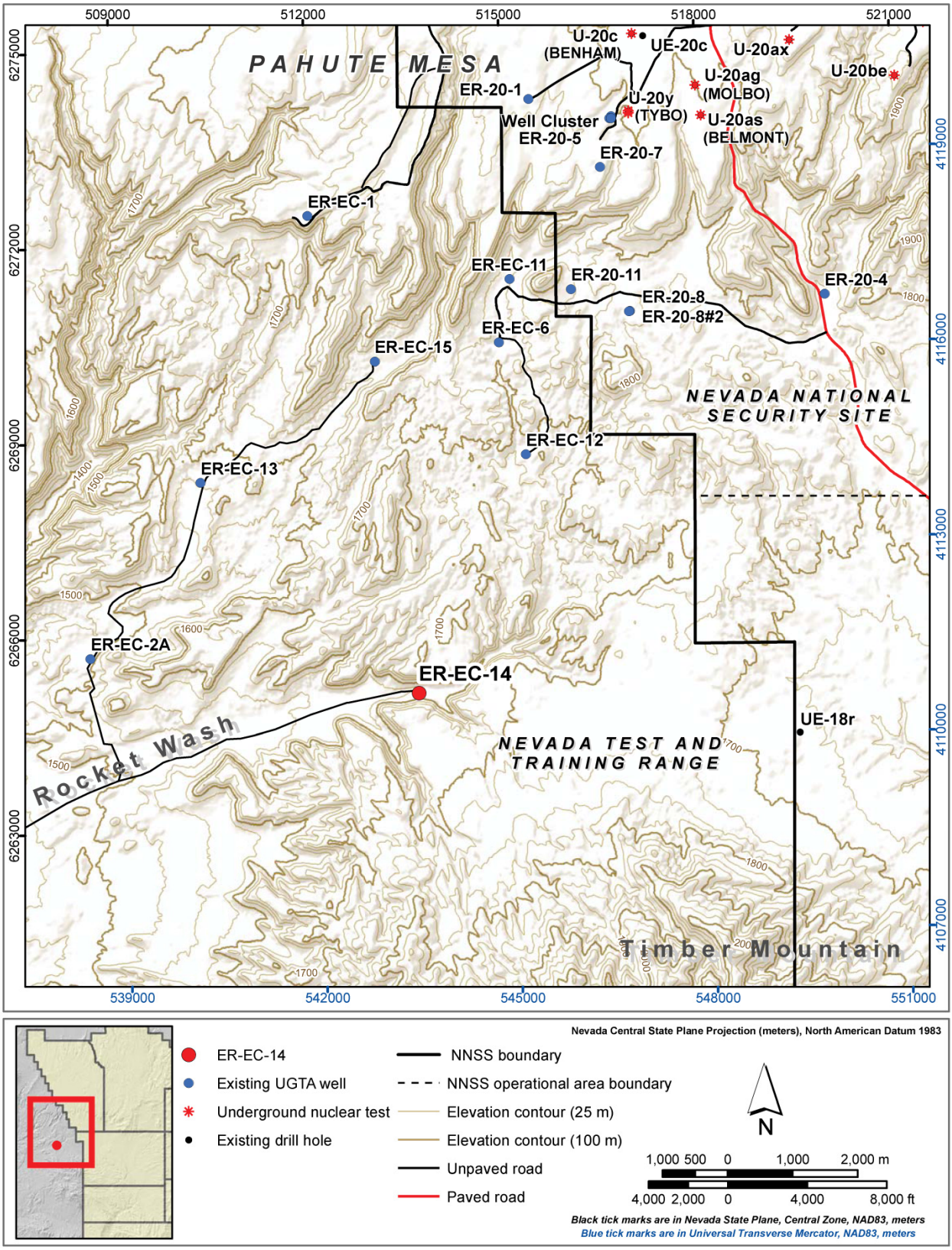


Figure 1-2
Topographic Map of the Well ER-EC-14 Area Showing the Locations of Roads and Nearby Drill Holes

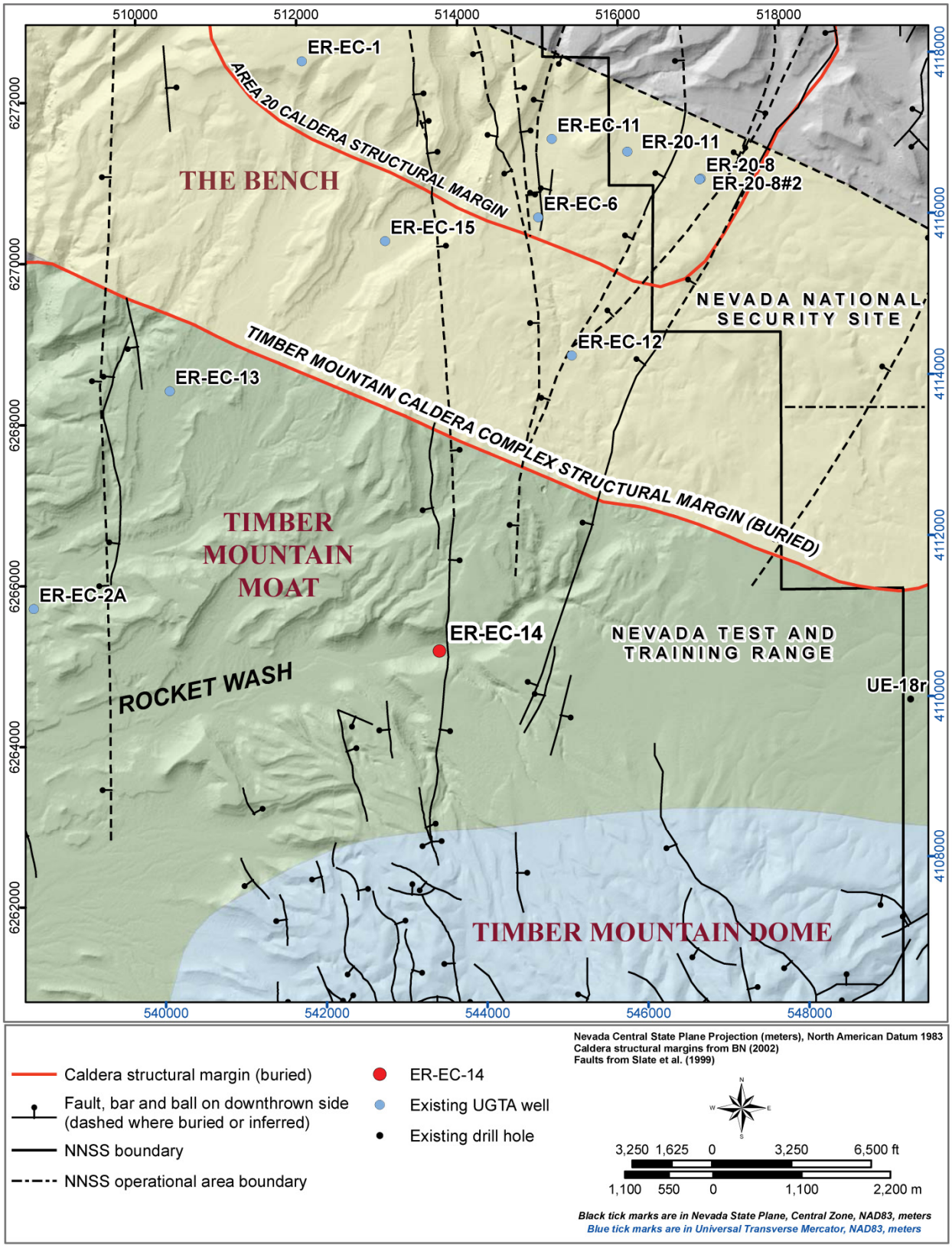


Figure 1-3
Shaded Relief Map of the Well ER-EC-14 Area Showing the Location of the Timber Mountain Moat and Nearby Drill Holes

Phase I hydrostratigraphic framework model (HFM) of the Pahute Mesa–Oasis Valley (PM–OV) area (Bechtel Nevada [BN], 2002) and subsequent flow and transport modeling.

1.2 Project Organization

The construction of Well ER-EC-14 was intended to help fulfill the goals of the UGTA Activity. Several groups function within the Activity, whose responsibilities include ensuring that UGTA goals are properly planned and achieved. The roles of these groups regarding construction of Well ER-EC-14 are described in this section.

The UGTA Technical Working Group (TWG) is a group of scientists and engineers from NNSA/NSO, Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), NDEP, the Desert Research Institute, the U.S. Geological Survey (USGS), National Security Technologies, LLC (NSTec; NNSS management and operating contractor), and Navarro-Intera, LLC (N-I; environmental contractor). 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-14 Drilling Advisory Team, which included the NNSA/NSO UGTA Activity Lead, the CAU Lead, the N-I field manager, the NSTec UGTA manager/drilling engineer, a hydrologist, a geologist, and a radiochemist, provided technical advice during drilling, design, and construction of the well, to ensure that Well ER-EC-14 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* (Stoller-Navarro Joint Venture [SNJV], 2009a) for descriptions of the general plan and goals of the Pahute Mesa Phase II drilling initiative project. See *Addendum #2 to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria for Investigation Wells ER-EC-14 and ER-20-11* (N-I, 2011) for well-specific goals.

NSTec provided site supervision, engineering, construction, inspection, and geologic support. The drilling company was United Drilling, Inc. (UDI), a subcontractor to NSTec. The roles and responsibilities of these and other contractors involved in the project are described in NSTec subcontract number 107553 and in Field Activity Work Package (FAWP) numbers D-008-001.11 and D-009-001.12 (NSTec, 2011; 2012).

N-I was the principal environmental contractor for the project and was responsible for general environmental compliance and waste management at the drill site. N-I was responsible for collecting and analyzing fluid samples for water quality and chemistry, and for monitoring and documenting disposition of fluids and drill cuttings produced from the borehole. N-I personnel

also collected geologic, hydrologic, and drilling parameter data during drilling, as described in N-I (2012a).

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). Well-specific operation strategies for fluid management are further identified in the well-specific fluid management strategy letter (N-I, 2012b) (reproduced in Appendix B-2 of this report) as required by the FMP and approved by NDEP before fluid-generating activities are initiated. 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 Phase II 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, 2011; 2012; N-I, 2012a) and the UGTA Project Health and Safety Plan (NSTec, 2008).

This report presents well construction, environmental compliance, and waste management data, and summarizes scientific data gathered during the drilling of Well ER-EC-14. Some of the information in this report is preliminary and unprocessed but is being released with the drilling and completion data for convenient reference. Some of these data were obtained from N-I's preliminary Well ER-EC-14 data package (N-I, 2013), which is now superseded by this document. Hydrogeologic information for this area is presented in the data documentation package for the PM–OV HFM (BN, 2002). Documentation for Phase I flow and transport modeling, which guided the Phase II data collection activity, can be found in SNJV (2006; 2007; 2009b). Pre-drilling geologic information for this area is compiled in Addendum 2 to the Phase II drilling criteria document (N-I, 2011). Information about well development, aquifer testing, and groundwater analytical sampling (which are outside the scope of this report) are typically compiled and distributed separately.

1.3 Location and Significant Nearby Features

Well ER-EC-14 is located south of Pahute Mesa on the NTTR at an elevation of 1,580.7 meters (m) (5,185.9 feet [ft]) (Figures 1-1 and 1-2). The well site is located in the headwaters of Rocket Wash and surface drainage is to the west. Nearby boreholes include UGTA Well ER-EC-2A, which is located about 5.1 km (3.2 mi) to the west (U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office [NNSA/NV], 2002), and Exploratory Hole UE-18r, which is located about 6.0 km (3.7 mi) to the east. Additional nearby wells drilled as part of the Phase II drilling program include Well ER-EC-12 (NNSA/NSO, 2011a), located about 4.2 km (2.6 mi) to the north, and Well ER-EC-13 (NNSA/NSO, 2011b), located about 4.8 km (3.0 mi) to the northwest.

The Well ER-EC-14 site is located in an area known as the Timber Mountain moat structural domain, which is defined as the area between the Bench to the north and the Timber Mountain caldera resurgent dome to the south (Figure 1-3). Additional information about Well ER-EC-14 is provided in Table 1-1.

The underground nuclear tests closest to and generally upgradient from Well ER-EC-14 are TYBO (U-20y) and BELMONT (U-20as) (Figure 1-2). The TYBO test, located 9.5 km (5.9 mi) to the north-northeast, was conducted below the regional water table (Prothro and Warren, 2001). The BELMONT test, located approximately 9.8 km (6.1 mi) to the north-northeast, was located in a thick interval (155.4 m [510 ft]) of bedded tuff immediately above the water table; however, its explosion cavity is calculated to extend below the water table (N-I, 2011). Additional information for these and other nearby tests is provided in Table 1-2.

1.4 Objectives

The primary purpose for drilling Well ER-EC-14 was to provide detailed hydrogeologic information for the Tertiary volcanic section at shallow to intermediate depths within the TMCC to enhance the understanding of the hydrogeology in the area immediately downgradient of Pahute Mesa underground nuclear tests. An important secondary objective is to obtain information that will help characterize the hydrogeology of the TMCC structural margin and its effects on groundwater flow (NNSA/NSO, 2009a). Well ER-EC-14 is expected to produce data that will improve flow and transport modeling for CAUs 101 and 102. The Well ER-EC-14 location may be a favorable location for a long-term monitoring well.

The objectives for Well ER-EC-14, as described in Appendix F of the addendum to the drilling and completion criteria (N-I, 2011) are listed below. Note that since publication of the Well ER-EC-14 criteria document (N-I, 2011), the hydrostratigraphic unit (HSU) known as the Timber Mountain composite unit (TMCM) has been subdivided into smaller, more well-defined HSUs, including the Rainier Mesa welded-tuff aquifer (RMWTA) and the Ammonia Tanks welded-tuff aquifer.

- Obtain geologic information to reduce uncertainties in the HFM and improve subsequent groundwater flow and transport modeling for the northwestern moat area of the TMCC. In particular, data from the well are expected to aid in accomplishing the following specific goals:

Table 1-1
Site Data Summary for Well ER-EC-14

Site Coordinates [a]	**Nevada State Plane – Central Zone, NAD 27** N 870,057.2 ft E 545,491.1ft **Nevada State Plane – Central Zone, NAD 83** N 6,265,194.5 m E 513,786.1 m **UTM – Zone 11, NAD 83** N 4,110,534.9 m E 543,386.3 m **UTM – Zone 11, NAD 27** N 4,110,337.9 m E 543,466.5 m **Geographic – NAD 83** (degrees, minutes, seconds) Latitude: 37° 08′ 24.7″ Longitude: 116° 30′ 41.4″ **Township and Range** [c] Southeast ¼ of Northwest ¼ of Section 21 Township 9 south, Range 49 east
Surface Elevation [a, b]	1,580.7 m (5,185.9 ft)
Drilled Depth	724.8 m (2,378 ft)
Preliminary Fluid Level Depth [d]	311.8 m (1,023.0 ft)
Fluid Level Elevation	1,268.9 m (4,162.9 ft)
Surface Geology	Alluvium (young alluvial deposits [Qay])

a Measurements made by NSTec Survey on January 17, 2013, 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 Measurement of elevation of ground at wellhead made by NSTec Survey on January 17, 2013. National Geodetic Vertical Datum 1929 (NARA, 1973). Elevations are relative to mean sea level.

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

d Measured in the shallow piezometer by N-I on November 5, 2012.

Table 1-2
Information for Underground Nuclear Tests Relevant to Well ER-EC-14

Emplacement Hole Name	Test Name [a]	Test Date [a]	Surface Elevation [b] meters (feet)	Depth of Burial [b] meters (feet)	Estimated Depth to Regional Water Level [b] meters (feet)	Announced Yield [a] (kilotons)	Working Point Formation [c, d]	Working Point HSU [c, e]	Lateral Distance to Well ER-EC-14 Location miles (kilometers)
U-20y	TYBO	5/14/1975	1,907 (6,257)	765 (2,510)	630 (2,067)	200–1,000	Tpt	TSA	5.9 (9.5)
U-20as	BELMONT	10/16/1986	1,898 (6,227)	605 (1,985)	614 (2,014)	20–150	Tpb(b)	UPCU	6.1 (9.8)
U-20ag	MOLBO	2/12/1982	1,900 (6,234)	638 (2,093)	619 (2,031)	20–150	Tpb	BA	6.4 (10.3)
U-20c	BENHAM	12/19/1968	1,915 (6,281)	1,402 (4,600)	639 (2,096)	1,150	Th	CHZCM	6.6 (10.7)

a DOE/NV (2000)
b NNSA/NSO (2009a)
c BN (2002)
d Stratigraphic Nomenclature:
- **Tpt** = Topopah Spring Tuff
- **Tpb(b)** = rhyolite of Benham, bedded
- **Tpb** = rhyolite of Benham, lava flow
- **Th** = Calico Hills Formation

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

- Provide detailed hydrogeologic information for the shallow-to-intermediate-depth Tertiary volcanic section.
- Provide information regarding the presence and extent of aquifer-like units within rhyolite of Beatty Wash within the TMCC.
- Provide information that will help characterize structural features such as the TMCC structural margin, the nearby M2 fault, and the M1 extension of the Boxcar fault, and investigate what effect they may have on groundwater flow.
- Provide detailed information on the geology and configuration of aquifer units in the upper portion of the saturated section where contaminant transport is most likely.

- Obtain properties of the welded Ammonia Tanks Tuff within the TMCM, such as detailed fracture data, hydrothermal alteration, and hydrologic information.

- Obtain representative aqueous geochemistry samples from the Fortymile Canyon composite unit (FCCM) and TMCM to better define possible groundwater flow paths based on water chemistry.

- Obtain detailed water-level data to determine the regional water level and investigate local groundwater flow toward and/or along the inferred southward extension of the Boxcar fault (referred to here as the M1 fault).

- Investigate the possibility that perched water zones are present above the regional water level.

- Obtain geologic samples for detailed mineralogical analyses to help define the distribution of reactive minerals in the volcanic section.

Additional data that will help characterize the hydrology south of Pahute Mesa will be obtained during later hydraulic testing at this well. Specific criteria for these tests will be provided elsewhere (e.g., FAWPs and specific hydrologic testing plans), but, ultimately, Well ER-EC-14 is expected to provide the following:

- Data for determination of the vertical hydraulic gradient
- Data for determination of horizontal and vertical conductivity
- Hydraulic properties of the saturated HSUs penetrated

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

1.5 Project Summary

This section summarizes construction operations for Well ER-EC-14; the details are provided in Sections 2.0 through 8.0 of this report.

A 106.7-centimeter (cm) (42-inch [in.]) diameter surface conductor hole was constructed by drilling to a depth of 22.3 m (73 ft), and installing a string of 30-in. conductor casing to the depth of 21.6 m (71 ft). Drilling of the main hole with a 22-in. chisel tooth tricone bit, using an air-foam drilling fluid in conventional circulation, began on September 27, 2012, and continued to the depth of 325.5 m (1,068 ft) reached on October 1, 2012. A string of 16-in. surface casing was set to 308.1 m (1,010.9 ft). The hole diameter was then decreased to 37.5 cm (14.75 in.), and the hole was drilled to a total depth (TD) of 724.8 m (2,378 ft), which was reached on October 11, 2012. The open-hole water level prior to installation of the completion string was measured at 311.2 m (1,021 ft) on October 12, 2012, during geophysical logging. On November 5, 2012, a water level of 311.8 m (1,023.0 ft) was measured in the shallow piezometer. No tritium above levels detectable by field methods was measured in this hole during drilling.

The completion casing string, slotted in two intervals, is set at the depth of 690.9 m (2,266.8 ft), and consists of 6⅝-in. stainless-steel casing suspended from 7⅝-in. internally epoxy-coated carbon-steel casing via a crossover sub. The bottom of the carbon-steel casing is positioned in the unsaturated zone at a point approximately 5.5 m (18 ft) above the water table. The upper slotted portion of the completion casing extends from 414.2 to 507.8 m (1,358.8 to 1,666.0 ft), and the lower slotted interval extends from 595.3 to 690.2 m (1,953.1 to 2,264.4 ft). Both intervals allow access to a welded-tuff aquifer in the Rainier Mesa Tuff.

Two piezometer strings were installed in Well ER-EC-14. Both piezometer strings are composed of 2⅞-in. stainless-steel tubing that hangs from 2⅜-in. carbon-steel tubing via a crossover sub. The shallow piezometer string was landed at 507.8 m (1,666.0 ft) and is slotted from 412.1 to 507.2 m (1,351.9 to 1,663.9 ft). The deep piezometer string was landed at 688.6 m (2,259.2 ft) and is slotted from 592.9 to 688.0 m (1,945.1 to 2,257.1 ft). Both slotted intervals within the piezometer strings were set to monitor levels during hydraulic testing.

Composite drill cuttings were collected every 3.0 m (10 ft) from the depth of 21.3 m (70 ft) to TD. Open-hole geophysical logging of the well was conducted to help verify the geology and characterize the hydrologic properties of the rocks; some logs also aided in the construction of the well by indicating borehole volume and condition. The well was drilled mostly within Tertiary volcanic rocks, with a small section of alluvium at the surface.

No well development or hydrologic testing was conducted in this well immediately after completion.

1.6 Contact Information

Inquiries concerning Well ER-EC-14 should be directed to the Federal UGTA Activity Lead at:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Environmental Management Operations
Post Office Box 98518
Las Vegas, Nevada 89193-8518

2.0 Drilling Summary

2.1 Introduction

This section contains detailed descriptions of Well ER-EC-14 drilling operations. The general drilling requirements for both 2012 Pahute Mesa Phase II wells were provided in *Addendum #2 to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigations Wells Drilling and Completion Criteria for Investigation Wells ER-EC-14 and ER-20-11* (N-I, 2011). Specific requirements for Well ER-EC-14 were outlined in FAWP numbers D-008-001.11 and D-009-001.12 (NSTec, 2011; 2012).

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-14. 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.

By industry convention, casing and tubing are identified using English units (e.g., 30-in. casing or 2⅞-in. carbon-steel tubing), which is usually equivalent to the outside diameter of the pipe. In this report, these descriptors are used to designate the type of casing or tubing (its "name"), and no metric conversion is provided. The same is true for drill bits (e.g., 12¼-in. bit), but when the size of the resulting hole is mentioned, both metric and English units are given.

2.2 Drilling History

Field operations at Well ER-EC-14 began on August 3, 2011, when an NSTec crew set up the Auger II drill rig to auger a 106.7-cm (42-in.) diameter conductor hole to the depth of 22.3 m (73 ft). A string of 30-in. conductor casing was set at the depth of 21.6 m (71 ft). The conductor casing was cemented in place on August 10, 2011, using 2.6 cubic meters (m^3) (3.3 cubic yards [yd^3]) of Redi-Mix Formula 400 (see cement composition in Appendix A-3). The cement was pumped into the annulus between the casing and the formation to seal the annulus from the depth of 22.3 m (73 ft) to ground level. The crew finished preparations for drilling of the main hole by drilling the "rat" and "mouse" holes, and moved off the location on August 15, 2011.

There was no activity at the ER-EC-14 site until the UDI crew began mobilizing from Well ER-20-11 to Well ER-EC-14 on September 15, 2012, and started rigging up the Wilson Mogul 42B drill rig. They finished rigging up on September 27, 2012, and began drilling from the top of cement inside the 30-in. casing at 19.9 m (65.3 ft). The drill crew worked through the cement to the bottom of the 30-in. casing with a 22-in. chisel tooth tricone bit. The drilling fluid was an air/water/soap mix in conventional circulation. Drilling of the 55.9-cm (22-in.) hole continued to the depth of 64.6 m (212 ft), then the hole was circulated and cleaned. The drill

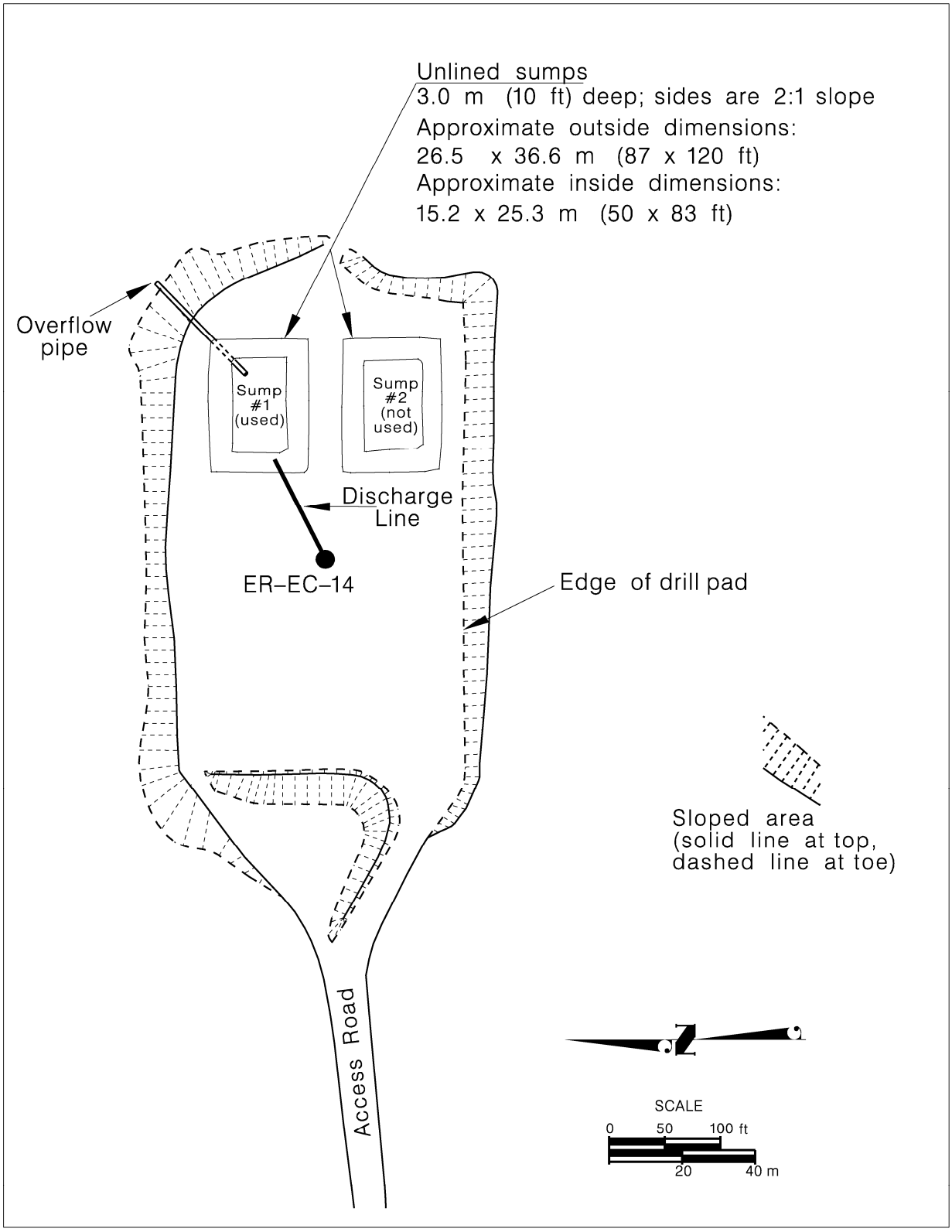
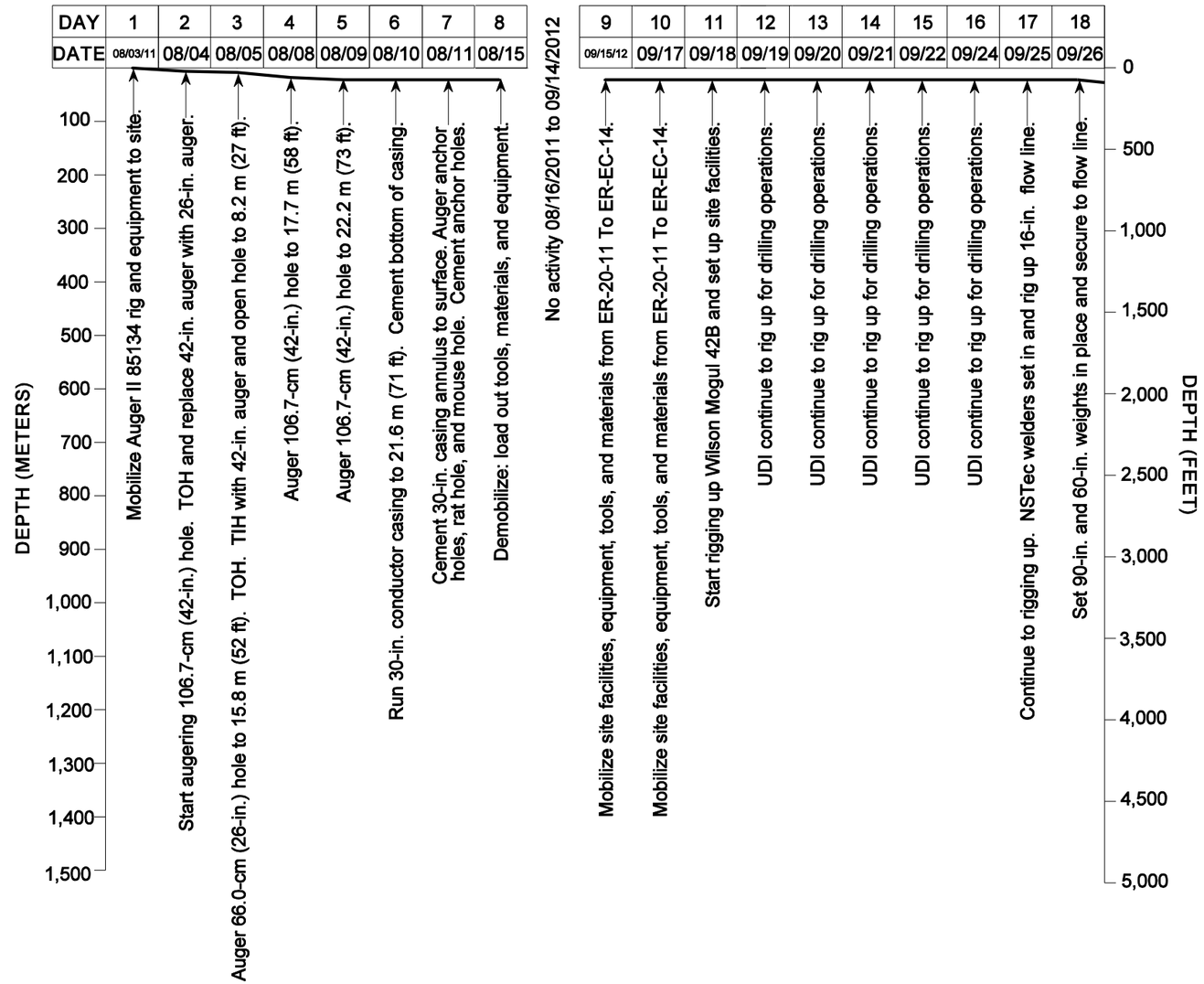


Figure 2-1
Drill Site Configuration for Well ER-EC-14

LEGEND

BA	Baker Atlas
BHA	bottom hole assembly
CA-6	six-arm caliper
CBIL	circumferential borehole imaging log
cm	centimeter(s)
CN	compensated neutron
cu. ft	cubic feet
cu. m	cubic meters
DC(s)	drill collar(s)
FL	fluid level
ft	foot (feet)
HDIL	high density induction log
HWDP	"Hevi-Wate" drill pipe
in.	inch(es)
m	meter(s)
NAIL	nuclear annulus investigation log
N-I	Navarro-Intera, LLC
NSTec	National Security Technologies, LLC
ORIT	orientation log
RIH	run in hole
SGR	spectral gamma ray
SP	spontaneous potential
STAR	borehole resistivity imaging tool
TD	total depth
TIH	trip into hole
TL	temperature log
TOC	top of cement
TOG	top of gravel
TOH	trip out of hole
TOS	top of sand
UDI	United Drilling Inc.
WOC	wait on cement
XMAC	cross-multipole array acoustilog
ZDL	Z-densilog



WELL ER-EC-14 SUMMARY

Activity	Date
Begin drilling for conductor hole:	08/04/2011
Conductor hole completed and 30-in. casing set at 21.6 m (71.0 ft):	08/10/2011
Begin drilling 55.9-cm (22-in.) surface hole:	09/27/2012
Set 16-in. surface casing at 308.1 m (1,010.9 ft):	10/04/2012
Begin drilling 37.5-cm (14.75-in.) hole:	10/06/2012
Reach total drilled depth of 724.8 m (2,378 ft):	10/11/2012
Well completed:	10/16/2012

FIGURE 2-2

WELL ER-EC-14
DRILLING AND COMPLETION
HISTORY
SHEET 1 OF 2

FIGURE 2-2

WELL ER-EC-14
DRILLING AND COMPLETION
HISTORY
SHEET 2 OF 2

Table 2-1
Abridged Drill Hole Statistics for Well ER-EC-14

LOCATION DATA:				
Coordinates:	Nevada State Plane (Central Zone)	(NAD 27):	N 870,057.2 ft	E 545,491.1 ft
	Nevada State Plane (Central Zone)	(NAD 83):	N 6,265,194.5 m	E 513,786.1 m
	Universal Transverse Mercator (Zone 11)	(NAD 83):	N 4,110,534.9 m	E 543,386.3 m
	Universal Transverse Mercator (Zone 11)	(NAD 27):	N 4,110,337.9 m	E 543,466.5 m
Surface Elevation [a]: 1,580.7 m (5,185.9 ft)				
DRILLING DATA:				
Spud Date:	09/27/2012 (main hole drilling with Wilson Mogul 42B rig)			
Total Depth (TD):	724.8 m (2,378 ft)			
Date TD Reached:	10/11/2012			
Date Well Completed:	10/16/2012 (date completion string was cemented in place)			
Hole Diameter:	106.7 cm (42 in.) from surface to 22.3 m (73 ft); 55.9 cm (22 in.) from 22.3 to 325.5 m (73 to 1,068 ft); 37.5 cm (14.75 in.) from 325.8 m (1,068.9 ft) to TD of 724.8 m (2,378 ft).			
Drilling Techniques:	Drill 106.7 cm (42 in.) hole from surface to 22.3 m (73 ft) with dry-hole auger; rotary drill with 22-in. tricone bit, using air-foam in direct circulation from 22.3 to 325.8 m (73 to 1,068.9 ft). Center-punch with 14¾-in. tricone bit and continued rotary drilling using air-foam in direct circulation to the TD of 724.8 m (2,378 ft).			
CASING DATA:	30-in. conductor casing to 21.6 m (71 ft); 16-in. surface casing 0 to 308.1 m (0 to 1,010.9 ft)			
WELL COMPLETION DATA:				
A string of 7⅝-in. carbon-steel casing, connected to 6⅝-in. stainless-steel casing via a crossover sub, was installed in Well ER-EC-14. The carbon-steel casing terminates within the unsaturated zone approximately 5.5 m (18 ft) above the water table. The 7⅝-in. outside-diameter casing has an inside diameter (id) of 17.70 cm (6.969 in.). The 6⅝-in. casing has an id of15.5 cm (6.104 in.). The completion string was landed at 690.9 m (2,266.8 ft). Two 2⅞-in. piezometer strings (id of 5.90 cm [2.323 in.]) were also installed. Both stainless-steel tubing strings hang from strings of 2⅜-in. carbon-steel tubing (id of 5.07 cm [1.995 in.]) via crossover subs. The shallow piezometer was landed at 507.8 m (1,666.0 ft) and the deep piezometer was landed at 688.6 m (2,259.2 ft).				
Depth of Slotted Section:	6⅝-in. completion casing (upper):	414.2 to 507.8 m (1,358.8 to 1,666.0 ft)		
	6⅝-in. completion casing (lower):	595.3 to 690.2 m (1,953.1 to 2,264.4 ft)		
	Shallow 2⅞-in. piezometer string:	412.1 to 507.2 m (1,351.9 to 1,663.9 ft)		
	Deep 2⅞-in. piezometer string:	592.9 to 688.0 m (1,945.1 to 2,257.1 ft)		
Depth of Sand Packs:	394.7 to 404.8 m (1,295 to 1,328 ft) 575.8 to 585.2 m (1,889 to 1,920 ft)			
Depth of Gravel Packs:	404.8 to 519.4 m (1,328 to 1,704 ft) 585.2 to 723.0 m (1,920 to 2.372 ft)			
Depth of Pump:	Not installed at the time of completion			
Water Depth:	Fluid-level depths measured on November 5, 2012: 311.9 m (1,023.2 ft) in the deep piezometer string and 311.8 m (1,023.0 ft) in the shallow piezometer string.			
DRILLING CONTRACTOR: United Drilling, Inc.				
GEOPHYSICAL LOGS BY: Baker Atlas				
SURVEYING CONTRACTOR: National Security Technologies, LLC				

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

string was removed so that two roller reamers and a shock sub could be added to the bottom-hole assembly. Drilling of the 55.9-cm (22-in.) hole continued to a depth of 87.8 m (288 ft), when drilling was suspended and the site was shut down due to operations on the NTTR, for a total time of approximately 40 hours. Drilling resumed on the morning of September 30, 2012, and continued to the depth of 137.5 m (451 ft). The crew then removed the drill string to replace nine joints of "Hevi-Wate" drill pipe with seven drill collars and jars. Approximately 1.5 m (5 ft) of fill was encountered when the string was lowered back into the hole.

The first observation of water in the drilling effluent was reported at the depth of approximately 315.8 m (1,036 ft) on October 1, 2012. When the borehole had reached the depth of 325.5 m (1,068 ft), the decision was made to suspend drilling to conduct open-hole geophysical logging in the unsaturated zone and set surface casing. After approximately 1 day of stand-down time to wait on the arrival of Baker Atlas, geophysical logging operations were completed on October 3, 2012. A fluid level of 311.2 m (1,021 ft) was estimated from the geophysical logs.

On October 4, 2012, a casing subcontractor installed a string of 16-in. casing, which was set at the depth of 308.1 m (1,010.9 ft). The bottom of the surface casing was cemented with 14.2 m^3 (18.6 yd^3) of Type II neat cement. The top of the cement in the annulus is estimated to be at a depth of approximately 237.7 m (780 ft) based on geophysical log data.

After the flow line was welded onto the surface casing at the well head, operations at the rig site were placed on standby for approximately 20 hours until the new flow line configuration could be inspected. Operations resumed on October 6, 2012, when drilling of the 37.5-cm (14.75-in.) hole began.

The top of cement was tagged inside the surface casing at the depth of 306.6 m (1,006 ft), and the cement and the casing shoe were drilled to 325.5 m (1,068 ft). Drilling continued with little or no fill accumulation when drilling was stopped to add pipe to the string (to make a connection) until October 9, 2012, when the crew tripped out of the hole to change out the drill bit. Drilling resumed after drilling approximately 1.5 m (5 ft) of fill and continued with as much as 1.8 m (6 ft) of fill on connections until October 11, 2012, when the TD of 724.8 m (2,378 ft) was reached. The drillers circulated fluid in the hole for 30 minutes, then pulled the drill string up a short distance and then lowered it again, and found that 1.8 m (6 ft) of fill had accumulated.

The tritium analyses of drilling effluent conducted on site during drilling indicated that all samples were below levels detectable by field methods (see discussion in Section 3.1.2). The water production rate during borehole advancement, based on visual estimates and calculated bromide tracer dilution, ranged from 11.4 to 340.7 liters per minute (Lpm) (3 to 90 gallons per minute [gpm]) starting at the depth of approximately 313.0 m (1,027 ft). Water production

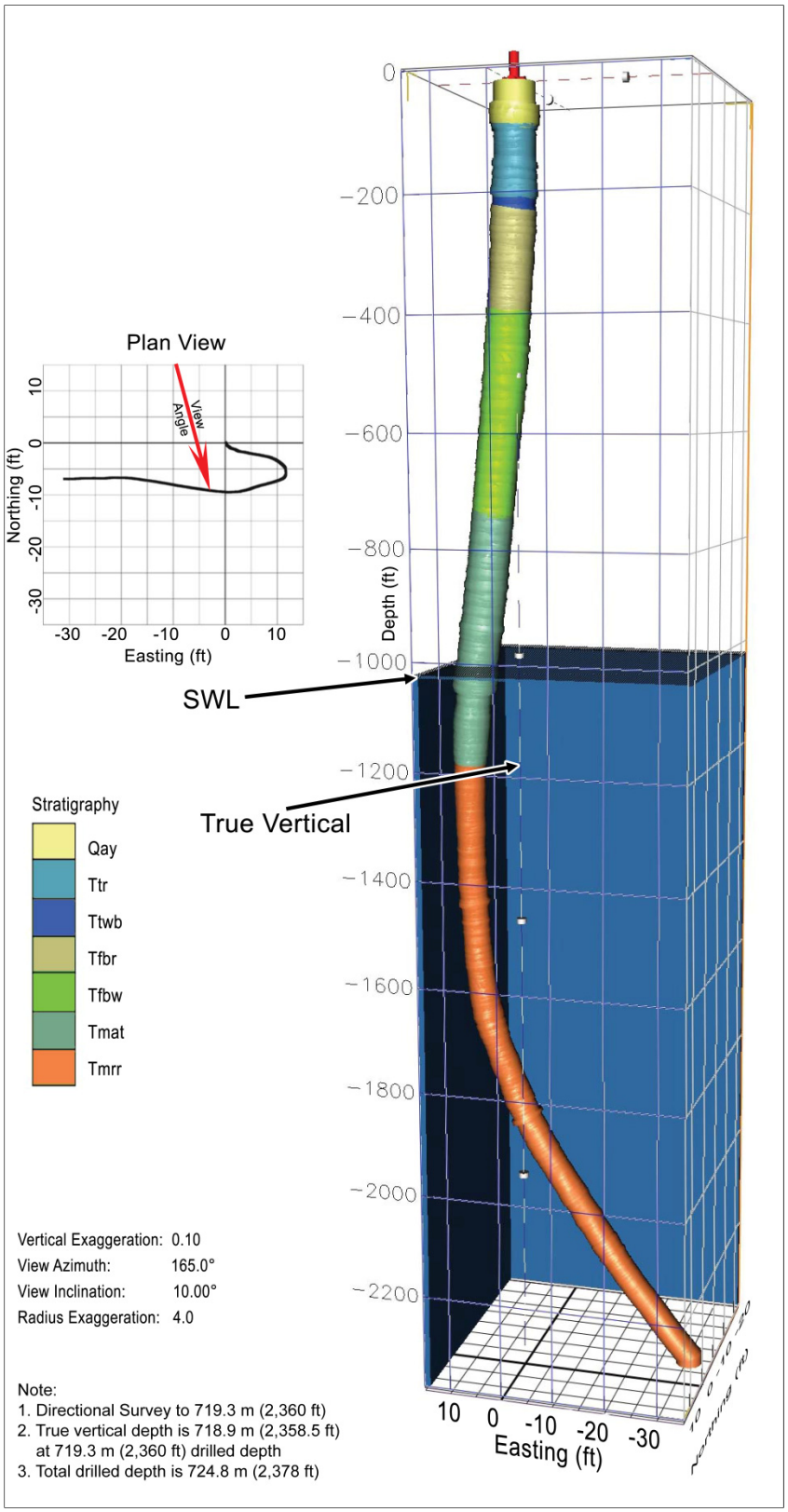
began increasing at the depth of approximately 451.4 m (1,481 ft) and reached a maximum of about 3,028 Lpm (800 gpm) within the densely welded Rainier Mesa Tuff, starting at the depth of about 687.6 m (2,256 ft), and continuing to TD. See Section 6.2 for more information on groundwater production.

Geophysical logging operations were conducted in the main hole by Baker Atlas on October 11/12, 2012. During logging operations, Baker Atlas recorded a water level depth of 311.2 m (1,021 ft) and tagged fill at 723.0 m (2,372 ft). Baker Atlas rigged down and departed the location on October 12, 2012. N-I collected two depth-discrete fluid samples from the depth of 453.5 m (1,488 ft) using a bailer.

On October 13, 2012, the drill crew installed two 2⅞-in. stainless-steel piezometer strings, each with one slotted interval. The deep piezometer string was set at 688.6 m (2,259.2 ft), and the shallow piezometer string was set at 507.8 m (1,666.0 ft). A casing subcontractor inserted the completion casing string, which has two slotted intervals, landing it on October 14, 2012, at a depth of 690.9 m (2,266.8 ft). The annulus around the production casing and the two piezometer strings were packed with sand and gravel, and cemented. Stemming operations were completed on October 16, 2012. See Section 8.0 for more details about completion activities.

The drillers started demobilizing the rig and drilling equipment on October 17, 2012, and crews worked one shift per day after that, until demobilization was completed on October 24, 2012. One bridge plug that isolates the two slotted intervals in the completion casing string was installed at 541.3 m (1,776 ft) by Baker Atlas on October 24, 2012.

The inclination of the borehole was determined from borehole orientation logs run by Baker Atlas during both logging operations (October 3 and 12, 2012). The changes in borehole orientation visible on the borehole orientation plots are relatively gentle and generally correspond to formation changes. The upper part of the borehole follows a southeasterly path; however, the borehole orientation changes to a more westerly path starting at the depth of approximately 426.7 m (1,400 ft), which corresponds to the depth where the borehole encountered a more densely welded portion of the Rainier Mesa Tuff. The average borehole inclination is 1.5 degrees. The greatest deviation is 5.1 degrees, between the depths of 573.0 and 588.3 m (1,880 and 1,930 ft), within densely welded tuff. At TD, the borehole is approximately 9.7 m (31.7 ft) west-northwest of the collar location, on a bearing of 89.8 degrees. At the lowest logged depth of 719.3 m (2,360 ft), the true vertical depth is calculated to be 718.9 m (2,358.6 ft), a difference of 0.4 m (1.4 ft). Despite the bend in path, no difficulties were encountered in this interval during installation of the completion casing. Figure 2-3 presents a three-dimensional view of the borehole showing deviation, the borehole profile from the caliper log, and stratigraphy.



Modified from N-I, 2013

Figure 2-3
Well ER-EC-14 Directional Survey Showing Caliper Profile and Stratigraphy
(SWL = static water level. See Table 5-1 for key to stratigraphic nomenclature)

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-14 are listed in Appendix A-3.

2.3 Drilling Problems

No significant drilling problems were encountered during construction of Well ER-EC-14. Drilling delays were mainly due to operational activities related to the well-site location, rather than drilling problems. The well site was on standby for a total of approximately 4 days over the course of well construction due to a site shutdown, waiting on the flow line inspection, and waiting on geophysical logging contractors.

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3.0 Management of Fluids, Drill Cuttings, and Waste

This section describes how fluids and drill cuttings produced from the Well ER-EC-14 borehole and hydrocarbon and sanitary waste generated during well construction were managed. The information in this section was obtained from N-I (2013).

3.1 Fluid and Drill Cuttings Management

3.1.1 Fluid Management Strategy

The management of drilling fluids and solid waste (i.e., cuttings) is addressed in the *Underground Test Area Project Waste Management Plan; Attachment 1 Fluid Management Plan for the Underground Test Area Project* (NNSA/NSO, 2009b). The *Final Well Specific Fluid Management Strategy for UGTA Well ER-EC-14, EC South Area, Nevada Test and Training Range* (N-I, 2012b; reproduced in Appendix B-2), as required by the UGTA FMP, addresses specific fluid management strategies to be employed at Well ER-EC-14 for fluid-generating activities relating to well drilling, well construction, and well development and testing activities. The drilling fluid discharge was monitored routinely during drilling in accordance with these plans to guide operational decisions for proper fluid containment and, ultimately, proper fluid disposal.

Two onsite infiltration basins (Sumps #1 and #2) were constructed to contain fluids and drill cuttings during operations at Well ER-EC-14. Both sumps were unlined. A 10¾-in. discharge line ("overflow pipe") was installed in Sump #1 to convey fluids to the surface infiltration area, if needed. Figure 2-1 shows the relative size and positions of unlined Sumps #1 and #2 on the Well ER-EC-14 drill pad.

The air-foam drilling fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional, or direct, circulation). The drilling effluent was discharged into Sump #1. The overflow pipe was opened when Sump #1 filled, and fluid was allowed to flow into the infiltration area north of the pad site (and then following the natural drainage to the west) on October 9–11, 2012. Sump #2 was not used.

Water used to prepare the drilling fluids was obtained from Well ER-EC-13, an existing UGTA well that was pumped and sampled July 13, 2012. Sample data were reviewed, and all analytes detected were below limits prescribed in the National Primary Drinking Water Regulations (Code of Federal Regulations [CFR], 2012a) limits.

3.1.2 Fluid Management Sampling Results

An important element of the FMP strategy (NNSA/NSO, 2009b) is the onsite monitoring program. This program is intended to provide the timely detection of indicator contaminants and determines onsite fluid management requirements.

Discharged drilling fluids were collected hourly by N-I personnel during periods of borehole advancement. NSTec radiological control technicians (RCTs) used NSTec-supplied liquid scintillation counters (LSCs) to analyze the fluid samples on site for tritium for the purpose of fluid management and worker protection. A minimum detectable activity (MDA) is associated with the analysis of each sample; the average minimum MDA for the onsite LSCs at Well ER-EC-14 was approximately 1,500 picocuries per liter (pCi/L). Samples were collected and analyzed for tritium for screening purposes, and the reported results are not intended to accurately represent lower concentrations of tritium (i.e., less than approximately 1,500 pCi/L) due to errors in counting statistics or issues relating to the nature of fluids analyzed (e.g., drilling fluids).

The onsite monitoring results for the drilling fluid (listed in Appendix B-1) indicated that tritium levels were well below the drinking water standards limit of 20,000 pCi/L (CFR, 2012a), as measured by field instruments. In accordance with NNSS radiological control guidelines (Radiological Control Managers' Council, 2012), onsite fluid samples with initial tritium results greater than the MDA were reanalyzed until the results stabilized. After the eight samples with elevated initial tritium levels were re-analyzed, the tritium levels were found to be below the MDA. The higher initial tritium levels are attributed to a chemical interaction between solids (cement and rock) in the effluent and the scintillation cocktail used in the analysis (chemo-luminescence). Tritium results from drilling fluid discharge samples from both the unsaturated and saturated zones in Well ER-EC-14 ranged from 0 to 1,623 pCi/L, all below the MDAs of the individual analyses.

Following the completion of drilling activities, N-I personnel collected an FMP (NNSA/NSO, 2009b) confirmatory sample and a duplicate sample from Sump #1 on October 13, 2012. The samples were analyzed by an offsite laboratory for total and dissolved metals, gross alpha and beta, and tritium. The analytical results for the FMP confirmatory samples from Sump #1 are presented in Appendix B-1.

3.1.3 Disposition of Fluids and Drill Cuttings

The FMP (NNSA/NSO, 2009b) and the ER-EC-14 FMP strategy letter (Appendix B-2) establish concentrations for specified parameters below which drilling fluids may be discharged to a lined sump, an unlined containment basin infiltration area, or directly to the ground surface. The

results of Well ER-EC-14 monitoring samples and FMP confirmatory samples indicated that fluids generated from drilling the unsaturated and saturated zones at ER-EC-14 met the FMP criteria for discharge to a designated infiltration area.

The fluid volumes produced during unsaturated and saturated zone drilling are presented on the Well ER-EC-14 Fluid Disposition Reporting Form, which is reproduced in Appendix B-1. At the completion of drilling on October 11, 2012, an estimated combined total of 2,380.5 m^3 (628,862 gallons [gal]) of drilling fluid and cuttings remained in unlined Sump #1.

3.2 Environmental Compliance and Waste Management

N-I was responsible for environmental compliance and waste management at the Well ER-EC-14 site. Periodic site evaluations were conducted during site operations to ensure compliance with the Occupational Safety and Health Act (CFR, 2012b), the Resource Conservation and Recovery Act (CFR, 2012c), the UGTA Waste Management Plan (NNSA/NSO, 2009b), and internal contractor procedures.

Waste generated during drilling operations at the Well ER-EC-14 site consisted of hydrocarbon and sanitary wastes. A summary of waste type, volume, and disposition of waste streams generated during drilling is provided in Appendix C. Sanitary waste generated at the well site during drilling operations was routinely collected by NSTec and disposed at the Area 23 solid waste landfill on the NNSS. The hydrocarbon waste was removed from the Well ER-EC-14 drill site and transported by N-I personnel to Building 6-909 at the NNSS for interim storage until disposed of by NSTec. NSTec drained the 7,571-liter (2,000-gal) condensate tank and transported the contents to the Area 12 surface impoundment at the NNSS for evaporation. All waste was characterized using process knowledge and onsite monitoring results.

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4.0 Geologic Data Collection

4.1 Introduction

This section describes the sources of geologic data obtained from Well ER-EC-14 and the methods of data collection. Confirming and characterizing the subsurface structure, stratigraphy, and hydrogeology within the TMCC were among the primary objectives of Well ER-EC-14, so the proper collection of geologic and hydrogeologic data from the borehole was considered fundamental to successful completion of the well-construction project.

Geologic data collected at Well ER-EC-14 consist of drill cuttings and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures, as listed in the N-I FAWP (N-I, 2012a).

4.2 Drill Cuttings

No samples were collected during augering of the shallow conductor hole. During drilling of the main hole, N-I personnel collected composite drill cuttings at 3.0-m (10-ft) intervals. Triplicate samples, each consisting of approximately 550 cubic centimeters of material, were collected from 231 intervals from 21.3 m (70 ft) to TD. The quality of the cuttings samples is generally fair.

These samples are stored under environmentally controlled, secure conditions at the USGS Geologic Data Center and Core Library in Mercury, Nevada. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample; one set was left unsealed in the original sample containers; and the third set was processed and stored according to standard USGS Core Library procedures, except that because the samples had been adequately rinsed at the rig site to remove residual drilling fluid, washing of the samples by the USGS was not necessary. The third set was used by NSTec geologists to construct the detailed lithologic log presented in Appendix D. 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.

4.3 Sidewall Core Samples

No sidewall core samples were collected from Well ER-EC-14 because the stratigraphy and lithology were well enough understood from the drill cuttings and geophysical logs, and data from nearby Wells ER-EC-13 and ER-EC-2A.

4.4 Sample Analysis

Eighteen samples of drill cuttings from various depths in Well ER-EC-14 were submitted to Comprehensive Volcanic Petrographics, LLC, for petrographic analysis. Splits of the same samples were submitted to the Earth Systems Observations 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 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, which will be used in evaluation of geophysical log signatures and in transport modeling. The results of the petrographic analyses are reported in Warren (2013), and the results of the mineralogic and chemical analyses are reported in WoldeGabriel et al. (2013). Table 4-1 lists all samples analyzed.

4.5 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. surface casing at 308.1 m (1,010.9 ft), and in the saturated zone after the TD was reached at 724.8 m (2,378 ft). The overall quality of the geophysical log data collected was good, but several of the log signatures in the upper part of the borehole were affected by a slight but consistent "wobble" in the borehole, which caused an oscillating pattern on geophysical log plots. Similar oscillation has been observed in geophysical logs from previous UGTA Phase II wells, including Wells ER-20-7 and ER-EC-15 (NNSA/NSO, 2010; NNSA/NSO, 2011c), and the cause is not clear. This primarily affected the density and neutron porosity logs in the upper part of the borehole.

A complete listing of the logs, date run, and depths is provided in Table 4-1. Note that a gamma-ray log is typically included with each logging run for depth correlation. The logs are available from NSTec in Mercury, Nevada, and copies are on file at the N-I office 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 E.

Table 4-1
Rock Samples from Well ER-EC-14 Selected for Petrographic, Mineralogic, and Chemical Analysis [a]

Depth [b, c]		Sample Identifier [d]
Meters	Feet	
64.0	210	EREC/14 – 210 D
100.6	330	EREC/14 – 330 D
143.3	470	EREC/14 – 470 D
219.5	720	EREC/14 – 720 D
243.8	800	EREC/14 – 800 D
295.7	970	EREC/14 – 970 D
362.7	1,190	EREC/14 – 1,190 D
384.1	1,260	EREC/14 – 1,260 D
411.5	1,350	EREC/14 – 1,350 D
420.6	1,380	EREC/14 – 1,380 D
448.1	1,470	EREC/14 – 1,470 D
472.4	1,550	EREC/14 – 1,550 D
499.9	1,640	EREC/14 – 1,640 D
524.3	1,720	EREC/14 – 1,720 D
545.6	1,790	EREC/14 – 1,790 D
588.3	1,930	EREC/14 – 1,930 D
658.4	2,160	EREC/14 – 2,160 D
724.9	2,378.2	EREC/14 – 2,378.2 D

a Mineralogic analysis by x-ray diffraction; chemical analyses 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) aggregate sample.

d “D” in sample identifier indicates drill cuttings sample.

Table 4-2
Well ER-EC-14 Geophysical Log Summary

Geophysical Log Type[a]	Log Purpose	Date Logged	Run Number	Bottom of Logged Interval[b] meters (feet)	Top of Logged Interval[b] meters (feet)
*Differential Temperature / Gamma Ray	Saturated zone: groundwater temperature / stratigraphic and depth correlation	10/3/2012 10/11/2012	TL-1 / GR-1 TL-2 / GR-5	325.4 (1,067.5) 722.8 (2,371.5)	184.7 (606) 206.7 (678)
*Aligned Borehole Profile (i.e., Oriented 6-Arm Caliper) / Gamma Ray	Borehole conditions, cement volume calculation, lithologic features, borehole orientation / stratigraphic and depth correlation	10/3/2012 10/11/2012	CA6-1 / ORIT-1 / GR-2 CA6-2 / ORIT-2 / GR-6	322.5 (1,058) 719.9 (2,362)	21.6 (71) 307.8 (1,010)
*Gamma Ray / *Digital Spectralog	Stratigraphy, mineralogy, and natural and man-made radiation determination	10/3/2012 10/11/2012	GR-3 / SGR-1 GR-6 / SGR-2	315.2 (1,034) 711.7 (2,335)	0 (0) 289.6 (950)
*High Definition Induction / Gamma Ray / Spontaneous Potential	Lithologic determination; saturation of formations; stratigraphic and depth correlation	10/3/2012	HDIL-1 / GR-3 / SP-1	321.9 (1,056)	21.6 (71)
*Compensated Z-Densilog / *Compensated Neutron / Gamma Ray	Stratigraphic and lithologic determination / identification of welding, alteration, rock porosity, and water content	10/3/2012 10/11/2012	ZDL-1 / CN-1 / GR-4 ZDL-2 / CN-2 / GR-8	324.6 (1,065) 722.1 (2,369)	21.6 (71) 228.6 (750)
*X-Multipole Array Acoustilog / Gamma Ray	Primary matrix porosity	10/12/2012	XMAC-1 / ORIT-3 / GR-9	716.3 (2,350)	307.8 (1,010)
Resistivity Imaging / Gamma Ray	Saturated zone: lithologic characterization, bedding dip, fracture and void analysis	10/12/2012	STAR-1 / ORIT-4 / GR-10	722.1 (2,369)	310.9 (1,020)
*R_t Explorer / Gamma Ray / Spontaneous Potential	Lithologic determinations, identification of alteration, recognition of welding, distinguishing low versus high porosity	10/11/2012	RTEX-1 / GR-7 / SP-2	716.9 (2,352)	307.8 (1,010)

Note: All logs provided by Baker Atlas, a division of Baker Hughes, Inc.

a Logs presented in geophysical log summary, Appendix E, are indicated by *. A gamma-ray log is included on each logging run to aid in depth correlation.

b Drilled depth

5.0 Geology and Hydrogeology

5.1 Introduction

This section describes the geology and hydrogeology of Well ER-EC-14. The basis for the discussions here is the detailed geologic characterization of Well ER-EC-14 presented as a detailed lithologic log in Appendix D. The detailed lithologic log was developed using drill cuttings, geophysical logs, and drilling parameters. Data from petrographic analyses on selected lithologic samples from Well ER-EC-14 were incorporated into the lithologic log.

5.2 Geology

This section is divided into three discussions relating to the geology of Well ER-EC-14. Section 5.2.1 briefly describes the geologic setting of the TMCC area and the Well ER-EC-14 site. The stratigraphic and lithologic units penetrated at the well are discussed in Section 5.2.2. 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 5.2.3. Detailed descriptions of the stratigraphy, lithology, and alteration of the geologic units encountered are provided in the detailed lithologic log presented in Appendix D. Tables 5-1 and 5-2 provide the definitions of symbols used to represent stratigraphic units and HSUs in various figures in this report. See Figure 5-1 for a surface geologic map of the area surrounding the Well ER-EC-14 site.

5.2.1 Geologic Setting

Well ER-EC-14 is located within the northwestern moat of the TMCC. The TMCC is a large resurgent caldera complex formed mainly by eruptions of the Rainier Mesa Tuff (11.6 million years ago [Ma]) and Ammonia Tanks Tuff (11.45 Ma), each of which formed a separate caldera (Sawyer et al., 1994). Resurgence of magma after the eruption of the Ammonia Tanks Tuff domed up the central portion of the caldera complex, forming a resurgent dome that is today the prominent topographic feature called Timber Mountain. The topographic low area, or caldera moat, surrounding the resurgent dome was filled with younger tuffs and lavas erupted from nearby vents as well as alluvial debris shed from surrounding highlands. Well ER-EC-14 is located about halfway between the lower slopes of Timber Mountain and the outer-most structural margin of the TMCC, which in this portion of the caldera complex coincides with the northern structural margin of the Rainier Mesa caldera (Figure 5-1). The well lies within the structural margin of the Rainier Mesa caldera, but was found to be positioned outside the structural margin of the Ammonia Tanks caldera (see discussion in Section 5.3).

Table 5-1
Key to Stratigraphic Units and Symbols of the Well ER-EC-14 Area

Stratigraphic Unit	Map Symbol
Quaternary and Tertiary Deposits	**QTa**
Young alluvial deposits	Qay
Colluvium	QTc
Intermediate alluvial deposits	Qai
Older alluvial deposits	QTa
Caldera moat-filling sediments	Tgc
Thirsty Canyon Group	**Tt**
Trail Ridge Tuff	Ttt
Pahute Mesa Tuff	Ttp
Comendite of Ribbon Cliff	Ttc
Rocket Wash Tuff	Ttr
basalt of Rocket Wash	Ttrb
intermediate-age basalt	Tft
Volcanics of Fortymile Canyon	**Tb**
Beatty Wash Formation	Tfb
Rhyolite of Chukar Canyon	Tfbr
rhyolite of Beatty Wash	Tfbw
Timber Mountain Group	**Tm**
trachyte of East Cat Canyon	Tmay
Tuff of Buttonhook Wash	Tmaw
Ammonia Tanks Tuff	Tma
mafic-rich Ammonia Tanks Tuff	Tmar
mafic-poor Ammonia Tanks Tuff	Tmap
bedded Ammonia Tanks Tuff	Tmab
landslide deposits	Tmax
rhyolite of Tannenbaum Hill	Tmat
landslide deposits	Tmatx
Rainier Mesa Tuff	Tmr
mafic-rich Rainier Mesa Tuff	Tmrr
mafic-poor Rainier Mesa tuff	Tmrp
landslide deposits	Tmrx
Tuff of Holmes Road	Tmrh
Paintbrush Group	**Tp**
Tiva Canyon Tuff	Tpc
Topopah Spring Tuff	Tpt
mafic-rich Topopah Spring Tuff	Tptr
Calico Hills Formation	**Th**
Crater Flat Group	**Tc**
Bullfrog Tuff	Tcb
Belted Range Group	**Tb**
Grouse Canyon Tuff	**Tbg**
Pre-Grouse Canyon Caldera Units	**To**
Paleozoic Sedimentary Rocks	**Pz**

Table 5-2
Key to Hydrostratigraphic Units and Symbols of the Well ER-EC-14 Area

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 aquifer	THCM
Ammonia Tanks welded-tuff aquifer [a]	ATWTA
Rainier Mesa welded-tuff aquifer [a]	RMWTA
Subcaldera volcanic confining unit	SCVCU
Tiva Canyon aquifer	TCA
Lower Paintbrush confining unit	LPCU
Topopah Spring aquifer	TSA
Calico Hills confining unit	CHCU
Crater Flat confining unit	CFCU
Belted Range aquifer	BRA
Pre-Belted Range composite unit	PBRCM
Ammonia Tanks intrusive confining unit	ATICU
Lower carbonate aquifer	LCA

a Since publication of the drilling and completion criteria (N-I, 2011), the TMCM HSU has been subdivided into smaller, more well-defined HSUs, including the RMWTA and the ATWTA.

Well ER-EC-14 is sited within a narrow canyon in the upper drainage of Rocket Wash. The canyon is carved in ash-flow tuffs of the Thirsty Canyon Group that were erupted between 9.3 and 9.4 Ma from the Black Mountain caldera (Slate et al., 1999) and flowed southeastward into the moat of the TMCC. The Black Mountain caldera is located approximately 4.8 km (3 mi) northwest of Well ER-EC-14. An east-dipping normal fault, informally referred to as the M2 fault, with only minor offset at the surface is located 112.8 m (370 ft) east of the well (Figure 5-1).

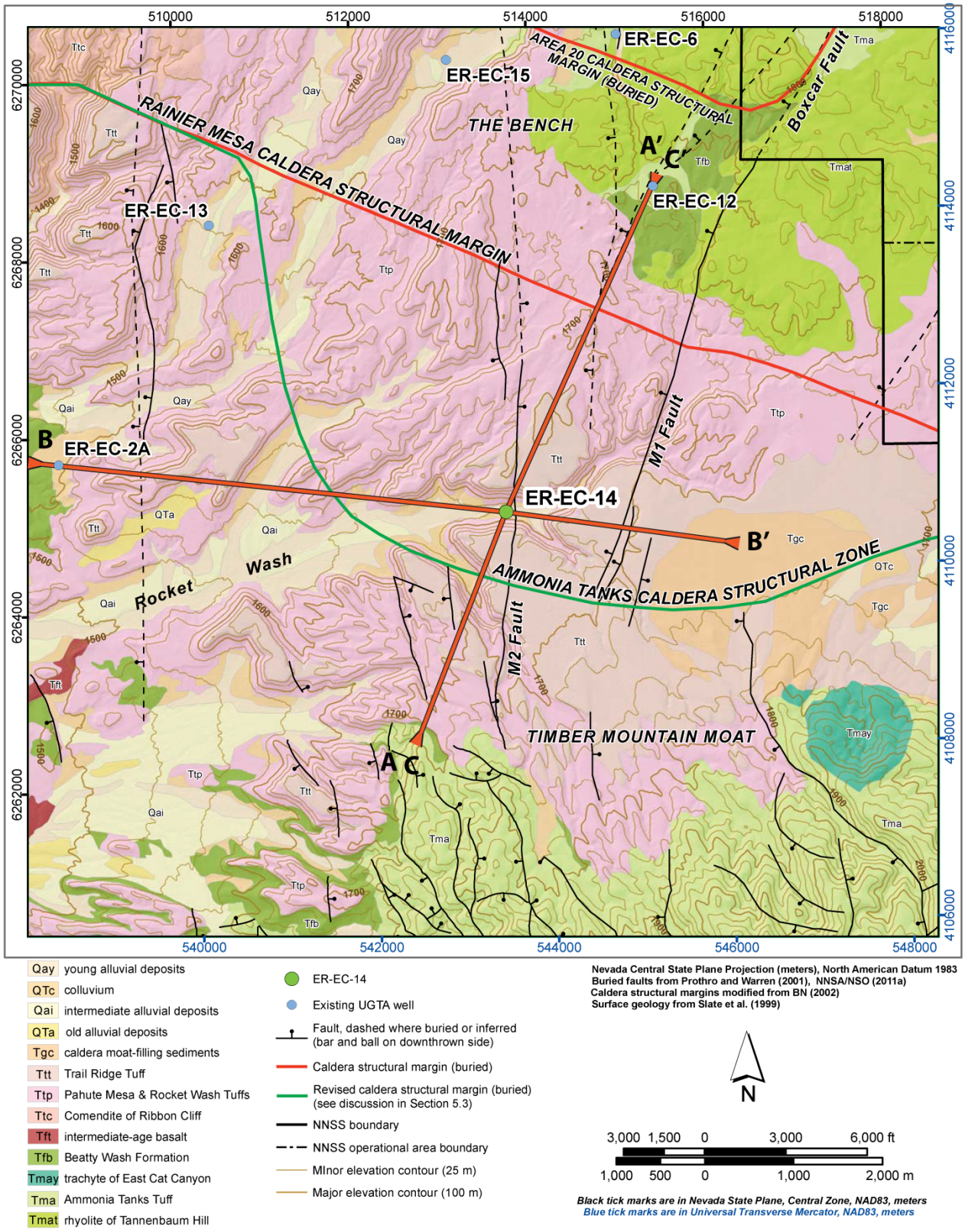


Figure 5-1
Surface Geologic Map of the Well ER-EC-14 Area

5.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Well ER-EC-14 are illustrated in Figure 5-2, and an interpretation of the distribution of stratigraphic units in the vicinity of the well is shown in cross section in Figures 5-3 and 5-4.

Drilling at Well ER-EC-14 began in alluvial deposits that floor the canyon in the vicinity of the well. Although no samples were collected during the drilling and casing of the conductor hole to a depth of 21.3 m (70 ft), the alluvial deposits are estimated to be 15.2 m (50 ft) thick, and are certainly less than 21.3 m (70 ft) thick at the well site because moderately-welded ash-flow tuff was encountered when drilling of the main-hole started at 21.3 m (70 ft). This ash-flow tuff is assigned to the Rocket Wash Tuff, a formation near the base of the Thirsty Canyon Group, which forms the lower walls of the canyon where Well ER-EC-14 is located. Below the surficial alluvium, the well penetrated approximately 42.7 m (140 ft) of Rocket Wash Tuff consisting, from top to bottom, of 24.4 m (80 ft) of moderately welded ash-flow tuff, 7.9 m (26 ft) of partially welded ash-flow tuff, and 10.4 m (34 ft) of bedded tuff. The assignment of Rocket Wash Tuff is based on surface mapping (Slate et al., 1999), lithologic character, and the absence of quartz phenocrysts and biotite. At the depth of 57.9 m (190 ft), the well encountered the top of a 6.7-m (22-ft) thick basalt assigned to basalt of Rocket Wash (Warren, 2013), which represents the base of the Thirsty Canyon Group in the borehole.

Below the Thirsty Canyon Group, Well ER-EC-14 encountered 53.0 m (174 ft) of mostly bedded tuffs of the rhyolite of Chukar Canyon, a unit within the Volcanics of Fortymile Canyon. The rocks are generally unaltered (i.e., vitric) above 77.1 m (253 ft), and mostly zeolitic below this depth, to the base of the unit at 117.7 m (386 ft). The stratigraphic assignment of rhyolite of Chukar Canyon is based on stratigraphic position directly beneath the Thirsty Canyon Group, the presence of biotite and sphene, and the petrographic analysis of a drill cuttings sample from a depth of 100.6 m (330 ft) (Warren, 2013).

An additional 108.8 m (357 ft) of Volcanics of Fortymile Canyon was encountered below the rhyolite of Chukar Canyon. This interval, which was penetrated from 117.7 to 226.5 m (386 to 743 ft), consists of zeolitic nonwelded and bedded tuffs that are assigned to the rhyolite of Beatty Wash based mainly on petrographic analyses of drill cuttings samples from two depths within the interval (Warren, 2013).

The nonwelded and bedded tuffs of the rhyolite of Beatty Wash in Well ER-EC-14 overlie 142.3 m (467 ft) of zeolitic to quartzo-feldspathic nonwelded tuff assigned to the rhyolite of Tannenbaum Hill, a formation of the Timber Mountain Group. The stratigraphic assignment is

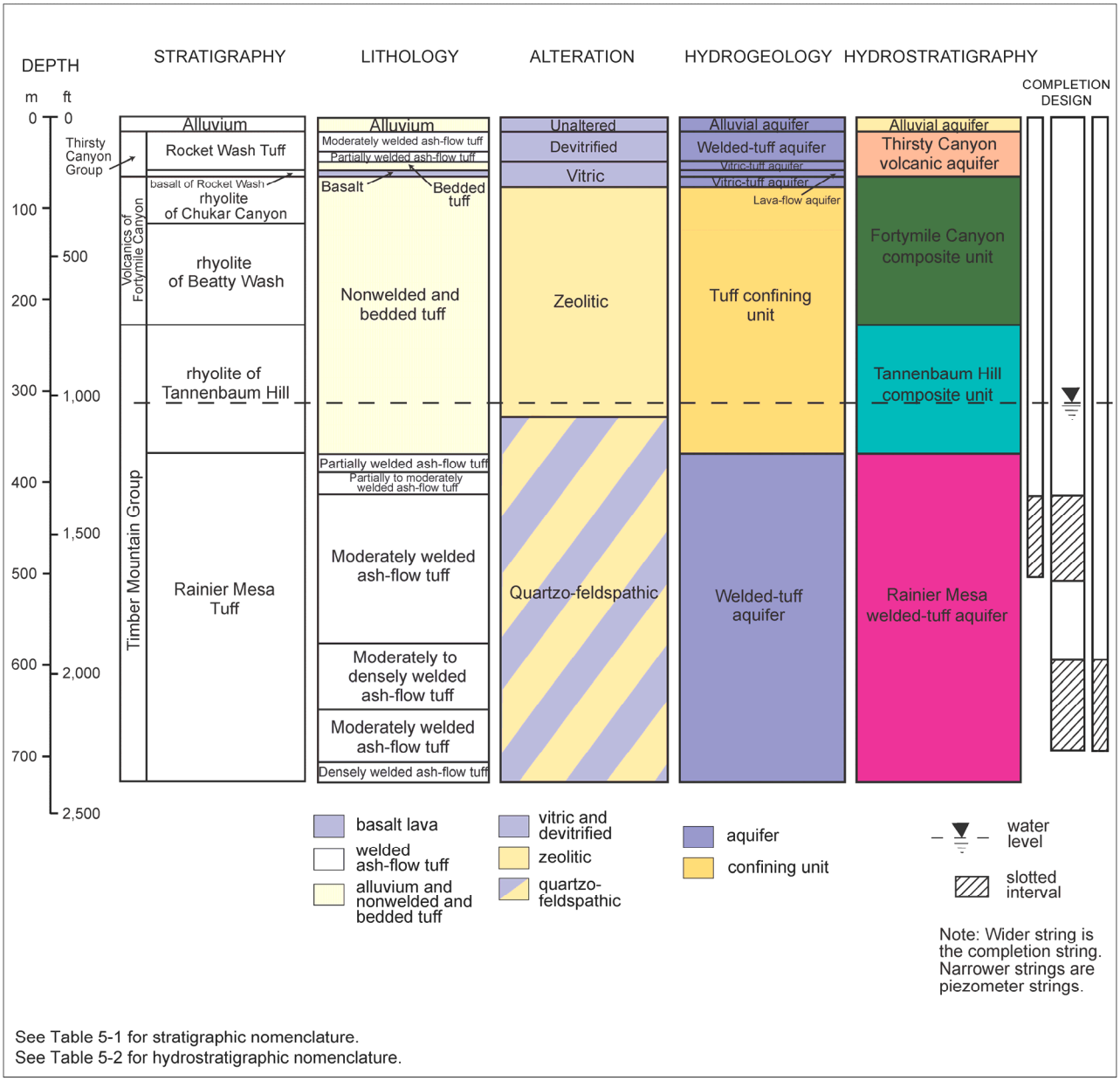


Figure 5-2
Graphical Presentation Showing Geology and Hydrogeology for Well ER-EC-14

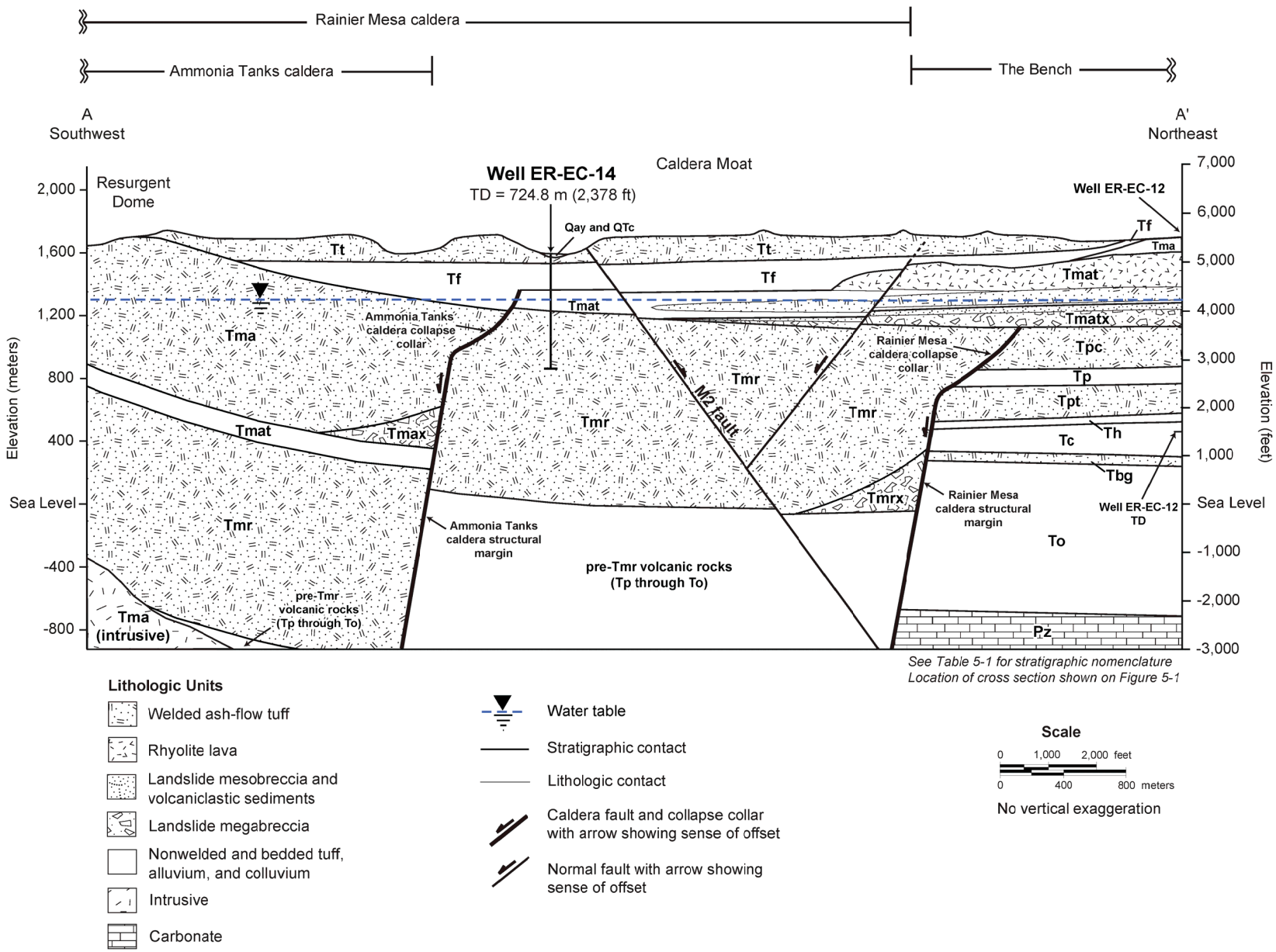


Figure 5-3
Southwest–Northeast Geologic Cross Section A–A' through Well ER-EC-14

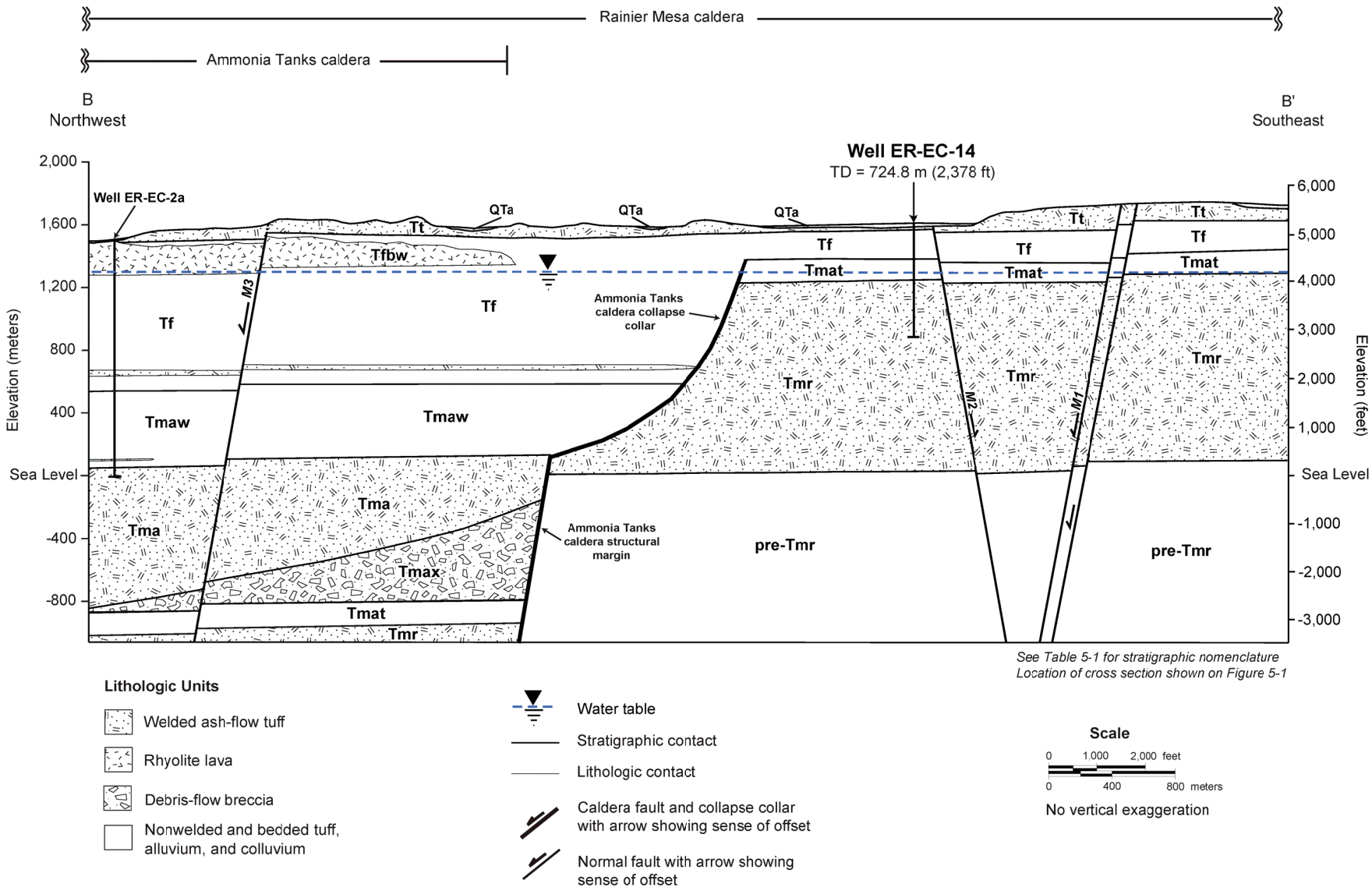


Figure 5-4
Northwest–Southeast Geologic Cross Section B–B' through Well ER-EC-14

based on petrographic analyses of drill cuttings samples from three depths within the interval (Warren, 2013). The presence of rhyolite of Tannenbaum Hill directly below rhyolite of Beatty Wash with no intervening Ammonia Tanks Tuff, clearly indicates that Well ER-EC-14 lies outside of the Ammonia Tanks caldera.

The top of a thick section of welded ash-flow tuff was encountered directly below the rhyolite of Tannenbaum Hill at a depth 368.8 m (1,210 ft), and this welded unit was penetrated until TD was reached at the depth of 724.8 m (2,378 ft). The entire interval is assigned to the mafic-rich member of the Rainier Mesa Tuff, also a formation of the Timber Mountain Group. The stratigraphic assignment is based on petrographic analyses of drill cuttings samples from eleven depths within the interval (Warren, 2013). The uppermost 43.0 m (141 ft) of the interval is partially welded, whereas the remaining 313.0 m (1,027 ft) is moderately to densely welded. The entire interval shows quartzo-feldspathic alteration as evidenced by corroded to completely pseudomorphic feldspar phenocrysts. The observation that the mafic-rich member of the Rainier Mesa Tuff is more than 356.0 m (1,168 ft) thick in Well ER-EC-14 strongly suggests that the well lies within the Rainier Mesa caldera.

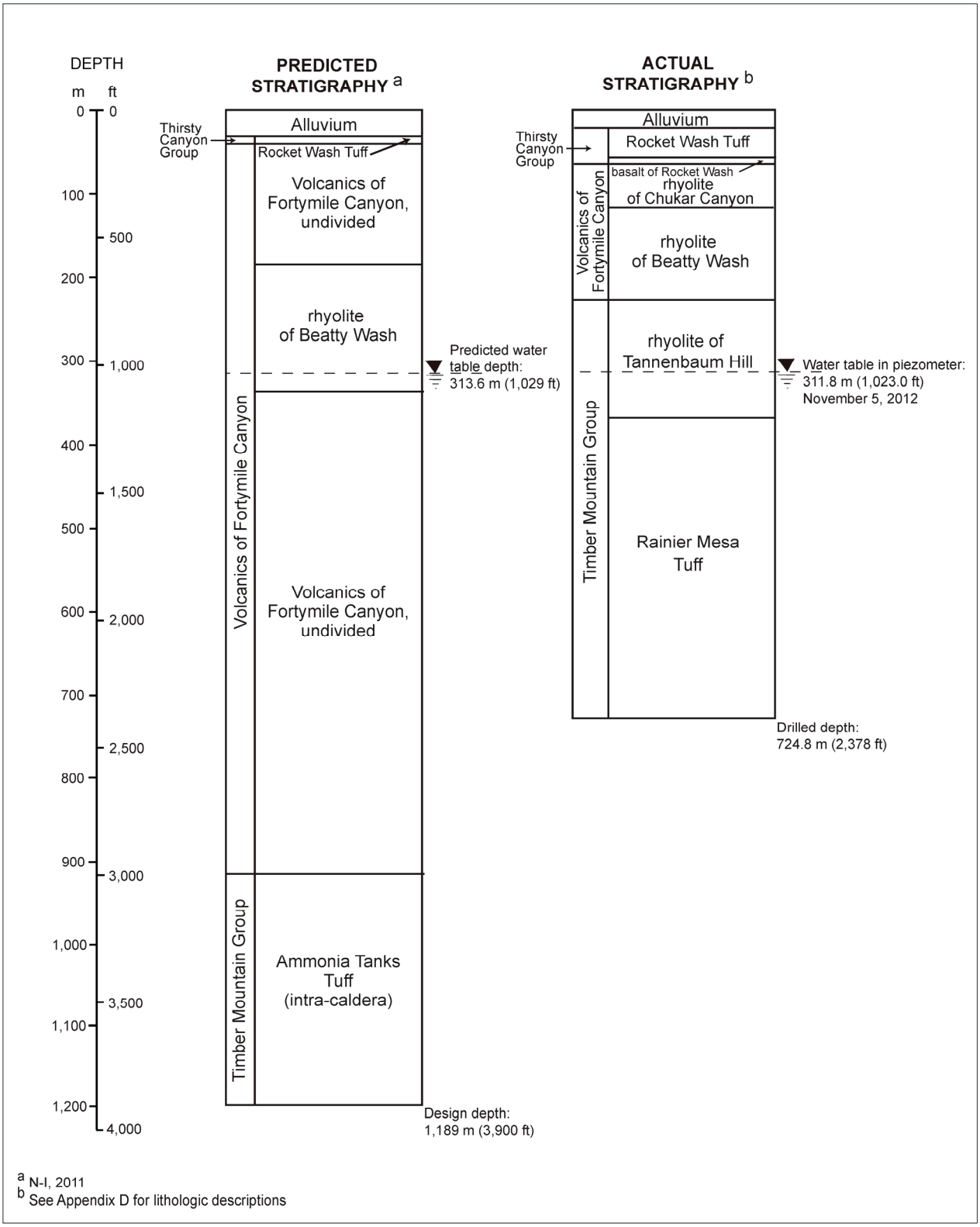
5.2.3 Alteration

The rocks encountered in Well ER-EC-14 show a general tendency of increasing alteration intensity with depth. Rocks are generally unaltered above 77.1 m (253 ft), where nonwelded and bedded tuffs retain their original vitric (i.e., glassy) character, and welded tuffs show typical devitrification. Below 77.1 m (253 ft), to the base of the rhyolite of Beatty Wash at 226.5 m (743 ft), nonwelded and bedded tuffs are mostly zeolitic. Zeolitization continues to be the dominant alteration mode through the upper portion of the underlying rhyolite of Tannenbaum Hill, to the depth of 326.1 m (1,070 ft). Below 326.1 m (1,070 ft), and to the TD of the well, quartzo-feldspathic alteration becomes the dominant alteration assemblage. Minor amounts of argillic alteration also occur throughout this section, particularly with the interval 389.8 to 435.9 m (1,279 to 1,430 ft).

5.3 Predicted and Actual Geology

The geology encountered at Well ER-EC-14 is significantly different than predicted prior to drilling of the well (Figure 5-5). The actual geology encountered in the well indicates that the differences are related to the well's position relative to the buried caldera margins of the TMCC.

Prior to drilling, the well location was thought to be within both the Rainier Mesa and Ammonia Tanks calderas, a structural position similar to that of Well ER-EC-2A (NNSA/NV, 2002) to the west and Exploratory Hole UE-18r (Ferguson et al., 1994) to the east. Consequently, it was



[a] N-I, 2011
[b] See Appendix D for lithologic descriptions

Figure 5-5
Predicted and Actual Stratigraphy at Well ER-EC-14

predicted that Well ER-EC-14 would encounter a geologic section somewhat similar to these holes, including a thick section of Volcanics of Fortymile Canyon overlying a very thick section of intra-caldera Ammonia Tanks Tuff. Drilling results, however, clearly indicate that Well ER-EC-14 is located outside of the Ammonia Tanks caldera based on the complete absence of Ammonia Tanks Tuff in the borehole. The well's position outside of the Ammonia Tanks caldera also explains the presence and high structural positions of the rhyolite of Tannenbaum Hill and Rainier Mesa Tuff relative to Well ER-EC-2A and Exploratory Hole UE-18r, as well as the much thinner occurrence of the overlying Volcanics of Fortymile Canyon. The thick section of Rainier Mesa Tuff encountered in Well ER-EC-14 strongly suggests that the well is inside the Rainier Mesa caldera, as predicted prior to drilling.

Figure 5-1 shows the revised location of the Ammonia Tanks caldera margin based on data from Well ER-EC-14. The revised interpretation of the TMCC boundaries will be incorporated into the planned update of the Phase I HFM (BN, 2002).

5.4 Hydrogeology

The saturated rocks in Well ER-EC-14 are classified hydrogeologically as tuff confining units and welded-tuff aquifers based on criteria set forth in BN (2002) and Prothro et al., (2009). The zeolitic and quartzo-feldspathic nonwelded and bedded tuffs that are saturated in the lower portion of the rhyolite of Tannenbaum Hill form a tuff confining unit. The underlying section of welded Rainier Mesa Tuff forms a thick welded-tuff aquifer. Incorporating stratigraphic information, these hydrogeologic units are assigned to the Tannenbaum Hill composite unit (THCM) and RMWTA HSUs, respectively. An interpretation of the distribution of HSUs in the vicinity of Well ER-EC-14 is provided in Figure 5-6. Note that since publication of the drilling and completion criteria for Well ER-EC-14 (N-I, 2011), the RMWTA has been split from the TMCM HSU. This change will be incorporated into the updated version of the Phase I HFM.

Prior to drilling, it was predicted that the water table in Well ER-EC-14 would be encountered at a depth of 313.6 m (1,029 ft), within a lava-flow aquifer of the Fortymile Canyon composite unit HSU (rhyolite of Beatty Wash stratigraphic unit). The actual water table depth, measured on November 15, 2012, in the shallow piezometer string, was 311.8 m (1,023.0 ft) and was within a tuff confining unit of the THCM HSU (rhyolite of Tannenbaum Hill stratigraphic unit).

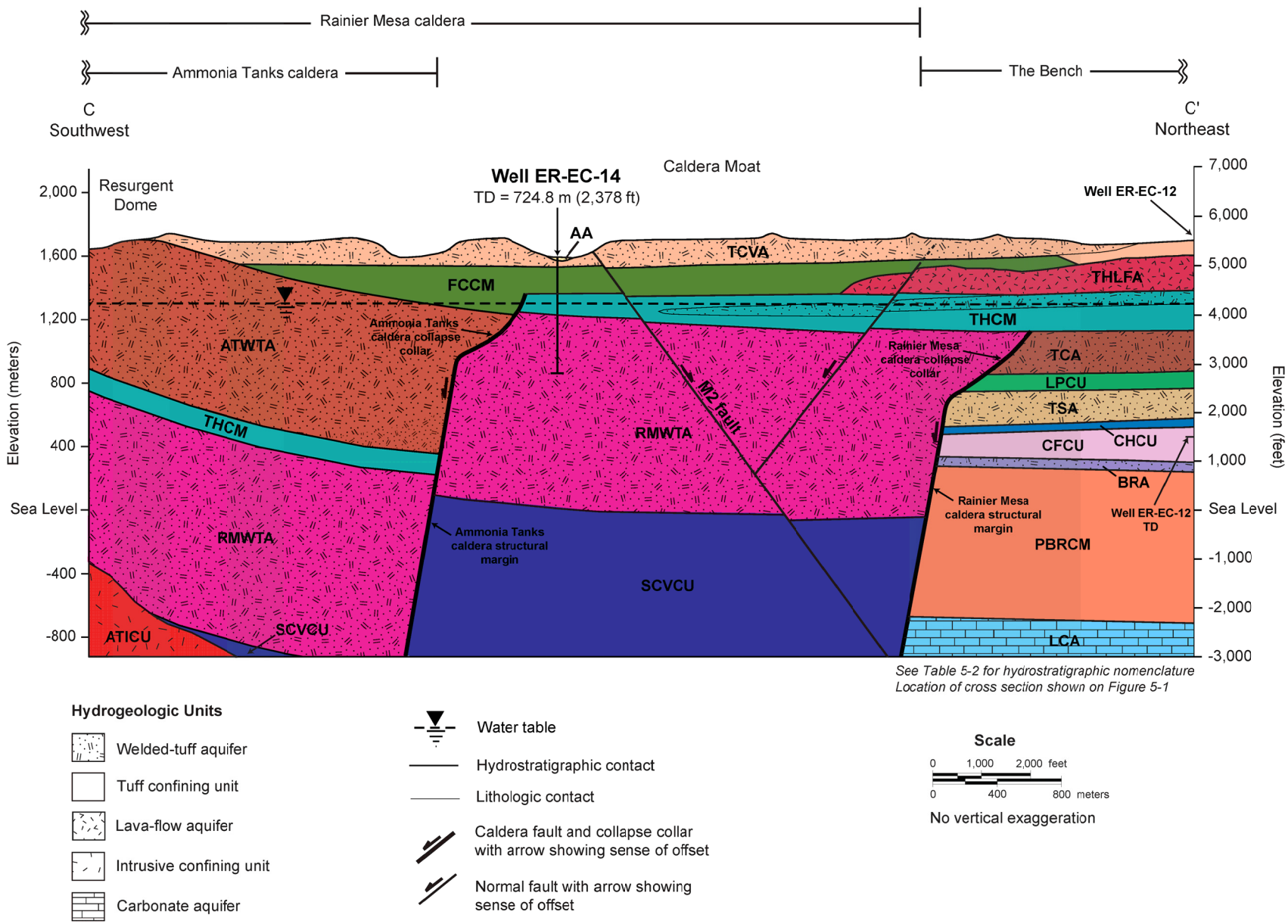


Figure 5-6
Southwest–Northeast Hydrostratigraphic Cross Section C–C' through Well ER-EC-14

6.0 Hydrology

Hydrologic data collected at the well site included water-level measurements, estimates of groundwater production rates during drilling, and borehole water quality measurements from discharged drilling fluids. The following sections summarize the well hydrology data obtained during drilling and well completion operations, as modified from N-I (2013). The saturated portion of Well ER-EC-14 consists of RMWTA along with a minor portion of the overlying THCM. An interpretation of the possible distribution of the HSUs in the vicinity of Well ER-EC-14 is shown in Figure 5-6.

6.1 Water Levels

Prior to drilling, the water level at Well ER-EC-14 was estimated to be near the bottom of the rhyolite of Beatty Wash, within the FCCM, at a depth of 313.6 m (1,029 ft) below ground surface (N-I, 2011). During the two episodes of geophysical logging, Baker Atlas recorded fluid levels on several geophysical logs at approximately 311.2 m (1,021 ft) below ground surface within the rhyolite of Tannenbaum Hill. N-I personnel measured the water level in both the shallow and deep piezometer strings on November 5, 2012, prior to installation of pressure transducers and well development operations. The fluid level within the shallow piezometer was measured at 311.8 m (1,023.0 ft), and the fluid level within the deep piezometer was measured at 311.9 m (1,023.2 ft) below ground surface. Fluid level measurements made in the borehole are summarized in Table 6-1.

The fluid levels presented here should be considered preliminary, and may not represent a discrete, equilibrated groundwater level. Well development and hydrologic testing at Well ER-EC-14, which will provide more accurate water level data, are planned to take place later in 2013.

6.2 Water Production

Water production was estimated during drilling of Well ER-EC-14 on the basis of dilution of a lithium bromide tracer, as measured at the rig site by N-I field personnel. The tracer was added to drilling fluids before being injected down-hole. Concentrations of bromide in mixing tanks and in discharged fluids were monitored regularly as drilling progressed. Differences between injected and discharged bromide concentrations were used to calculate groundwater production rates. However, while this method is fairly good for relatively low water production (less than about 757 Lpm [200 gpm]), it is subject to several variables and conditions. More accurate water production estimates are possible when other information, such as visual estimates of water production at the flow line and water level in the sump, is incorporated. When appropriate,

Table 6-1
Well ER-EC-14 Water Level Measurements

Date Time	Fluid Depth [a]		Fluid Elevation [b]		Notes
	meters	feet	meters	feet	
10/03/2012 09:30	311.2	1,021	1,269.5	4,164.9	Estimated fluid level reported by Baker Atlas on the temperature log.
10/03/2012 12:00	311.2	1,021	1,269.5	4,164.9	Estimated fluid level reported by Baker Atlas on the HDIL/SP log.
10/03/2012 19:30	311.2	1,021	1,269.5	4,164.9	Estimated fluid level reported by Baker Atlas on the ZDL/CN log.
10/11/2012 11:30	311.2	1,021	1,269.5	4,164.9	Estimated fluid level reported by Baker Atlas on the temperature log.
10/11/2012 18:30	311.2	1,021	1,269.5	4,164.9	Estimated fluid level reported by Baker Atlas on the R_t Explorer log.
10/11/2012 21:30	311.2	1,021	1,269.5	4,164.9	Estimated fluid level reported by Baker Atlas on the ZDL/CN log.
10/18/2012 14:15	311.8	1,022.9	1,268.9	4,163.0	Fluid level measured by N-I within the main completion casing using a calibrated Solinst e-tape.
10/18/2012 14:45	311.8	1,022.9	1,268.9	4,163.0	Fluid level measured by N-I within the deep piezometer tubing using a calibrated Solinst e-tape.
10/18/2012 15:10	311.8	1,023.0	1,268.9	4,162.9	Fluid level measured by N-I within the shallow piezometer tubing using a calibrated Solinst e-tape.
11/05/2012 10:50	311.8	1,023.0	1,268.9	4,162.9	Fluid level measured by N-I within the shallow piezometer tubing using a calibrated Solinst e-tape.
11/05/2012 12:50	311.9	1,023.2	1,268.8	4,162.7	Fluid level measured by N-I within the deep piezometer tubing using a calibrated Solinst e-tape.

Data from N-I (2013)

a Depths are below ground surface elevation.

b Ground surface used as reference datum. Ground surface elevation was surveyed by NSTec on January 17, 2013, at 1,580.7 m (5,185.9 ft) above mean sea level.

Notes:

HDIL/SP log = high-definition induction/ spontaneous potential log

ZDL/CN log = compensated Z-Density/compensated neutron log

visual estimates of water production were used to improve upon production rates calculated from bromide tracer data, and these modified rates are shown in the drilling parameters plot in Appendix A-1. Table F-1 in Appendix F presents the bromide tracer results and calculated water production rates from Well ER-20-11, with no modifications based on visual estimates. Table F-2 presents estimated water production rates incorporating visual data, as plotted in Appendix A-1.

The first observation of water in returns was reported on October 1, 2012, at the approximate depth of 315.8 m (1,036 ft). Based on bromide dilution calculations and visual observations, estimated water production ranged from 11.4 to 18.9 Lpm (3 to 5 gpm) while drilling the rhyolite of Tannenbaum Hill. Estimated water production rates increased from 18.9 to 567.8 Lpm (5 to 150 gpm) as the hole was deepened to 454.2 m (1,490 ft) and penetrated the welded Rainier Mesa Tuff. Below the depth of approximately 454.2 (1,490 ft) to TD at 724.8 m (2,378 ft), while drilling the Rainier Mesa Tuff, the estimated water production gradually increased from 567.8 to 3,028.3 Lpm (150 to 800 gpm).

See Appendix F for a list of bromide tracer injection concentrations and corresponding estimated water production rates. A plot of estimated water production rates is shown with drilling parameters and borehole stratigraphy in Appendix A-1. More representative water production data will be available after hydraulic testing is conducted following development of the well.

6.3 Groundwater Chemistry

N-I monitored discharged drilling fluids during borehole advancement for pH, temperature, and electrical conductivity and used these data to evaluate changes in groundwater conditions during drilling. Water-quality measurements were affected by cement and the use of drilling foam and polymer during drilling operations, and do not accurately reflect natural groundwater quality; however, they may be reflective of changed conditions within the borehole during drilling.

N-I site personnel collected a set of depth-discrete bailer samples at the depth of 453.5 m (1,488 ft) within the open borehole on October 12, 2012, before the installation of the well completion casing. The samples were collected using a wireline-deployed depth-discrete stainless-steel bailer, with a capacity of 6 liters (1.6 gal). The purpose of the samples was to provide initial groundwater chemistry data based on select groundwater characterization parameters as identified in the UGTA Quality Assurance Project Plan (NNSA/NSO, 2011d). The bailer and associated sampling equipment were decontaminated according to appropriate procedures before sample collection. The groundwater characterization samples were sent to an outside laboratory for analysis, and the analytical results are presented in Appendix B-1, Table B-1-2.

6.4 Radionuclides Encountered

N-I site personnel collected discharged drilling fluid samples hourly during borehole advancement. The samples were analyzed on site for tritium by NSTec RCTs for purposes of fluid management and worker protection, as described in Section 3.1.2. Onsite analyses for tritium were performed using LSCs. The average MDA for the LSCs was approximately 1,500 pCi/L. All tritium results were below the limit of 20,000 pCi/L established in the National Primary Drinking Water Regulations (CFR, 2012a). Results from drilling fluid returns from both the unsaturated and saturated zone ranged from 0 to 1,623 pCi/L, all below the MDA for the individual analyses. The tritium analyses results are discussed in more detail in Section 3.1.2; the tritium monitoring results, including onsite re-analyses, are presented in Appendix B-1, Table B-1-1.

An onsite tritium analysis was also performed on the depth-discrete bailer sample collected at the depth of 453.5 m (1,488 ft), and the result was below the MDA. Analyses for other radionuclides were performed by an offsite laboratory, and the results are presented in Table B-1-2 in Appendix B-1. Gross alpha and gross beta were the only radionuclides reported above the minimum detection limits and are attributed to natural background due to the geologic medium.

7.0 Precompletion and Open-Hole Development

Initial well development conducted in Well ER-EC-14 consisted of using the drill string to air-lift groundwater to remove residual cuttings and drilling fluids from the borehole for a period of 30 minutes immediately after the TD was reached.

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8.0 Well Completion

8.1 Introduction

Well completion refers to the installation in a borehole of a string of tubing or casing that is slotted or screened at one or more locations along its length. The completion process also typically includes emplacement of backfill materials around the string, 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 serves as a conduit for inserting a pump in the well, for inserting devices for measuring fluid level, and for sampling, so that accurate potentiometric and water chemistry data can be collected from known portions of the borehole.

The proposed design for Well ER-EC-14 was presented in *Addendum #2 to the Central and Western Pahute Mesa Phase II Hydrogeologic Investigation Wells Drilling and Completion Criteria for Investigation Wells ER-EC-14 and ER-20-11* (N-I, 2011). The proposed completion plans are summarized in Section 8.2.1 of this report, and the actual well completion design, based on the hydrogeology encountered in the borehole, is presented in Section 8.2.2. The rationale for differences between the planned and actual design is discussed in Section 8.2.3, and the completion methods are presented in Section 8.3. Figure 8-1 is a schematic diagram of the well completion design. Figure 8-2 shows a plan view and profile of the final wellhead surface completion. Figure 8-3 is a photograph showing the ER-EC-14 wellhead at the surface. Table 8-1 is a construction summary for the completion and piezometer strings.

8.2 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.

8.2.1 Proposed Completion Design

The original proposed well completion design (N-I, 2011) was based on the assumption that Well ER-EC-14 would penetrate the water table within the Volcanics of Fortymile Canyon that form a confining unit within the FCCM, or possibly the rhyolite of Beatty Wash, a lava-flow aquifer within the FCCM, if present, and reach a TD within the Ammonia Tanks Tuff, a welded-tuff aquifer within the TMCM. The primary goal of the proposed completion design was to provide groundwater production data from the TMCM and FCCM, and to provide access to groundwater for monitoring and sampling. A 30-in. surface casing string was intended to extend to the depth of approximately 313.6 m (1,029 ft) to stabilize and isolate the unsaturated zone from the underlying saturated rocks.

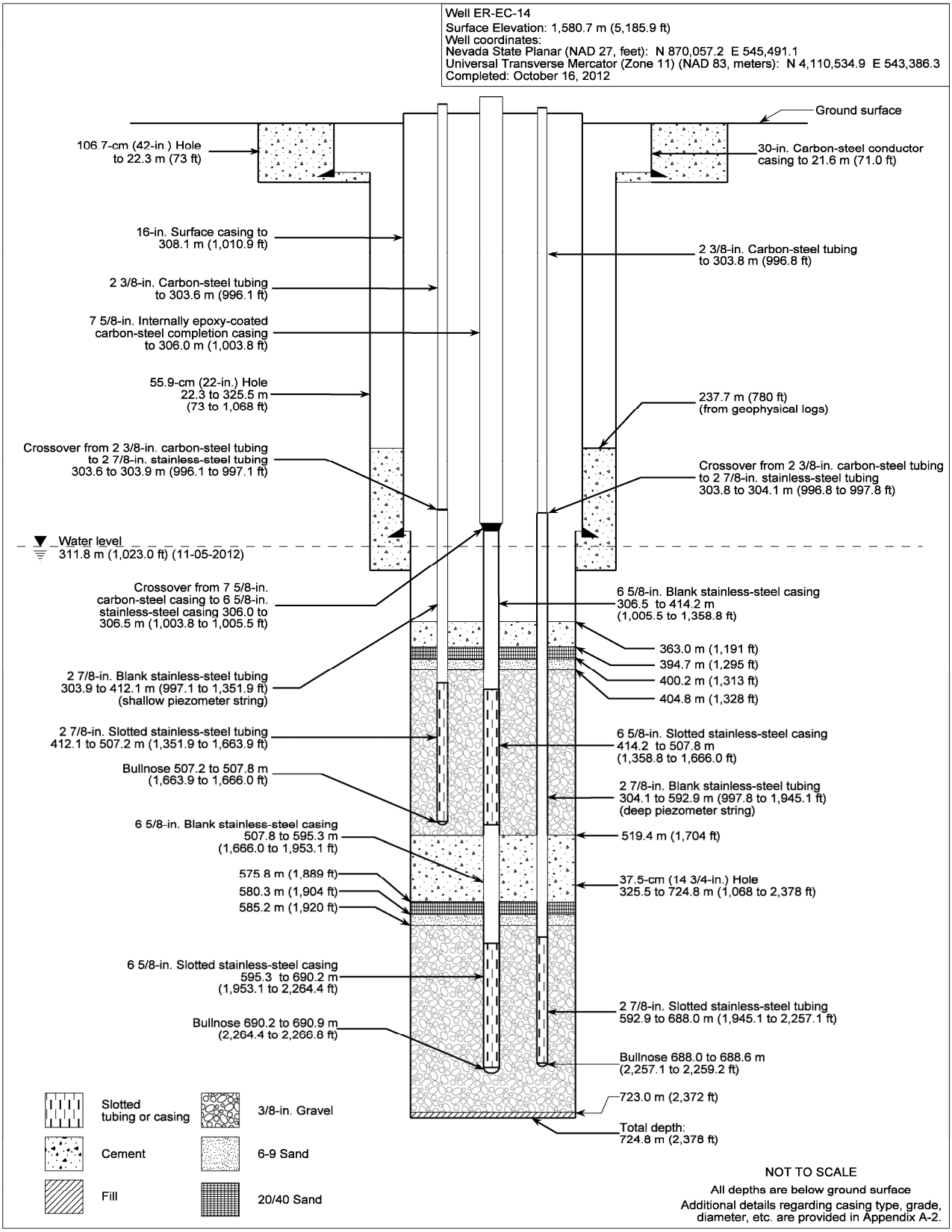
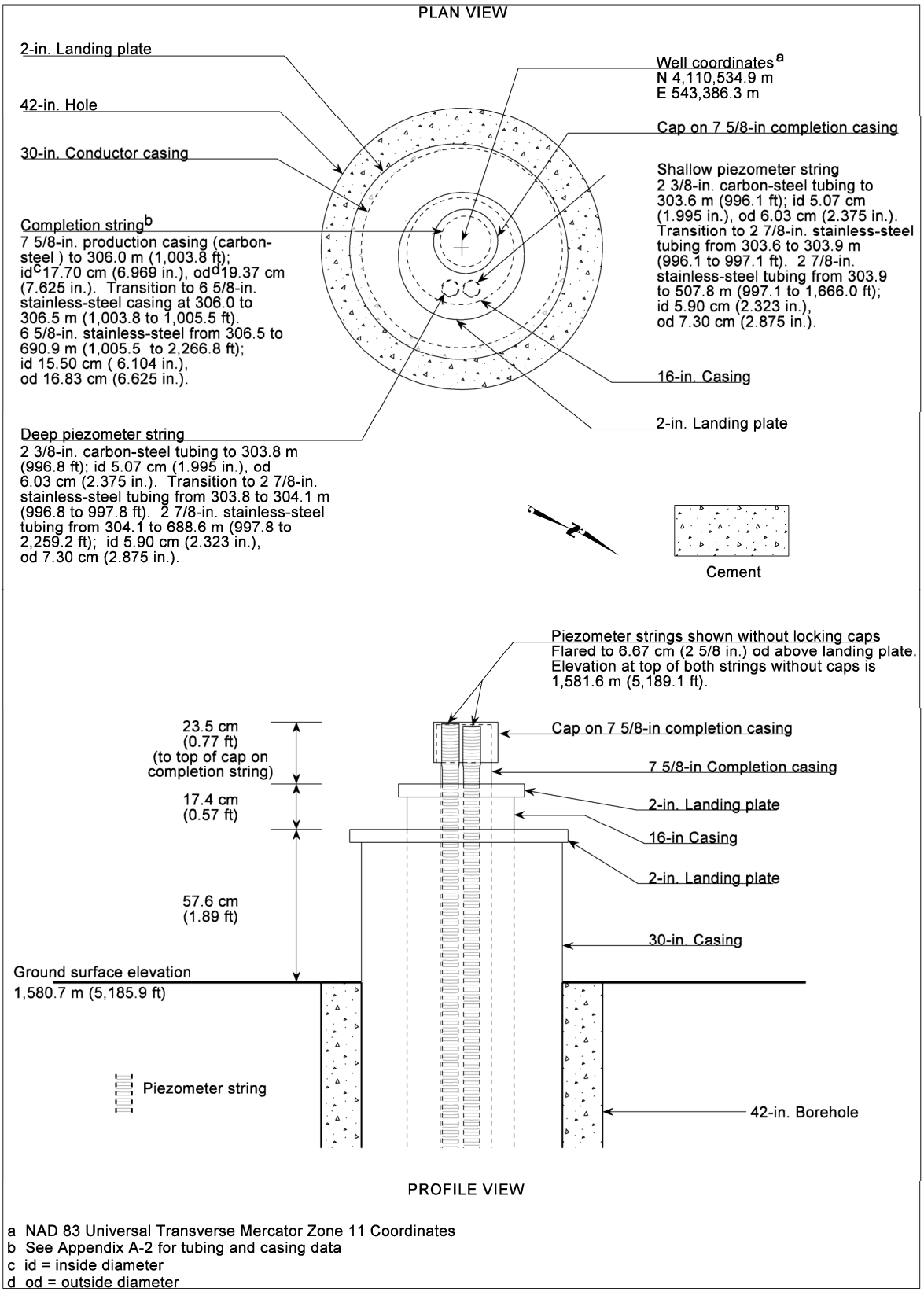
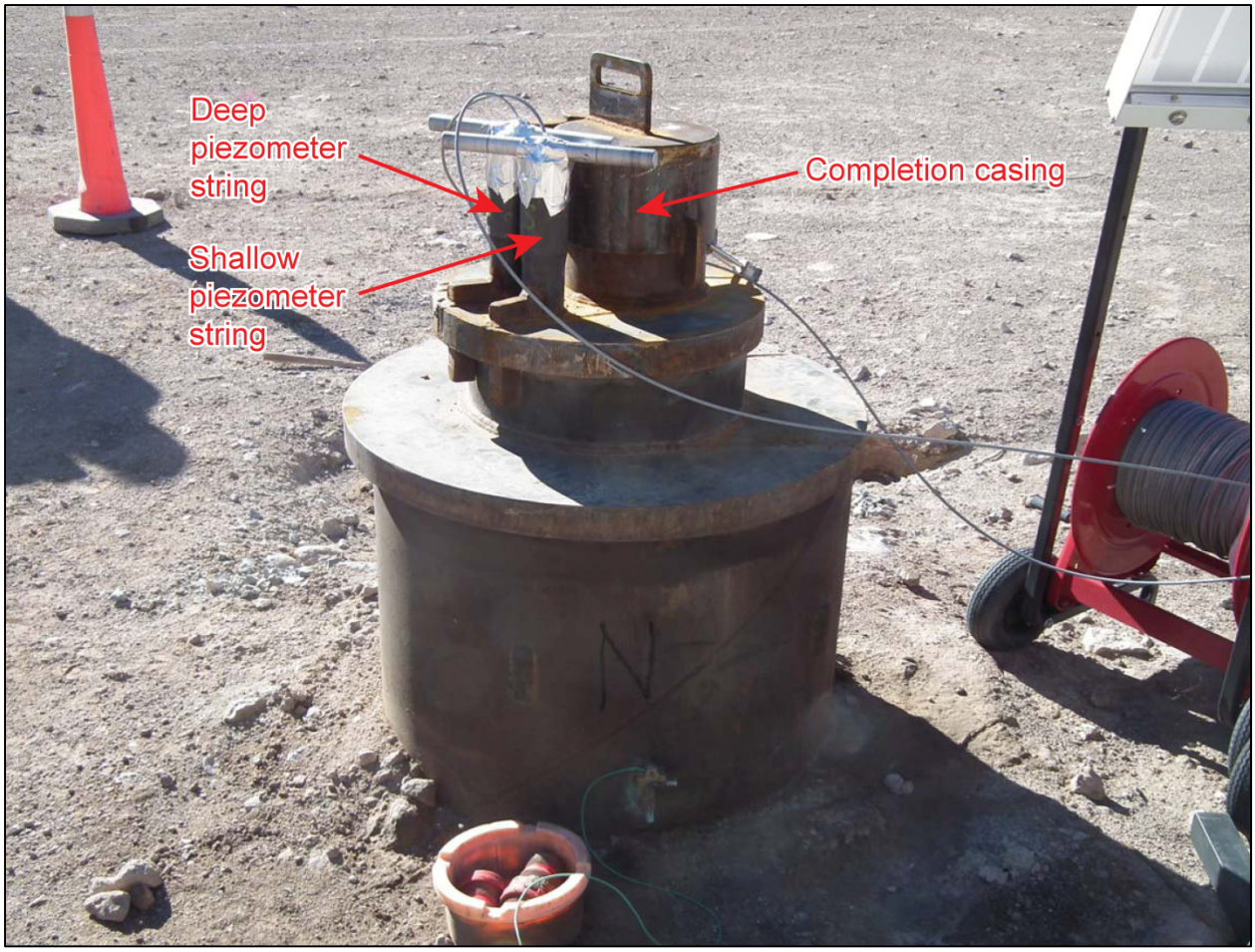


Figure 8-1
As-Built Completion Schematic for Well ER-EC-14



a NAD 83 Universal Transverse Mercator Zone 11 Coordinates
b See Appendix A-2 for tubing and casing data
c id = inside diameter
d od = outside diameter

Figure 8-2
Wellhead Diagram for Well ER-EC-14



Photograph by NSTec, January 30, 2013

Figure 8-3
Photograph of the ER-EC-14 Wellhead

On the basis of these expectations, Well ER-EC-14 was planned to be completed with a string of 6⅝-in. completion casing extending through the TMCM and FCCM in the 37.5-cm (14.75-in.) borehole. The completion casing was to be slotted and gravel packed at up to three intervals, with two zones of approximately 91.4 m (300 ft) each be developed within the Ammonia Tanks Tuff welded-tuff aquifer. It was proposed that the third interval may be developed in the Beatty Wash Formation tuff confining unit, assuming a productive interval could be identified based on drilling and geophysical logging. The completion string was to consist of epoxy-coated carbon-steel casing to within 9.1 m (30 ft) above the water table and stainless-steel casing below the water table. If an intermediate casing string was necessary due to excessive water production or sloughing, subsequent borehole and casing size may be reduced, resulting in compromises to the proposed well design.

Table 8-1
Well ER-EC-14 Completion String Summary (page 1 of 2)

String	Casing and Tubing	Configuration meters (feet)	Cement meters (feet)	Cement [a] meters (feet)	Sand/Gravel meters (feet)
Shallow Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 303.9 (0 to 997.1)	Blank	None	None
	2⅞-in. stainless-steel tubing	303.9 to 412.1 (997.1 to 1,351.9)	Blank	Type II Neat Cement 363.0 to 396.7 (1,191 to 1,295)	**20/40 Sand** 394.7 to 400.2 (1,295 to 1,133) **6-9 Sand** 400.2 to 404.8 (1,313 to 1,328)
	2⅞-in. stainless-steel tubing	412.1 to 507.2 (1,351.9 to 1,663.9)	Slotted [b]	None	**⅜-in. Washed Gravel** 404.8 to 519.4 (1,328 to 1,704)
	2⅞-in. stainless-steel tubing	507.2 to 507.8 (1,663.9 to 1,666.0)	Blank and bullnosed		
Deep Piezometer String	2⅜-in. carbon-steel tubing with crossover sub	0 to 304.1 (0 to 997.8)	Blank	None	None
	2⅞-in. stainless-steel tubing	304.1 to 592.9 (997.8 to 1,945.1)	Blank	Type II Neat Cement 519.4 to 575.8 (1,704 to 1,889)	**20/40 Sand** 575.8 to 580.3 (1,889 to 1,904) **6-9 Sand** 580.3 to 585.2 (1,904 to 1,920)
	2⅞-in. stainless-steel tubing	592.9 to 688.0 (1,945.1 to 2,257.1)	Slotted [b]	None	**⅜-in. Washed Gravel** 585.2 to 723.0 (1,920 to 2,372)
	2⅞-in. stainless-steel tubing	688.0 to 688.6 (2,257.1 to 2,259.2)	Blank and bullnosed		

Table 8-1
Well ER-EC-14 Completion String Summary (page 2 of 2)

String	Casing and Tubing	Configuration meters (feet)	Cement meters (feet)	Cement [a] meters (feet)	Sand/Gravel meters (feet)
Completion Casing	7⅝-in. epoxy-coated carbon-steel production casing with crossover sub	0 to 306.5 (0 to 1,005.5)	Blank	None	None
	6⅝-in. stainless-steel production casing	306.5 to 414.2 (1,005.5 to 1,358.8)	Blank	Same as for shallow piezometer string	Same as for shallow piezometer string
	6⅝-in. stainless-steel production casing	414.2 to 507.8 (1,358.8 to 1,666.0)	Slotted [c]	None	Same as for shallow piezometer string
	6⅝-in. stainless-steel production casing	507.8 to 595.3 (1,666.0 to 1,953.1)	Blank	Same as for deep piezometer string	Same as for deep piezometer string
	6⅝-in. stainless-steel production casing	595.3 to 690.2 (1,953.1 to 2,264.4)	Slotted [c]	None	
	6⅝-in. stainless-steel production casing	690.2 to 690.9 (2,264.4 to 2,266.8)	Blank and bullnosed		

Note: A removable bridge was installed within the completion casing at 541.3 m (1,776 ft) by Baker Atlas on October 24, 2012 to isolate the two completion zones from each other.

a See Appendix A-3 for cement composition.

b Vertical slots in each joint are 0.159 cm (0.0625 in.) wide and 5.4 cm (2.125 in.) long, arranged in 68 rows, on 7.62-cm (3.0-in.) centers. The 8 slots per row are positioned radially around the tubing at 45 degrees. Each row is offset by 22.5 degrees from the next.

c Vertical slots in each joint are 0.159 cm (0.0625 in.) wide and 7.0 cm (2.75 in.) long, arranged in 66 rows, on 7.62-cm (3.0-in.) centers. The 12 slots per row are positioned radially around the casing at 30 degrees. Each row is offset by 15 degrees from the next.

Up to 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 in the TMCM and FCCM. 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 main completion string. The tubing strings were to be separated by the same cement isolation intervals as in the completion string.

8.2.2 As-Built Completion Design

The final Well ER-EC-14 completion design was determined by the UGTA Well ER-EC-14 Drilling Advisory Team after the TD of 724.8 m (2,378) was reached. The team modified the initial completion plan on the basis of onsite evaluation of data such as lithology, water production, water level, borehole condition, drilling data, and data from geophysical logs. The new plan required two completion zones, both within the RMWTA. The upper completion zone was positioned within the interval where the first dramatic increase in water production began. The lower zone encompasses the zone where a significant increase in water production was noted, and includes the interval where the maximum water production was measured. Both intervals also coincide with slight changes in the water temperature (which could indicate inflow or outflow of water from the borehole). The option to install a full completion in the FCCM was not used because no aquifer units are present in that interval.

The main completion string consists of a string of 6⅝-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing and was set at the depth of 690.9 m (2,266.8 ft). The 7⅝-in. internally epoxy-coated carbon-steel casing and crossover sub extends from the surface to the depth of 306.5 m (1,005.5 ft), which is about 5.5 m (18 ft) above the water table. The stainless-steel 6⅝-in. casing is slotted in two separate zones. The upper zone is slotted in the interval 414.2 to 507.8 m (1,358.8 to 1,666.0 ft), and the bottom zone is slotted in the interval 595.3 to 690.2 m (1,953.1 to 2,264.4 ft). Both zones are open to the RMWTA. The upper slotted section consists of 15 slotted joints, and the lower slotted section consists of 15 slotted joints, and the two slotted sections are separated by 87.5 m (287.1 ft) of blank casing. The completion string was terminated with a 0.74 m (2.42 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 7.0 cm (2.75 in.) long. The vertical slots in each joint are arranged in 66 rows on 7.62-cm (3.0-in.) centers. The 12 slots per row are positioned radially around the casing at 30 degrees. Each row is offset by 15 degrees from the next. The two slotted sections of the casing string are gravel packed. Cement isolation intervals separate the two completion zones.

Photograph by N-I, October 13, 2012

Figure 8-4
Photograph of Slotted Tubing for Well ER-EC-14

Two 2⅞-in. piezometer strings were installed in Well ER-EC-14. 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 507.8 m (1,666.0 ft), and is slotted from 412.1 to 507.2 m (1,351.9 to 1,663.9 ft). The deep piezometer string was landed at 688.6 m (2,259.2 ft), and is slotted from 592.9 to 688.0 m (1,945.1 to 2,257.1 ft). Both slotted piezometer intervals consist of 15 slotted joints. The openings in the slotted tubing joints are 0.159 cm (0.0625 in.) wide and 5.4 cm (2.125 in.) long. The vertical slots in each joint are arranged in 68 rows, on 7.62-cm (3.0-in.) centers. The 8 slots per row are positioned radially around the tubing at 45 degrees. Each row is offset by 22.5 degrees from the next. The slotted sections of the 2⅞-in. tubing strings were gravel packed and separated by cement. Figure 8-4 illustrates the arrangement of slots on the piezometer tubing installed in Well ER-EC-14.

On October 24, 2012, a removable bridge plug was installed at 541.3 m (1,776 ft) between the two slotted intervals in the 6⅝-in. completion string to isolate the two completion zones from each other.

8.2.3 Rationale for Differences between Planned and Actual Well Design

The original completion design was based largely on geologic information from nearby UGTA Wells ER-EC-2a and ER-EC-13 (NNSA/NV, 2002; NNSA/NSO, 2011b) and Exploratory Hole UE-18r (Ferguson et al., 1994), as presented in Appendix F of the criteria (N-I, 2011). Because deep subsurface data was scarce in the vicinity of proposed Well ER-EC-14, the subsurface geology predicted for the lowermost portion of the hole was somewhat speculative.

It was predicted that at least one thick lava flow, the rhyolite of Beatty Wash, could be penetrated in the unsaturated zone, within the Volcanics of Fortymile Canyon. Below this zone, it was predicted that the borehole would penetrate welded Ammonia Tanks Tuff.

As discussed in Section 5.3, the geology of Well ER-EC-14 was as expected to the depth of 368.8 m (1,210 ft), where the borehole penetrated welded Rainier Mesa Tuff. The Well ER-EC-14 Drilling Advisory Team decided to modify the completion design to include two completion zones within the RMWTA shortly after geophysical logging operations were completed. The decision was based on formation characteristics as discerned from examination of drill cuttings and geophysical logs, and the incremental increases in water production as recorded during drilling (Appendix A-1).

8.3 Well Completion Method

Completion activities began on October 13, 2012, after geophysical logging was completed. The drill crew ran the two 2⅞-in. piezometer strings and 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 subcontractor then inserted the main completion string, landing it at 690.9 m (2,266.8 ft) on October 14, 2012. Colog, Inc. ran a background nuclear annular investigation log (NAIL) tool in the 7⅝-in. and 6⅝-in. completion string prior to placement of stemming materials, and monitored the rise of stemming materials with the NAIL tool.

The two completion zones were gravel packed and isolated from each other with sand and cement barriers. First, a layer of ⅜-in. washed gravel 137.8 m (452 ft) thick was emplaced on top of fill at 723.0 m (2,372 ft) to surround the deep slotted interval. Then a 4.9 m (16 ft) layer of 6-9 coarse silica sand and a 4.6 m (15 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 519.4 to 575.8 m (1,704 to 1,889 ft). Next, a layer of ⅜-in. washed gravel 114.6 m (376 ft) thick was emplaced around the upper completion zone. A 4.6 m (15 ft) layer of 6-9 coarse silica sand and a 5.5 m (18 ft) layer of fine silica sand were placed above the gravel that surrounds the upper completion zone, and a section of Type II neat cement was placed on the sand layers from 394.7 to 363.0 m (1,295 to 1,191 ft). The borehole is open from the top of cement to the surface (see Figure 8-1).

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.

After stemming was completed on October 16, 2012, the tremie 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 immediate after completion.

9.0 Planned and Actual Costs and Scheduling

This section provides brief discussions of the planned and actual schedule and costs for constructing Well ER-EC-14.

The original NSTec-approved baseline work package cost estimate for drilling and completing Well ER-EC-14 was based on drilling to a planned TD of 1,036.3 m (3,400 ft) and installing one production casing string and up to three piezometer strings. This estimate was submitted before the drilling criteria document (N-I, 2011) was issued with an updated planned TD of 1,188.7 m (3,900 ft). In the baseline estimate, a 29-day schedule for constructing a 1,036.3-m (3,400-ft) deep well was used.

The well was drilled 311.5 m (1,022 ft) shallower than originally planned, to a TD of 724.8 m (2,378 ft), and 463.9 m (1,522 ft) shallower than specified in the drilling criteria (N-I, 2011). A single completion casing string with two slotted intervals, and two piezometer strings were installed. It took 20 days to construct Well ER-EC-14, starting with the drilling of the 55.9-cm (22-in.) surface hole. Few drilling problems were encountered, so the surface hole took 2 days fewer to drill than planned, and the main hole took 6 days fewer than planned.

The cost analysis for Well ER-EC-14 begins with the mobilization of the UDI drill rig to the drill site, where the conductor hole had already been constructed. The total construction cost for Well ER-EC-14 includes all drilling costs: charges by the drilling subcontractor, charges by other support subcontractors (including compressor services, drilling fluids, casing services, down-hole tools, and geophysical logging), and charges by NSTec for mobilization and demobilization of equipment, cementing services, RCT services, inspection services, site supervision, and geotechnical consultation. The cost of building the 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-14 with a planned TD of 1,036.3 m (3,400 ft) was $4,579,730. The actual cost for constructing the well with the TD of 724.8 m (2,378 ft) was $4,677,378, or 2.1 percent more than the estimated cost. Figure 9-2 presents a comparison of the planned and actual costs, by day, for construction of Well ER-EC-14.

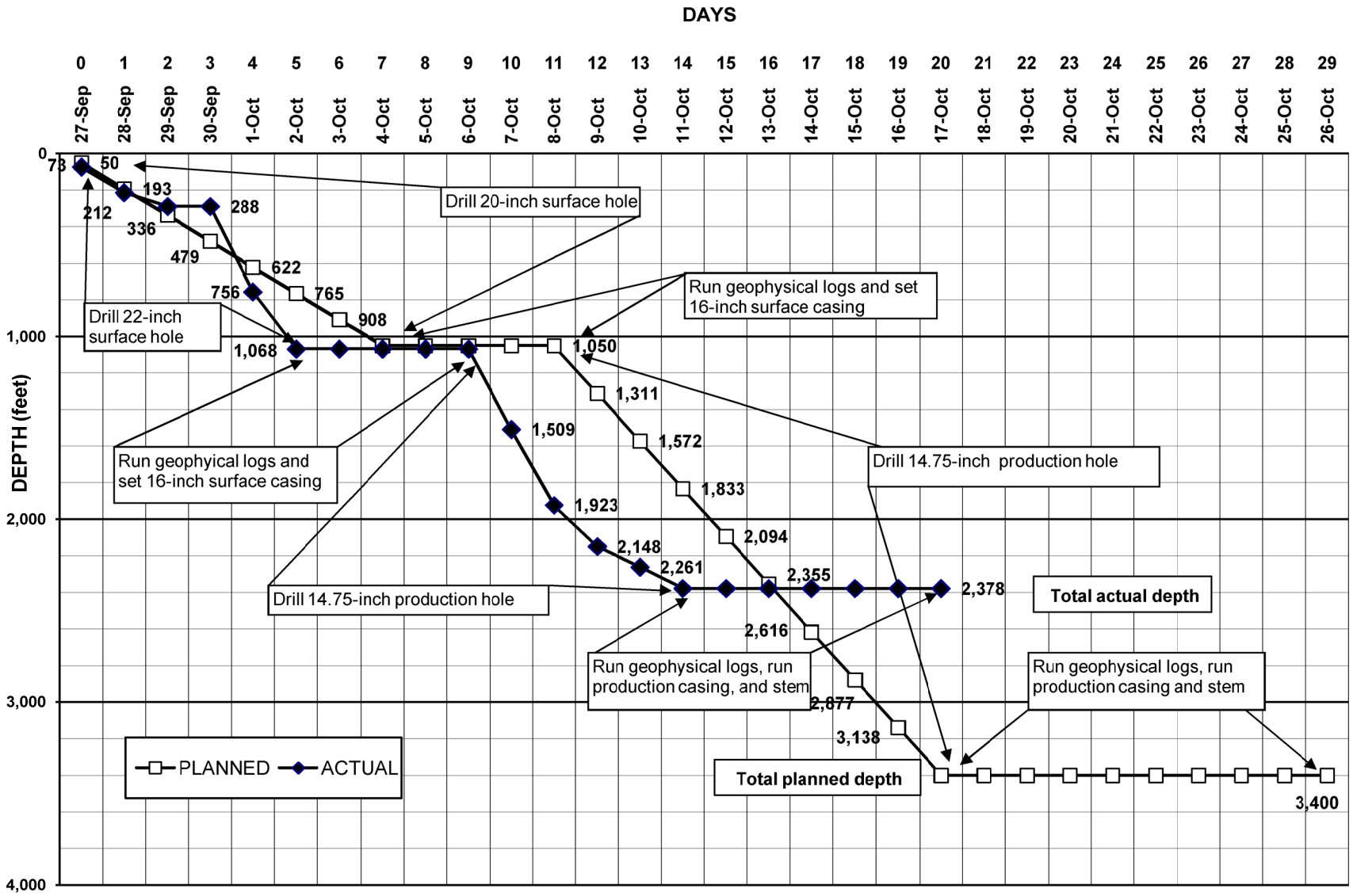


Figure 9-1
Planned and Actual Construction Progress for Well ER-EC-14
Note that the planned TD is based on a preliminary plan developed prior to issue of the drilling criteria document (N-I, 2011)

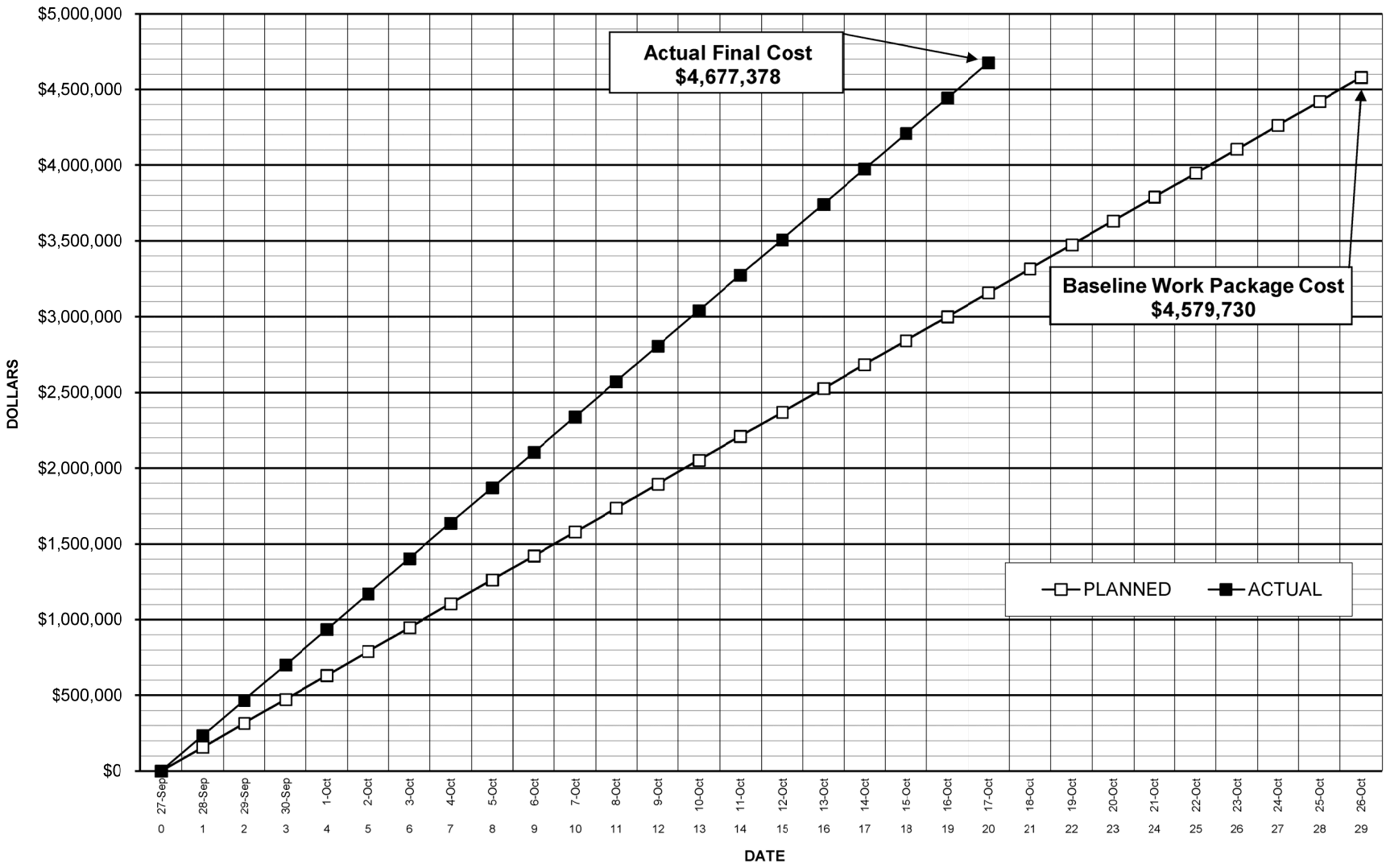


Figure 9-2
Planned and Actual Cost of Constructing Well ER-EC-14
Note that the planned cost is based on a preliminary plan developed prior to issue of the drilling criteria document (N-I, 2011)

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10.0 Summary, Recommendations, and Lessons Learned

10.1 Summary

Main hole drilling at Well ER-EC-14 commenced on September 27, 2012, and concluded on October 11, 2012, at a total drilled depth of 724.8 m (2,378 ft). The borehole reached TD within altered, moderately to densely welded ash-flow tuff of the Rainier Mesa Tuff. No major problems were encountered during drilling.

The completion string consists of 6⅝-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing. The carbon-steel casing and crossover sub extends from the surface to the depth that is about 5.5 m (18 ft) above the water table. The stainless-steel 6⅝-in. casing is slotted in two separate zones. The upper zone is slotted in the interval 414.2 to 507.8 m (1,358.8 to 1,666.0 ft), and the bottom zone is slotted in the interval 595.3 to 690.2 m (1,953.1 to 2,264.4 ft). Both zones are open to the RMWTA for monitoring and sampling groundwater. The two slotted sections of the casing string are gravel packed and separated by cement. On October 24, 2012, a removable bridge plug was installed at 541.3 m (1,776 ft) between the two slotted intervals in the 6⅝-in. completion string to isolate the two completion zones from each other.

The well has two 2⅞-in. piezometer strings that allow access to each of the two isolated intervals within the RMWTA. Both strings consist of 2⅞-in. stainless-steel tubing suspended from 2⅜-in. carbon-steel tubing, connected via crossover subs. The shallow piezometer string is slotted from 412.1 to 507.2 m (1,351.9 to 1,663.9 ft), and the deep piezometer string is slotted from 592.9 to 688.0 m (1,945.1 to 2,257.1 ft). The slotted sections of the 2⅞-in. tubing strings are within the same gravel-packed intervals as the slotted sections of the completion casing string.

Data collected during drilling of Well ER-EC-14 include composite drill cuttings samples collected every 3.0 m (10 ft) from 21.3 m (70 ft) to TD. Open-hole geophysical logging was conducted in the open borehole 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-14 is collared in alluvium and penetrated 709.6 m (2,328 ft) of Tertiary volcanic rocks. These rocks consist of bedded and nonwelded tuffs and welded ash-flow tuffs. Water levels were measured in the well on November 5, 2012. The water level in the shallow piezometer string was 311.8 m (1,023.0 ft), and in the deep piezometer string was 311.9 m

(1,023.2 ft). The elevation of the water level is 1,268.9 m (4,162.9 ft). This should be considered a preliminary value until well development is conducted.

The stratigraphy and general lithology were different than expected at Well ER-EC-14 due to the position of the well relative to the buried caldera margins of the TMCC. The water level was generally as predicted.

No tritium above levels detectable by field methods were encountered in this hole. All FMP requirements for Well ER-EC-14 were met. Analysis of monitoring samples and FMP confirmatory samples indicated that fluids generated during drilling at Well ER-EC-14 met the FMP criteria for discharge to an unlined sump or designated infiltration area. All sanitary and hydrocarbon waste generated was properly handled and disposed of.

10.2 Recommendations

All the geologic and hydrologic data and interpretations from Well ER-EC-14 should be integrated in the PM–OV Phase II HFM. This will allow for more confidence in characterization of the 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-14 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. 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.

10.3 Lessons Learned

The efficiency of drilling and constructing wells to obtain hydrogeologic data in support of the UGTA Activity continues to improve as experience is gained with each new well. Sometimes difficult drilling conditions are encountered and challenges are confronted. New lessons were learned during the construction of Well ER-EC-14, the second well in the third campaign of the 2012 Pahute Mesa Phase II drilling initiative, which built upon those learned during drilling in the 2009 and 2010 initiative:

- CAU guidance teams and the drilling advisory team formed by the UGTA TWG continued to provide timely assistance and guidance for addressing “surprises” and assessing their impacts on the overall program. This was especially important while drilling in a structurally complex caldera setting, which is associated with considerable uncertainty.

- Communication among the multiple contractors performing work during construction of Well ER-EC-14 continued to improve. Daily pre-task hazard reviews and individual company safety briefings contributed toward a project with no safety incidents, near misses, or accidents.

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Appendix A
Drilling Data

A-1 Drilling Parameter Log for Well ER-EC-14
A-2 Tubing and Casing Data for Well ER-EC-14
A-3 Well ER-EC-14 Drilling Fluids and Cement Composition

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Appendix A-1
Drilling Parameter Log for Well ER-EC-14

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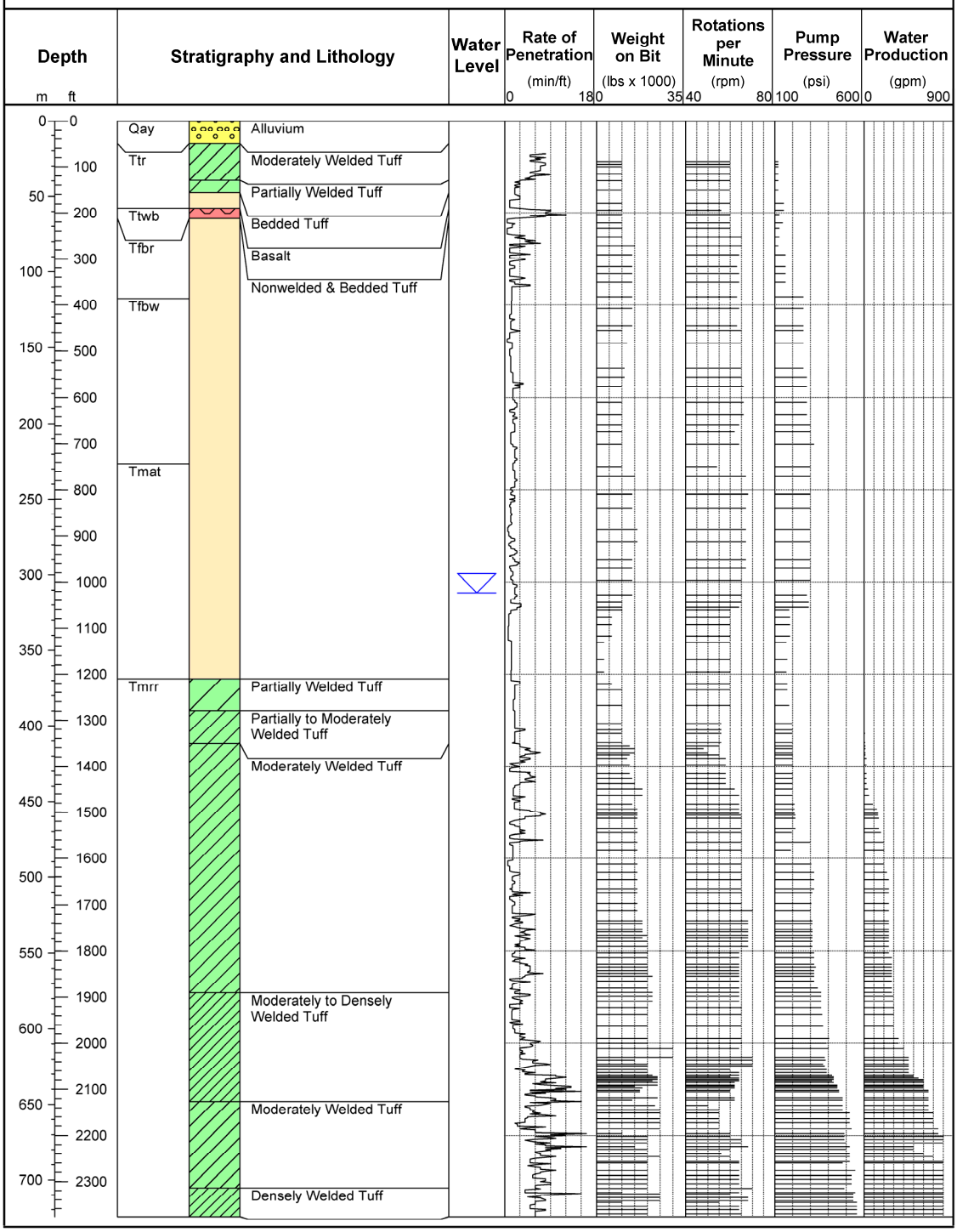
Well ER-EC-14

Logging Company: Baker Atlas
Drilled Depth: 724.8 m (2,378 ft)
Date TD Reached: October 11, 2012
Drill Method: Rotary/Air foam

Surface Elevation: 1,580.7 m (5,185.9 ft)
Coordinates (UTM [NAD 83]): 4,110,534.9 m
543,386.3 m
Water Level: 311.8 m (1,023.0 ft) on November 5, 2012



See Table 5-1 for key to stratigraphic unit symbols.

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Appendix A-2
Tubing and Casing Data for Well ER-EC-14

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Table A-2
Tubing and Casing Data for Well ER-EC-14

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 21.6 (0 to 71.0)	Carbon steel	K55	76.20 (30)	73.58 (28.97)	1.31 (0.515)	162.33
Surface	0 to 308.1 (0 to 1,010.9)	Carbon steel	J55	40.64 (16)	38.13 (15.01)	1.26 (0.495)	84
Completion (with crossover)	0 to 306.5 (0 to 1,005.5)	Epoxy-coated carbon steel	K55	19.37 (7.625)	17.70 (6.969)	0.83 (0.328)	26.4
Completion	306.5 to 690.9 (1,005.5 to 2,266.8)	Stainless steel	304L	16.83 (6.625)	15.50 (6.104)	0.66 (0.261)	NR [a]
Shallow Piezometer (with crossover)	0 to 303.9 (0 to 997.1)	Carbon steel	N80	6.03 (2.375)	5.07 (1.995)	0.48 (0.190)	4.7
Shallow Piezometer	303.9 to 507.8 (997.1 to 1,666.0)	Stainless steel	SS	7.30 (2.875)	5.90 (2.323)	0.70 (0.276)	7.66
Deep Piezometer (with crossover)	0 to 304.1 (0 to 997.8)	Carbon steel	N80	6.03 (2.375)	5.07 (1.995)	0.48 (0.190)	4.7
Deep Piezometer	304.1 to 688.6 (997.8 to 2,259.2)	Stainless steel	SS	7.30 (2.875)	5.90 (2.323)	0.70 (0.276)	7.66

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

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Appendix A-3
Well ER-EC-14 Drilling Fluids and Cement Composition

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Table A-3-1
Drilling Fluids Used in Well ER-EC-14

Typical Air-Foam/Polymer Mix
37.85 liters (10 gallons) Bachman Foam 0 to 1.89 liters (0 to 0.5 gallons) LP701 per 7,949 liters (50 barrels) water

NOTES:

1. Bachman Foam foaming agent is a product of Bachman Services, Inc.
2. LP701 polymer additive is a product of Geo Drilling Fluids, Inc.
3. All water used to mix drilling fluids for Well ER-EC-14 came from Well ER-EC-13.
4. A concentrated lithium bromide (LiBr) solution was added to all introduced fluids (1 liter LiBr per 50 barrels of fluid), 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-14 Cement Composition

Cement Composition	30-inch Conductor Casing	16-inch Surface Casing	6⅝-inch Completion Casing	2⅞-inch Shallow Piezometer String	2⅞-inch Deep Piezometer String
Redi-Mix Formula 400: 998 kg (2,200 lb) sand, 326 kg (719 lb) Portland cement, and 232 liters (61 gallons) water per cubic yard	0 to 22.3 m (0 to 73 ft)	None	None	None	None
Type II neat	None	216.7 to 325.5 m (711 to 1,068 ft)	363.0 to 394.7 m (1,191 to 1,295 ft) 519.4 to 575.8 m (1,704 to 1,889 ft)	363.0 to 394.7 m (1,191 to 1,295 ft)	519.4 to 575.8 m (1,704 to 1,889 ft)

Notes:

kg = kilograms
lb = pounds
m = meters
ft = feet

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Appendix B
Well ER-EC-14 Fluid Management Data

B-1 Fluid Management Data for Well ER-EC-14

B-2 Final Well Specific Fluid Management Strategy for UGTA Well ER-EC-14, EC South Area, Nevada Test and Training Range

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Appendix B-1
Fluid Management Data for Well ER-EC-14

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Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-EC-14 (five pages)

Sample ID Number	Depth		NSTec Onsite Tritium Analysis Results				Sample Description
	meters	feet	Tritium Results (pCi/L)	MDA (pCi/L)	Recount #1 (pCi/L)	Recount #2 (pCi/L)	
ER-EC-14-092712-01	N/A	N/A	0	1,585.95	-	-	Baker Tank
ER-EC-14-092712-02	22.9	75	732	1,585.95	-	-	Discharge Line
ER-EC-14-092712-03	25.6	84	0	1,459.54	-	-	Discharge Line
ER-EC-14-092712-04	28.0	92	0	4,335.03	-	-	Discharge Line
ER-EC-14-092712-05	30.2	99	346	1,585.95	-	-	Discharge Line
ER-EC-14-092712-06	32.6	107	0	1,498.98	-	-	Discharge Line
ER-EC-14-092712-07	35.7	117	316	1,498.98	-	-	Discharge Line
ER-EC-14-092712-08	38.1	125	295	1,498.98	-	-	Discharge Line
ER-EC-14-092712-09	42.7	140	560	1,493.86	-	-	Discharge Line
ER-EC-14-092712-10	50.0	164	170	1,459.54	-	-	Discharge Line
ER-EC-14-092712-11	56.4	185	377	1,320.53	-	-	Discharge Line
ER-EC-14-092812-12	60.0	197	1,007	1,386.56	-	-	Discharge Line
ER-EC-14-092812-13	61.9	203	9	1,352.74	-	-	Discharge Line
ER-EC-14-092812-14	63.4	208	1,156	1,378.94	-	-	Discharge Line
ER-EC-14-092812-15	70.7	232	1,016	1,386.56	-	-	Discharge Line
ER-EC-14-092812-16	N/A	N/A	223	1,650.28	-	-	Baker Tank
ER-EC-14-092812-17	71.9	236	385	1,504.58	-	-	Discharge Line
ER-EC-14-092812-18	79.2	260	1,814	1,463.95	2,054	0	Discharge Line
ER-EC-14-092812-19	83.8	275	1,157	1,289.82	-	-	Discharge Line
ER-EC-14-093012-20	89.3	293	0	1,544.10	-	-	Discharge Line
ER-EC-14-093012-21	95.1	312	562	1,359.39	-	-	Discharge Line
ER-EC-14-093012-22	101.5	333	518	1,579.62	-	-	Discharge Line
ER-EC-14-093012-23	N/A	N/A	808	1,250.67	-	-	Baker Tank
ER-EC-14-093012-24	108.5	356	0	1,584.73	-	-	Discharge Line
ER-EC-14-093012-25	116.4	382	0	1,504.58	-	-	Discharge Line
ER-EC-14-093012-26	125.9	413	220	1,422.11	-	-	Discharge Line
ER-EC-14-093012-27	132.6	435	0	1,584.73	-	-	Discharge Line
ER-EC-14-093012-28	138.1	453	0	1,584.73	-	-	Discharge Line
ER-EC-14-093012-29	146.3	480	38	1,584.73	-	-	Discharge Line
ER-EC-14-093012-30	155.8	511	0	1,585.91	-	-	Discharge Line
ER-EC-14-093012-31	166.1	545	0	1,505.49	-	-	Discharge Line
ER-EC-14-100112-32	174.3	572	0	1,544.10	-	-	Discharge Line

Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-EC-14 (five pages)

Sample ID Number	Depth		NSTec Onsite Tritium Analysis Results				Sample Description
	meters	feet	Tritium Results (pCi/L)	MDA (pCi/L)	Recount #1 (pCi/L)	Recount #2 (pCi/L)	
ER-EC-14-100112-33	181.4	595	0	1,584.73	-	-	Discharge Line
ER-EC-14-100112-34	189.6	622	323	1,427.36	-	-	Discharge Line
ER-EC-14-100112-35	198.7	652	813	1,431.19	-	-	Discharge Line
ER-EC-14-100112-36	206.7	678	0	1,400.46	-	-	Discharge Line
ER-EC-14-100112-37	216.4	710	341	1,352.74	-	-	Discharge Line
ER-EC-14-100112-38	222.5	730	0	1,232.50	-	-	Discharge Line
ER-EC-14-100112-39	231.6	760	741	1,239.00	-	-	Discharge Line
ER-EC-14-100112-40	239.9	787	871	1,269.22	-	-	Discharge Line
ER-EC-14-100112-41	N/A	N/A	392	1,431.19	-	-	Baker Tank
ER-EC-14-100112-42	249.0	817	0	1,468.77	-	-	Discharge Line
ER-EC-14-100112-43	258.2	847	1,039	1,320.53	-	-	Discharge Line
ER-EC-14-100112-44	268.2	880	314	1,289.82	-	-	Discharge Line
ER-EC-14-100112-45	276.8	908	725	1,352.74	-	-	Discharge Line
ER-EC-14-100112-46	286.8	941	0	1,364.62	-	-	Discharge Line
ER-EC-14-100112-47	296.0	971	0	1,584.73	-	-	Discharge Line
ER-EC-14-100112-48	306.0	1,004	0	1,544.18	-	-	Discharge Line
ER-EC-14-100112-49	315.2	1,034	0	1,544.18	-	-	Discharge Line
ER-EC-14-100112-50	320.0	1,050	507	1,422.11	-	-	Discharge Line
ER-EC-14-100612-51	329.2	1,080	282	1,543.02	-	-	Discharge Line
ER-EC-14-100612-52	N/A	N/A	544	1,327.77	-	-	Baker Tank
ER-EC-14-100612-53	344.4	1,130	844	1,582.58	-	-	Discharge Line
ER-EC-14-100612-54	356.0	1,168	0	1,871.63	-	-	Discharge Line
ER-EC-14-100612-55	368.8	1,210	131	1,672.77	-	-	Discharge Line
ER-EC-14-100612-56	375.5	1,232	298	1,585.91	-	-	Discharge Line
ER-EC-14-100612-57	382.2	1,254	377	1,584.73	-	-	Discharge Line
ER-EC-14-100612-58	391.4	1,284	0	1,805.28	-	-	Discharge Line
ER-EC-14-100612-59	398.7	1,308	0	1,794.84	-	-	Discharge Line
ER-EC-14-100612-60	404.5	1,327	0	1,668.13	-	-	Discharge Line
ER-EC-14-100612-61	411.8	1,351	0	1,624.23	-	-	Discharge Line
ER-EC-14-100612-62	416.7	1,367	192	1,672.77	-	-	Discharge Line
ER-EC-14-100612-63	419.4	1,376	0	1,833.65	-	-	Discharge Line
ER-EC-14-100712-64	423.1	1,388	0	1,794.84	-	-	Discharge Line

Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-EC-14 (five pages)

Sample ID Number	Depth		NSTec Onsite Tritium Analysis Results				Sample Description
	meters	feet	Tritium Results (pCi/L)	MDA (pCi/L)	Recount #1 (pCi/L)	Recount #2 (pCi/L)	
ER-EC-14-100712-65	430.1	1,411	790	1,544.18	-	-	Discharge Line
ER-EC-14-100712-66	433.7	1,423	3,446	1,493.86	1,433	1,036	Discharge Line
ER-EC-14-100712-67	437.4	1,435	4,732	1,415.23	2,436	1,259	Discharge Line
ER-EC-14-100712-68	443.2	1,454	1,623	1,680.59	-	-	Discharge Line
ER-EC-14-100712-69	450.5	1,478	48	1,543.09	-	-	Discharge Line
ER-EC-14-100712-70	456.9	1,499	0	1,543.09	-	-	Discharge Line
ER-EC-14-100712-71	460.2	1,510	284	1,320.53	-	-	Discharge Line
ER-EC-14-100712-72	463.3	1,520	324	1,392.54	-	-	Discharge Line
ER-EC-14-100712-73	469.4	1,540	1,223	1,392.54	0	-	Discharge Line
ER-EC-14-100712-74	N/A	N/A	536	1,311.68	-	-	Baker Tank
ER-EC-14-100712-75	476.1	1,562	2,223	1,392.54	842	-	Discharge Line
ER-EC-14-100712-76	480.7	1,577	816	1,320.53	-	-	Discharge Line
ER-EC-14-100712-77	488.9	1,604	1,451	1,431.19	0	-	Discharge Line
ER-EC-14-100712-78	498.0	1,634	459	1,397.11	-	-	Discharge Line
ER-EC-14-100712-79	504.1	1,654	708	1,422.11	-	-	Discharge Line
ER-EC-14-100712-80	510.2	1,674	525	1,415.23	-	-	Discharge Line
ER-EC-14-100712-81	517.9	1,699	0	1,504.58	-	-	Discharge Line
ER-EC-14-100712-82	524.3	1,720	0	1,544.10	-	-	Discharge Line
ER-EC-14-100712-83	528.2	1,733	0	1,544.10	-	-	Discharge Line
ER-EC-14-100712-84	534.6	1,754	0	1,498.98	-	-	Discharge Line
ER-EC-14-100712-85	537.7	1,764	0	1,422.11	-	-	Discharge Line
ER-EC-14-100712-86	542.2	1,779	350	1,378.94	-	-	Discharge Line
ER-EC-14-100712-87	546.8	1,794	0	2,103.81	-	-	Discharge Line
ER-EC-14-100712-88	549.6	1,803	0	1,463.95	-	-	Discharge Line
ER-EC-14-100812-89	557.8	1,830	0	1,543.09	-	-	Discharge Line
ER-EC-14-100812-90	559.9	1,837	845	1,386.56	-	-	Discharge Line
ER-EC-14-100812-91	563.9	1,850	495	1,466.97	-	-	Discharge Line
ER-EC-14-100812-92	566.9	1,860	0	1,544.18	-	-	Discharge Line
ER-EC-14-100812-93	575.2	1,887	33	1,463.95	-	-	Discharge Line
ER-EC-14-100812-94	577.3	1,894	348	1,280.45	-	-	Discharge Line
ER-EC-14-100812-95	582.5	1,911	0	1,898.38	-	-	Discharge Line
ER-EC-14-100812-96	587.7	1,928	1,032	1,210.19	-	-	Discharge Line

Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-EC-14 (five pages)

Sample ID Number	Depth		NSTec Onsite Tritium Analysis Results				Sample Description
	meters	feet	Tritium Results (pCi/L)	MDA (pCi/L)	Recount #1 (pCi/L)	Recount #2 (pCi/L)	
ER-EC-14-100812-97	596.2	1,956	820	1,311.68	-	-	Discharge Line
ER-EC-14-100812-98	603.5	1,980	1,006	1,179.49	-	-	Discharge Line
ER-EC-14-100812-99	606.9	1,991	199	1,386.56	-	-	Discharge Line
ER-EC-14-100812-100	610.2	2,002	1,608	1,352.74	532	-	Discharge Line
ER-EC-14-100812-101	N/A	N/A	0	1,505.38	-	-	Baker Tank
ER-EC-14-100812-102	612.6	2,010	19	1,544.18	-	-	Discharge Line
ER-EC-14-100812-103	615.7	2,020	0	1,755.13	-	-	Discharge Line
ER-EC-14-100812-104	620.9	2,037	0	1,707.69	-	-	Discharge Line
ER-EC-14-100812-105	623.3	2,045	582	1,584.64	-	-	Discharge Line
ER-EC-14-100812-106	625.4	2,052	0	1,544.18	-	-	Discharge Line
ER-EC-14-100812-107	631.5	2,072	0	1,584.73	-	-	Discharge Line
ER-EC-14-100812-108	633.1	2,077	437	1,543.09	-	-	Discharge Line
ER-EC-14-100812-109	634.6	2,082	344	1,544.13	-	-	Discharge Line
ER-EC-14-100812-110	636.1	2,087	0	1,433.80	-	-	Discharge Line
ER-EC-14-100912-111	638.3	2,094	0	1,359.39	-	-	Discharge Line
ER-EC-14-100912-112	640.4	2,101	0	1,579.62	-	-	Discharge Line
ER-EC-14-100912-113	643.7	2,112	18	1,468.77	-	-	Discharge Line
ER-EC-14-100912-114	644.7	2,115	290	1,422.11	-	-	Discharge Line
ER-EC-14-100912-115	645.6	2,118	147	1,422.11	-	-	Discharge Line
ER-EC-14-100912-116	648.0	2,126	207	1,422.11	-	-	Discharge Line
ER-EC-14-100912-117	649.8	2,132	112	1,397.11	-	-	Discharge Line
ER-EC-14-100912-118	653.5	2,144	766	1,311.68	-	-	Discharge Line
ER-EC-14-100912-119	655.3	2,150	440	1,320.53	-	-	Discharge Line
ER-EC-14-100912-120	657.5	2,157	199	1,359.39	-	-	Discharge Line
ER-EC-14-100912-121	661.1	2,169	791	1,359.39	-	-	Discharge Line
ER-EC-14-100912-122	664.5	2,180	0	1,543.02	-	-	Discharge Line
ER-EC-14-100912-123	668.4	2,193	658	1,289.82	-	-	Discharge Line
ER-EC-14-100912-124	N/A	N/A	0	1,433.80	-	-	Baker Tank
ER-EC-14-100912-125	670.3	2,199	513	1,466.97	-	-	Discharge Line
ER-EC-14-100912-126	672.4	2,206	1,022	1,397.11	-	-	Discharge Line
ER-EC-14-100912-127	674.2	2,212	14	1,459.54	-	-	Discharge Line
ER-EC-14-100912-128	676.7	2,220	613	1,544.18	-	-	Discharge Line

Table B-1-1
Tritium Activities Measured on Fluid Samples during Drilling of Well ER-EC-14 (five pages)

Sample ID Number	Depth		NSTec Onsite Tritium Analysis Results				Sample Description
	meters	feet	Tritium Results (pCi/L)	MDA (pCi/L)	Recount #1 (pCi/L)	Recount #2 (pCi/L)	
ER-EC-14-100912-129	677.9	2,224	119	1,544.18	-	-	Discharge Line
ER-EC-14-101012-130	679.1	2,228	433	1,311.68	-	-	Discharge Line
ER-EC-14-101012-131	681.8	2,237	0	1,386.56	-	-	Discharge Line
ER-EC-14-101012-132	684.3	2,245	55	1,427.36	-	-	Discharge Line
ER-EC-14-101012-133	685.8	2,250	346	1,386.56	-	-	Discharge Line
ER-EC-14-101012-134	689.8	2,263	1,032	1,352.74	-	-	Discharge Line
ER-EC-14-101012-135	693.1	2,274	0	1,505.49	-	-	Discharge Line
ER-EC-14-101012-136	N/A	N/A	0	1,615.35	-	-	Baker Tank
ER-EC-14-101012-137	695.2	2,281	0	1,431.19	-	-	Discharge Line
ER-EC-14-101012-138	696.5	2,285	1,247	1,543.02	-	-	Discharge Line
ER-EC-14-101012-139	699.5	2,295	62,797	1,543.02	0	-	Discharge Line
ER-EC-14-101012-140	702.0	2,303	0	1,582.58	-	-	Discharge Line
ER-EC-14-101012-141	704.1	2,310	974	1,650.28	-	-	Discharge Line
ER-EC-14-101012-142	705.3	2,314	0	1,620.12	-	-	Discharge Line
ER-EC-14-101012-143	708.1	2,323	0	1,582.58	-	-	Discharge Line
ER-EC-14-101012-144	709.0	2,326	0	1,584.73	-	-	Discharge Line
ER-EC-14-101012-145	710.8	2,332	0	1,668.13	-	-	Discharge Line
ER-EC-14-101012-146	713.5	2,341	0	1,427.36	-	-	Discharge Line
ER-EC-14-101012-147	715.4	2,347	0	1,544.10	-	-	Discharge Line
ER-EC-14-101012-148	717.8	2,355	0	1,585.91	-	-	Discharge Line
ER-EC-14-101012-149	720.5	2,364	0	1,575.95	-	-	Discharge Line
ER-EC-14-101112-150	723.3	2,373	0	1,543.02	-	-	Discharge Line

Data from N-I (2013)

Notes:

Where result presented is less than the MDA for that measurement, the sample is considered to contain no tritium at levels measurable by this method. These data are not intended to accurately represent lower concentrations of tritium (i.e., less than approximately 1,500 pCi/L) due to errors in counting statistics or issues relating to the nature of fluids analyzed (e.g., drilling effluent).

Baker tank is the holding tank from which water is obtained for mixing the down-hole drilling fluids

MDA = minimum detectable activity

N/A = not applicable

NSTec = National Security Technologies, LLC

pCi/L = picocuries per liter

– = no recorded data

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Table B-1-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-EC-14
(Page 1 of 2)

Analyte	Analytical Method [a]	Detection Limit	10/12/2012 Sample Number 119-101212-1 Taken at Depth of 453.5 meters (1,488 feet)		10/12/2012 Sample Number 119-101212-2 (Duplicate) Taken at Depth of 453.5 meters (1,488 feet)	
			Total	Dissolved	Total	Dissolved
Metals (milligrams per liter)						
Aluminum	SW-846 6010 [b]	0.2	0.2 U	0.2 U	0.2 U	0.2 U
Arsenic		0.01	0.004 J-	0.01 U	0.0075 J-	0.0046 J-
Barium		0.1	0.15 J-	0.0085 J-	0.015 J-	0.0088 J- U
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Calcium		1		15		15 J
Chromium		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Iron		0.1	0.42	0.21	0.39	0.2
Lead		0.003	0.003 U	0.003 UJ	0.003 UJ	0.003 UJ
Lithium		0.01		0.14 J		0.13 J
Magnesium		1		1 U		0.36 J-
Manganese		0.01	0.014	0.01	0.014	0.01 U
Potassium		1		2.5		2.5
Selenium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Silicon		0.05	24	23	23	23
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Sodium		1		78 J		77 J
Strontium		0.01		0.059 J		0.058 J
^{238}Uranium	SW-846 6020 [b]	0.0001		0.002		0.002
Mercury	SW-846 7470 [b]	0.0002	0.0000031	0.0000086	0.0002 U	0.0000077
Inorganic Compounds (milligrams per liter unless otherwise noted)						
Bromide	EPA 300.1 [c]	0.2		0.41		0.4
Chloride		1		22		22
Fluoride		0.1		6.1		6.1
Sulfate		1		44		44
Alkalinity as $CaCO_3$	EPA 310.1 [d]	10	130		130	
Bicarbonate as $CaCO_3$		10	130		130	
Carbonate as $CaCO_3$		10	10 U		10 U	
Total Dissolved Solids	EPA 160.1 [d]	20	320		320	
pH (SU)	EPA 150.1 [d]	0.1	8 J		8 J	
Specific Conductivity (µmhos/centimeter)	EPA 120.1 [d]	1	470		460	
Organics (milligrams per liter)						
Total Organic Carbon	EPA 415.1 [d]	1	4.2		3.7	
Redox Parameter (milligrams per liter)						
Total Sulfide	EPA 376.1 [d]	2	2 U		2 U	

Table B-1-2
Analytical Results for Depth-Discrete Bailer Samples from Well ER-20-11
(Page 2 of 2)

Analyte	Analytical Method [a]	Detection Limit	09/11/2012 Sample Number 119-101212-2 Taken at Depth of 453.5 meters (1,488 feet)		09/11/2012 Sample Number 119-101212-3 (Duplicate) Taken at Depth of 453.5 meters (1,488 feet)	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level I (picocuries per liter)						
		MDC [e]	Result	Error	Result	Error
Tritium	EPA 906.0 [f]	350	60 U	210	-170 U	210
Gross Alpha	EPA 900.0 [f]	1.7	1.8 U	1.2	13.1	3.2
Gross Beta		2.5, 2.7	3.2 U	1.7	7.4	2.3
^{238}Pu	HASL 300 [g] / ASTM D3865-02 [h]	0.024, 0.015	0 U	0.032	0 U	0.02
$^{239/240}Pu$	HASL 300 [g] / ASTM D3865-02 [h]	0.024, 0.015	0 U	0.032	0.006 U	0.02
Gamma Spectroscopy	EPA 901.1 [g]	Varies by nuclide	ND	Varies by nuclide	ND	Varies by Nuclide
			09/11/2012 Sample Number 119-101212-3 Taken at Depth of 453.5 meters (1,488 feet)		09/11/2012 Sample Number 119-101212-4 (Duplicate) Taken at Depth of 453.5 meters (1,488 feet)	
			Total	Dissolved	Total	Dissolved
Radiological Indicator Parameters-Level II (picocuries per liter)						
^{14}C	EERF C-01 [i]	400	80 UJ	240	30 UJ	240

Samples collected October 12, 2012 Source: N-I (2013)

a For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits. Analyses for samples 119-101212-1 and 119-101212-2 were performed by ALS Laboratory Group. Analyses for samples 119-101212-3 and 119-101212-4 were performed by ARS International.

b EPA (2012)

c EPA (1997)

d EPA (1983)

e MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 103-091112-1, the second with 103-091112-2.

f EPA (1980)

g U.S. Department of Energy (1997)

h ASTM (2002)

i EPA (1984)

ASTM = ASTM International
C = Carbon
CaCO3 = Calcium carbonate
Pu = Plutonium
EERF = Eastern Environmental Radiation Facility
SU = Standard unit
EPA = U.S. Environmental Protection Agency
SW = Solid waste
HASL = Health and Safety Laboratory

MDC = Minimum detectable concentration
J = Result is estimated
J- = Result is estimate bias low
ND = No gamma spectroscopy radionuclides detected above detection limit
U = Compound was analyzed for but was not detected ("non-detect")
UJ = Compound was non-detect, but result is bias low

Table B-1-3
Analytical Results for FMP Confirmatory Samples from Sump #1 (Unlined) at Well ER-EC-14

Analyte	Analytical Method[a]	Detection Limit	10/13/2012 FMP Samples from Well ER-EC-14 Sump #1			
			Sample No. 119-101312-1 Sump #1		Sample No. 119-101312-2 Sump #1 Duplicate	
			Total	Dissolved	Total	Dissolved
Metals (milligrams per liter)						
Arsenic	SW-846 6010[b]	0.01	0.011 J-	0.01 U	0.0049 J-	0.0099 J-
Barium		0.1	0.0016 J-	0.1 U	0.1 U	0.1 U
Cadmium		0.005	0.005 U	0.005 U	0.005 U	0.005 U
Chromium		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Lead		0.003	0.003 UJ	0.003 U	0.003 UJ	0.003 U
Selenium		0.005	0.005 U	0.005 U	0.01 U	0.01 U
Silver		0.01	0.01 U	0.01 U	0.01 U	0.01 U
Mercury	SW-846 7470[b]	0.0002	0.0000029	0.0002 U	0.0000035	0.0002 U
Radiological Indicator Parameters (picocuries per liter)						
		MDC[c]	Result	Error	Result	Error
Tritium	EPA 906.0[d]	350	-10 U	210	40 U	210
Gross Alpha	EPA 900.0[d]	1.2, 1.6	2.4	1.2	2 U	1.2
Gross Beta		1.8, 2.4	3.4	1.4	3.6 U	1.7

Source: N-I (2013)

a For commercial laboratory analysis, the most current EPA or equivalent accepted standard laboratory analytical methods may be used as appropriate to attain specified detection limits.

b EPA (2012)

c MDC varies by matrix, instrument, and count rates. Where two detection limits are given, the first corresponds with sample number 119-101312-1 and the second with 119-101312-2.

d EPA (1980)

EPA = U.S. Environmental Protection Agency

MDC = Minimum detectable concentration

J- = Result is estimated low

U = Compound was analyzed for but was not detected ("non-detect")

UJ = Compound was non-detect, but result is biased low

Note: Analyses were performed by ALS Laboratory Group

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Table B-1-4
Well ER-EC-14 Fluid Disposition Reporting Form

Site Identification: ER-EC-14
Site Location: Nevada Test and Training Range
Site Coordinates: (UTM AND 27, Zone 11) N 4,110,337.86 m; E 543,466.54m
Well Classification: ER Hydrogeologic Investigation Well
N-I Project No: UG12-415

Report Date: 01/02/2013
NNSA/NSO UGTA Activity Lead: Bill Wilborn
N-I Project Manager: Sam Marutzky
N-I Site Representative: Jeff Wurtz
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 [b]	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	9/27/2012	10/1/2012	4	325.79	248.04	119.85	136.34	N/A	NA	N/A	N/A	Yes
Phase I: Saturated-Zone Drilling	10/6/2012	10/11/2012	5	724.88	227.37	65.99	2,058.32	N/A	NA	8,194	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			9	724.88	475.41	185.84	2,194.66	N/A	NA	8,194	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] Discharge to an NDEP approved infiltration area as defined in the Well-Specific Fluid Management Strategy Letter for ER-EC-14.

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

N/A = Not Applicable; m = meters; m^3 = cubic meters

Total Facility Capacities (at 8 ft fluid level): Sump # 1 = 1,547 m^3 Sump #2 = 1,547 m^3 Infiltration Area (assuming very low/no infiltration) = N/A

Remaining Facility Capacity (Approximate) as of 10/11/2012: Sump #1 = 944.11 m^3 (61%) Sump #2 = 1,547 m^3 (100%)

Current Average Tritium, Sump #1 FMP samples = less than the minimum detectable concentration of 350 pCi/L.

Notes: None

N-I Authorizing Signature/Date: 1-3-13

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Appendix B-2
Final Well Specific Fluid Management Strategy for UGTA Well ER-EC-14, EC South Area, Nevada Test and Training Range

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FINAL
WELL SPECIFIC FLUID MANAGEMENT STRATEGY FOR UGTA WELL ER-EC-14, EC SOUTH AREA, NEVADA TEST AND TRAINING RANGE

September 25, 2012

INTRODUCTION

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office (NNSA/NSO), Underground Test Area Project (UGTA) is proposing to drill and construct hydrologic investigation Well ER-EC-14 as part of the Pahute Mesa Phase II Drilling Initiative. The program of hydrologic investigations is to be conducted in accordance with the Nevada Division of Environmental Protection (NDEP) approved Phase II Corrective Action Investigation Plan for Western and Central Pahute Mesa, CAU 101 and 102 (NNSA/NSO 2009a). The planned Well ER-EC-14 is located in the area of Western Pahute Mesa on lands of the Nevada Test and Training Range (NTTR), immediately southwest of operable area 20 of the Nevada National Security Site (NNSS) The purpose of the drilling and construction of Well ER-EC-14 is to acquire geologic, hydrologic and groundwater chemistry data from an area located to the south and southwest of areas of historic underground nuclear testing on the NNSS. The acquisition of data from this planned well location will be used to further develop flow and contaminate transport models of the area. This well specific fluid management strategy letter describes the monitoring and management of fluids generated during the drilling, well development, testing and sampling of the well in accordance with the requirements of the Fluid Management Plan (FMP) for the Underground Test Area Project, Rev 5., (NNSA/NSO 2009b).

Well ER-EC-14 is a planned hydrogeologic investigation well to be drilled and constructed by the NNSA/NSO, UGTA project as part of the Pahute Mesa Phase II drilling initiative. The original proposed Well ER-EC-14 site was moved by the Pahute Mesa Technical Advisory Team in 2011 to better accommodate the construction of a drill pad and the planned well depth was also revised to be deeper than originally proposed. Well ER-EC-14 was sited to examine hydrogeologic conditions and the nature and extent of radionuclide contamination in a location down gradient and relatively distal from areas of known radionuclide contamination in groundwater. The purpose of Well ER-EC-14 is to provide additional scientific data regarding the hydrogeologic character of the subsurface in an area that is interpreted to be down gradient from the sites of past underground nuclear testing principally at Benham (U-20c) and Tybo (U-20y) and to recently constructed characterization Wells ER-EC-11, ER-20-8, ER-20-8#2 and ER-20-11 that encountered radionuclides in groundwater.

Pahute Mesa Phase I hydrogeologic investigation wells were drilled and constructed in 1998 and 1999 as part of the Phase I investigation of Corrective Action Units 101 and 102, Western and Central Pahute Mesa (DOE 1999). Additional wells were constructed in 2009 and 2010 as part of Phase II investigations (NNSA/NSO 2009a). Figure 1 shows the location of planned Well ER-EC-14 relative to other existing wells that were drilled and completed as part of the Phase I and

Phase II investigations of Corrective Action Units 101 and 102, Western and Central Pahute Mesa (DOE 2009a). Figure 2 provides an orthophoto view of the planned Well ER-EC-14 location, showing the general physiographic character of the area and the proposed infiltration area. The planned completed depth of Well ER-EC-14 is approximately 1,188.7 meters (3,900 ft), below ground surface (bgs) with the predicted water table located at an approximate depth of 1,267 m (4,157 ft) bgs.

It is unlikely that Well ER-EC-14 will encounter radionuclide contamination exceeding the Safe Drinking Water Act (SDWA) for tritium (20,000 pCi/L) in groundwater resulting from fluid generating activities associated with well drilling, well construction, well pumping, hydraulic testing, monitoring and sampling activities. This is based on the analysis of the groundwater samples collected during drilling and aquifer testing at nearby Wells ER-EC-13, ER-EC-12, and ER-EC-2a. Tritium concentrations reported from the most recent laboratory analysis of groundwater samples collected at these locations following well development and testing do not indicate tritium above the minimum detection limits for the respective samples. Well ER-EC-14 is located in an area believed to be significantly downgradient of two principal underground tests. The Well ER-EC-14 is located 9.5 km (5.9 mi) southwest of the TYBO (U-20y) test with an announced yield of 200-1,000 kt and 10.7 km (6.6 mi) south-southwest of the BENHAM (U-20c) underground nuclear test with an announced yield of 1.15 Mt (DOE 2000). Both these underground tests were detonated below the water table and radionuclides from the tests have been identified in the Wells ER-20-7 and ER-20-5 #1.

Based on the present understanding of the conceptual groundwater flow and transport model, and the low tritium concentration encountered in groundwater at nearby wells ER-EC-12 and ER-EC-13 and ER-EC-2a, the radionuclide concentrations to be encountered within the groundwater at Well ER-EC-14 are unlikely to exceed the SDWA limit for tritium (20,000 pCi/L). This knowledge supports the conductance of Well ER-EC-14 well drilling, construction, pumping and monitoring under a FMP Far-field fluid management strategy. In the case that contaminated groundwater in excess of the FMP criteria for Far-field operations (tritium in excess of 400,000 pCi/L) off the NNSS were encountered the site operations would be transitioned to a FMP Near-field strategy for operations off the NNSS.

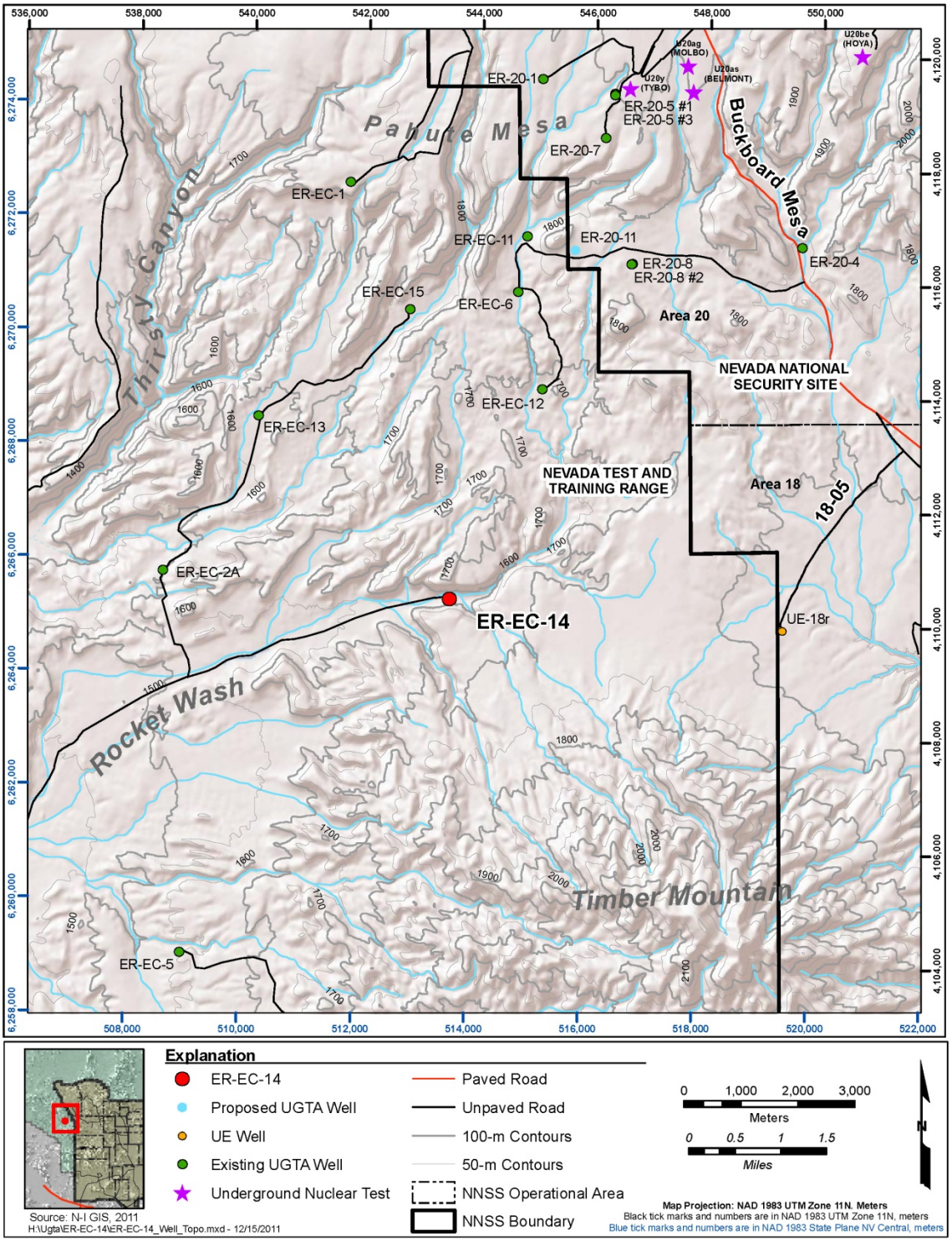

Figure 1
Well ER-EC-14 Location Map

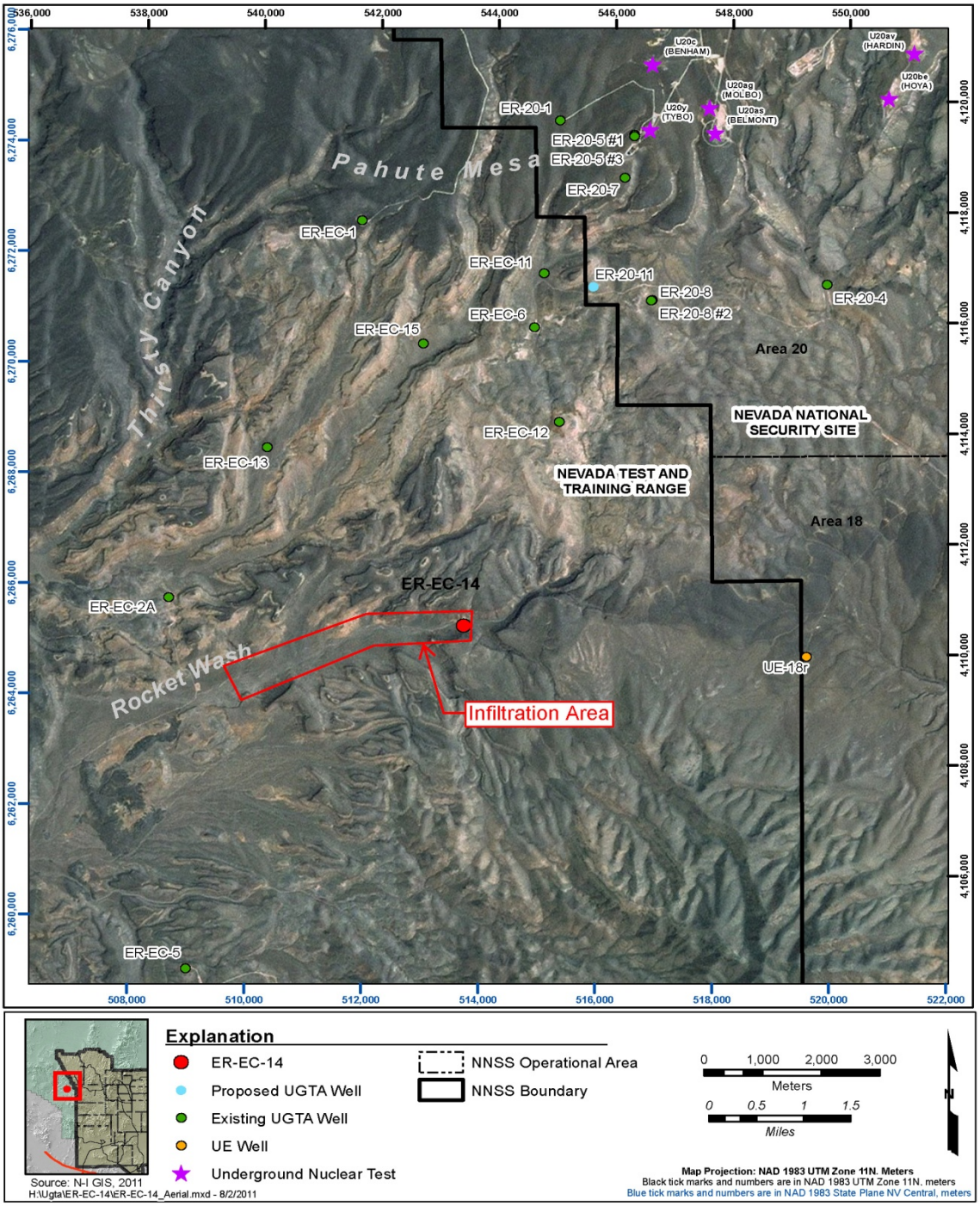

Figure 2
Orthophoto Map of Proposed Well ER-EC-14 Showing Proposed Infiltration Area

BACKGROUND AND ANALYTICAL DATA FROM NEARBY WELLS

As shown in Figure 1, several existing wells are in the vicinity of the Well ER-EC-14 location. The following provides a summary of the three closest wells and their groundwater chemistry. These wells generally provide background analytical data for groundwater that is contained within volcanic aquifers near or at the water table.

Well ER-EC-12: The ER-EC-12 well was drilled in 2009 as part of the Pahute Mesa Phase II Drilling Initiative. Well ER-EC-12 was drilled to a depth of 1,240 m (4,069 ft) and completed with two cased completion intervals, one within the Tiva Canyon Aquifer (TCA) and the Topopah Springs Aquifer (TSA). Well ER-EC-12 is located on the NTTR within the eastern portion of the EC-South area of the range, approximately 4.11 km (2.55 mi) northeast of the Well ER-EC-14. Drilling at Well ER-EC-12 was conducted under a Far-field FMP strategy. During drilling, on-site monitoring indicated several samples with tritium in excess of the Minimum Detectable Activity (MDA) of approximately 1,500 pCi/L Tritium concentrations were generally low with the highest recorded tritium monitoring sample with a concentration of 3,719 pCi/L. Subsequent well development and sampling did not detect tritium in excess of the NDWS. Well ER-EC-12 was sampled for all FMP parameters and met the FMP criteria for discharge to an unlined sump or designated infiltration area. The results of the most recent laboratory analysis of groundwater from ER-EC-12 are shown in Exhibit 1.

Well ER-EC-13: The ER-EC-13 well was drilled in 2009 as part of the Pahute Mesa Phase II Drilling Initiative. Well ER-EC-13 was drilled to a depth of 914 m (3,000 ft) and completed with two cased completion intervals, both within the Forty Mile Canyon Composite (FCCM). Well ER-EC-13 is located on the NTTR within the central portion of the EC-South area of the range, approximately 4.63 km. (2.88 mi.) west-northwest of the Well ER-EC-14. Drilling at Well ER-EC-13 was conducted under a Far-field FMP strategy. During drilling, on-site monitoring indicated several samples with tritium in excess of the MDA of approximately 1,500 pCi/L. The highest reported concentration for tritium during drilling was 2,318 pCi/L. Subsequent groundwater samples collected as part of well development and aquifer testing did not detect tritium in excess of the SDWA. Well ER-EC-13 was sampled for all FMP parameters and met the FMP criteria for discharge to an unlined sump or designated infiltration area. The results of the most recent laboratory analysis of groundwater from ER-EC-13 are shown in Exhibit 1.

Well ER-EC-2a was drilled in 2000 as part of the Pahute Mesa Phase I Drilling Initiative. Well ER-EC-2a was drilled to a depth 1,516.1 m (4,974.3 ft) bgs respectively within Tertiary volcanics. Well ER-EC-2a is located approximately 5.03 km (3.12 mi. ft) west of the Well ER-EC-14 location. Drilling at Wells ER-EC-2a was conducted under a Far-field FMP strategy. During drilling, on-site monitoring did not indicate tritium in excess of the Minimum Detectable Activity (MDA) of approximately 1,500 pCi/L. Subsequent groundwater samples obtained as part of well development and aquifer testing did not detect tritium in excess of the SDWA. Well ER-EC-2a was sampled for all FMP parameters and met the FMP criteria for discharge to an unlined sump or designated infiltration area. The results of the most recent laboratory analysis of groundwater from ER-EC-2a are shown in Exhibit 1.

WELL OPERATIONS STRATEGY

Based on the information presented above, it is proposed that fluid generating activities related to drilling, well construction, pumping and sampling at Well ER-EC-14 will be conducted using the Far-field well site operations strategy for wells located off the NNSS as specified in the FMP. This strategy may be transitioned to a Near-field strategy based on results of on-site monitoring as specified in the FMP and detailed below.

Fluid Containment and Discharge Criteria- The NNSA/NSO proposes the following fluid containment and discharge strategy for Well ER-EC-14:

- Fluids or groundwater generated from the well during drilling, well construction, well pumping and sampling will be routed from the well through a well head, well head manifold, through a flow line (drilling) or flexible piping (pumping operations) and discharged to an unlined sump constructed on the Well ER-EC-14 drill pad based on the FMP discharge criteria for wells located off the NNSS.

- In the event that on-site monitoring results do not exceed the FMP Far-field criteria for tritium (400,000 pCi/L) for wells located off the NNSS, operations will be conducted under a FMP Far-field operational strategy and both the unlined sumps may be utilized to contain generated fluids.

- Fluids that do not exceed the FMP criteria for tritium (400,000 pCi/L) for wells located off the NNSS may also be discharged or conveyed from the existing unlined sumps to a designated posted (or fenced) infiltration area as shown in Figure 2. Fluids will be routed and discharged to this infiltration area in a manner that minimizes the degradation or erosion of the natural ground surface.

- In the event that on-site monitoring results exceed the FMP Far-field criteria for tritium (400,000 pCi/L) for wells located off the NNSS, operations are to be conducted under a FMP Near-field operational strategy. Fluids generated will be contained within an on-site lined sump.

- In the unlikely case that on-site fluid containment capacity (lined sump) may be exceeded under a Near-field operational strategy well site operations will be suspended until sufficient suitable fluid storage can be made available.

On-Site Monitoring – In accordance with the FMP, tritium monitoring samples will be collected from the discharge line during fluid generating activities. Tritium monitoring samples at a minimum will be collected and analyzed hourly during drilling operations, except during periods where the borehole is not being advanced (e.g. circulating, well construction etc.). The results of on-site tritium monitoring will be compared to the FMP discharge criteria as results are available. For other fluid or groundwater generating well activities, tritium monitoring samples will be collected from the discharge line and analyzed on a daily basis.

In accordance with the FMP, lead monitoring samples will be collected during drilling from the discharge and analyzed every eight hours if tritium monitoring results exceed 200,000 pCi/L. The results of on-site lead monitoring will be compared to the FMP discharge criteria as results are available.

Notifications – NDEP will be notified of on-site monitoring results that exceed action levels as specified in the FMP.

REFERENCES

U.S. Department of Energy, Nevada Operations Office. 1999. *Corrective Action Investigation Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada Test Site, Nevada,* Rev. 1, DOE/NV--516. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration, Nevada Site Office. 2009a. Phase *II Corrective Action Investigation Plan for Corrective Action Units 101 and 102: Central and Western Pahute Mesa, Nevada Test Site, Nye County, Nevada*, DOE/NV--1312. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office. 2009b. Attachment 1, Fluid Management Plan for the Underground Test Area Project. Rev. 5. DOE/NV-370

U.S. Department of Energy, Nevada Operations Office. 2000. *United States Nuclear Tests, July 1945 through September 1992*, DOE/NV--209-REV 15. Las Vegas, NV.

Exhibit 1
Analytical Data for Wells ER-EC-2a, ER-EC-12 and ER-EC-13

Analysis Performed	ER-EC-2a [a]	ER-EC-13 [b]	ER-EC-12[c]
(mg/l)			
Aluminum	*0.2 U*	*0.4 U*	*1.9*
Arsenic	*0.0062 U*	*0.0058 U*	*0.01 U*
Barium	0.0077 J	0.1 U	0.017 J
Cadmium	0.005 U	0.005 U	0.005 U
Calcium	8.5	10	2.4
Chloride	59	62	68
Chromium	0.01 U	0.01 U	0.002J
Fluoride	4.2	5.4	3.4
Iron	0.58 J	0.1 U	2
Lithium	0.19 J	0.19 J	0.11
Lead	0.003 U	0.003 U	0.013
Magnesium	0.028 J	10.072 J	1 U
Manganese	0.0027J	0.01	0.085
Mercury	0.0002 U	0.0002 U	0.0002 U
Potassium	2.8	4 J	16
Selenium	0.005 U	0.005 U	0.005 U
Silicon	21 J	25	7.6
Silver	0.01 U	0.01 U	0.01 U
Sodium	120	120 J	99
Strontium	0.023 J	0.0081 J	0.036
Sulfate	89	95 J	35J
Total Organic Carbon	1 U	1 U	11
$_{238}U$	0.062	0.063	0.016
Alkalinity (as $CaCo_3$)	140	150	120
Specific Conductance (mhos/cm)	664	710	610
pH (SU)	8.29 J	8.2 J	10J
Total Dissolved Solids	430	460	350
Radionuclides (pCi/L)			
Gross Alpha	8.4 U	5.7 J	-0.52U
Gross Beta	4.4 U	3.6 U	12.9
$_{99}Tc$	1.1 U	-2.7 U	-2.2U
Tritium	-90 U	-90 U	-190U
$_{90}Sr$	0.67 U	-0.07 U	0.67U
$_{238}Pu$	-0.002 U	0.005 U	0.003U

[a] Composite GWC sample collected after purging the well on 05/20/2010.
[b] Composite GWC samples collected on 07/013/2012.
[c] Composite GWC samples collected 03/26/2012.
J = Estimated value.
U = Compound was analyzed for, but was not detected ("Non-detect").

Appendix C
Waste Management Data for Well ER-EC-14

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Table C-1
Final Waste Disposition for Well ER-EC-14 Drilling Operations

Container ID Number	Contents	Container Type and Size liters (gallons)	Estimated Volume liters (gallons)	Disposition [a]	Status/Comments
ER-EC-14-01	Hydrocarbon waste solids, absorbent pads, hydrocarbon-stained soil, filters	Open-top steel drum 208.2 (55)	189.3 (50)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-02	Used oil	Closed-top steel drum 208.2 (55)	75.7 (20)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-03	Hydrocarbon waste solids, absorbent pads, filters	Open-top steel drum 208.2 (55)	170.3 (45)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-04	Used synthetic oil	Closed-top steel drum 208.2 (55)	132.5 (35)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-05	Hydrocarbon waste solids, oily soil, absorbent pads	Open-top steel drum 208.2 (55)	189.5 (50)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-06	Hydrocarbon waste solids, absorbent pads, stained soil	Open-top steel drum 208.2 (55)	151.4 (40)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-07 [b]	Oily condensate from compressors	Condensate tank 7,570.8 (2,000)	0	Area 12 surface evaporation impoundment	Tank emptied before mobilization
ER-EC-14-08	Used oil	Closed-top steel drum 208.2 (55)	0	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-09	Hydrocarbon waste solids, absorbent pads, soil, filters	Open-top steel drum 208.2 (55)	170.3 (45)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-10	Hydrocarbon waste solids, absorbent pads, soil	Open-top steel drum 208.2 (55)	170.3 (45)	Moved to UGTA Building 6-909	Temporary storage pending disposal
ER-EC-14-11	Hydrocarbon waste solids, absorbent pads, oily soil	Open-top steel drum 208.2 (55)	75.7 (20)	Moved to UGTA Building 6-909	Temporary storage pending disposal
Total Waste Containers					
Pads/debris: 7 Used oil (liquid): 3					
Total number of 208.2-liter (55-gallon) waste containers: 10 Total number of 7,570.8-liter (2,000-gallon) waste containers: 1					

Data from N-I (2013)

a Waste to be transferred to National Security Technologies, LLC (NSTec) for disposal

b Waste transferred to NSTec for disposal

ID = Identification

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Appendix D
Detailed Lithologic Log for Well ER-EC-14

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Table D–1
Detailed Lithologic Log for Well ER–EC–14

Logged by Dawn Reed and Lance Prothro, National Security Technologies, LLC, January 2013

Depth Interval meters (feet)	**Thickness** meters (feet)	**Sample Type** [a]	**Depth of Analytical Samples** [b] meters (feet)	**Lithologic Description** [c]	**Stratigraphic Unit** (map symbol)
0–15.2 (0–50)	15.2 (50)	none	None	**Alluvium:** No samples collected from 0 to 21.3 m (0 to 70 ft) during conductor hole drilling. Lithology based on nearby surface exposures. Depth of bottom contact is uncertain.	Quaternary Alluvium (Qay)
15.2–39.6 (50–130)	24.4 (80)	DA	None	**Moderately Welded Ash-Flow Tuff:** Moderate reddish brown (10R 3/4) to grayish brown (5YR 3/2); devitrified; rare to minor pumice; minor to common feldspar phenocrysts, including large, tabular feldspar with some showing adularescence; minor mafic minerals of corroded and altered clinopyroxene and lesser olivine; rare to minor lithic fragments. Depth of upper contact uncertain, because cuttings were not collected during conductor hole drilling.	Rocket Wash Tuff (Ttr)
39.6–47.6 (130–156)	7.9 (26)	DA	None	**Partially Welded Ash-Flow Tuff:** Moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2); devitrified; minor to common pumice with vapor–phase mineralization; minor feldspar phenocrysts; rare clinopyroxene; minor lithic fragments.	
47.6–57.9 (156–190)	10.4 (34)	DA	None	**Bedded Tuff:** Dark yellowish orange (10YR 6/6) to moderate brown (5YR 4/4); vitric to weakly zeolitic; rare to minor fibrous pumice; rare to minor feldspar phenocrysts; rare to minor clinopyroxene; minor lithic fragments.	
57.9–64.6 (190–212)	6.7 (22)	DA	64.0 (210)	**Basalt:** Dusky brown (5YR 2/2) to very dusky red (10R 2/2); very abundant fine grained feldspar (groundmass) and iddingsite. X-ray diffraction analysis shows 20.9% smectite.	basalt of Rocket Wash (Ttwb)
64.6–71.9 (212– 236)	7.3 (24)	DA	None	**Nonwelded to Bedded Tuff:** Grayish orange (10YR 7/4); vitric to argillic; minor to common pumice; rare to minor felsic phenocrysts of quartz and feldspar; minor biotite and lesser clinopyroxene; rare lithic fragments.	rhyolite of Chukar Canyon (Tfbr)
71.9–77.1 (236–253)	5.2 (17)	DA	None	**Bedded Tuff (pumice fall deposits)**: Grayish orange (10YR 7/4) to pale yellowish brown (10YR 6/2); vitric; very abundant pumice; common to abundant felsic phenocrysts of feldspar and quartz; minor biotite; sphene; rare to minor lithic fragments.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
77.1–117.7 (253–386)	40.5 (133)	DA	100.6 (330)	**Bedded Tuff:** Grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4); mostly zeolitic, lesser argillic; common pumice; rare to minor felsic phenocrysts of feldspar and lesser quartz; rare to minor biotite; sphene and clinopyroxene are present; rare to common lithic fragments up to 2 millimeters in diameter.	rhyolite of Chukar Canyon (Tfbr)
117.7–226.5 (386–743)	108.8 (357)	DA	143.2 (470) 219.5 (720)	**Bedded and Nonwelded Tuff:** Yellowish gray (5Y 7/2) to grayish yellow (5Y 8/4) to pale greenish yellow (10Y 8/2); zeolitic; minor to common pumice; rare to minor felsic phenocrysts of feldspar and much less quartz; rare to minor biotite; sphene and pseudomorphs after sphene; rare chalcedony; minor lithic fragments.	rhyolite of Beatty Wash (Tfbw)
226.5–368.8 (743–1,210)	142.3 (467)	DA	243.8 (800) 295.7 (970) 362.7 (1,190)	**Nonwelded Tuff:** Grayish orange (10YR 7/4), light brown (5YR 6/4), pale reddish brown (10R 5/4) to dark yellowish orange (10YR 6/6); zeolitic above 326.1 m (1,070 ft), becoming mostly quartzo-feldspathic and less zeolitic below; rare to common pumice; rare to minor felsic phenocrysts of feldspar and lesser quartz; minor biotite; rare lithic fragments.	rhyolite of Tannenbaum Hill (Tmat)
368.8–389.8 (1,210–1,279)	21.0 (69)	DA	384.0 (1,260)	**Partially Welded Ash-Flow Tuff:** Medium light gray (N6) to light brownish gray (5YR 6/1); quartzo-feldspathic; minor felsic phenocrysts of feldspar, including pseudomorphs after feldspar and quartz; minor to common biotite; trace to rare lithic fragments.	Rainier Mesa Tuff (Tmrr)
389.8–411.8 (1,279–1,351)	21.9 (72)	DA	411.5 (1,350)	**Partially Welded to Moderately Welded Ash-Flow Tuff:** Light brownish gray (5YR 6/1); quartzo-feldspathic with minor argillic alteration (based on x-ray diffraction analyses); minor pumice; minor to common felsic phenocrysts of pseudomorphs after feldspar and quartz; minor to common biotite; rare lithic fragments.	
411.8–435.9 (1,351–1,430)	24.1 (79)	DA	420.6 (1,380)	**Moderately Welded Ash-Flow Tuff:** Light brownish gray (5YR 6/1); quartzo-feldspathic, spherulitic; minor argillic alteration based on x-ray diffraction analyses; common felsic phenocrysts of pseudomorphs after feldspar and lesser quartz; minor to common biotite; rare lithic fragments.	

Depth Interval meters (feet)	Thickness meters (feet)	Sample Type [a]	Depth of Analytical Samples [b] meters (feet)	Lithologic Description [c]	Stratigraphic Unit (map symbol)
435.9–456.6 (1,430–1,498)	20.7 (68)	DA	448.1 (1,470)	**Moderately Welded Ash-Flow Tuff:** Moderate brown (5YR 3/4) to dark reddish brown (10R 3/4); quartzo-feldspathic; common felsic phenocrysts of pseudomorphs after feldspar and lesser quartz; rare biotite; rare lithic fragments.	Rainier Mesa Tuff (Tmrr)
456.6–476.1 (1,498–1,562)	19.5 (64)	DA	472.4 (1,550)	**Moderately Welded Ash-Flow Tuff:** Grayish red (10R 4/2) to dark reddish brown (10R 3/4); quartzo-feldspathic; minor to common felsic phenocrysts of pseudomorphs after feldspar and lesser quartz; rare to minor biotite; rare lithic fragments.	
476.1–532.2 (1,562–1,746)	56.1 (184)	DA	499.9 (1,640) 524.3 (1,720)	**Moderately Welded Ash-Flow Tuff:** Moderate reddish brown (10R 4/6) to moderate brown (5YR 3/4); quartzo-feldspathic; minor to common felsic phenocrysts of pseudomorphs after feldspar and conspicuous quartz; minor black and lesser bronze biotite; trace to rare lithic fragments.	
532.2–576.1 (1,746–1,890)	43.9 (144)	DA	545.6 (1,790)	**Moderately Welded Ash-Flow Tuff:** Pale reddish brown (10R 5/4) to grayish red (10R 4/2); quartzo-feldspathic; common to abundant felsic phenocrysts of pseudomorphs after feldspar and conspicuous quartz; rare to minor biotite; trace to rare lithic fragments.	
576.1–648.0 (1,890–2,126)	71.9 (236)	DA	588.3 (1,930)	**Moderately Welded to Densely Welded Ash-Flow Tuff:** Grayish red (10R 4/2) to dark reddish brown (10R 3/4) to moderate reddish brown (10R 4/6); quartzo-feldspathic; common to abundant felsic phenocrysts of pseudomorphs after feldspar and conspicuous quartz; rare to minor mostly altered biotite; trace lithic fragments.	
648.0–705.3 (2,126–2,314)	57.3 (188)	DA	658.4 (2,160)	**Moderately Welded Ash-Flow Tuff:** Grayish red (10R 4/2) to pale reddish brown (10R 5/4); quartzo-feldspathic; minor flattened pumice; common to abundant felsic phenocrysts of pseudomorphs after feldspar and conspicuous quartz; rare biotite; trace lithic fragments.	
705.3–724.8 (2,314–2,378) (TD)	(64)	DA	724.8 (2,378)	**Densely Welded Ash-Flow Tuff:** Grayish red (10R 4/2) to pale reddish brown (10R 5/4); quartzo-feldspathic and silicified; minor flattened pumice; common to abundant felsic phenocrysts of pseudomorphs after feldspar and conspicuous quartz; rare biotite; trace lithic fragments.	

a Lithologic samples collected from interval during drilling and logging operations and utilized for lithologic interpretation. **DA** = drill cuttings that represent lithologic character of interval.

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 4–1 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.

Notes:

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%.

Appendix E
Geophysical Logs Run in Well ER-EC-14

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Appendix E contains plots of selected geophysical logs run in Well ER-EC-14. Table E-1 summarizes the logs presented. See Table 4-2 for more information.

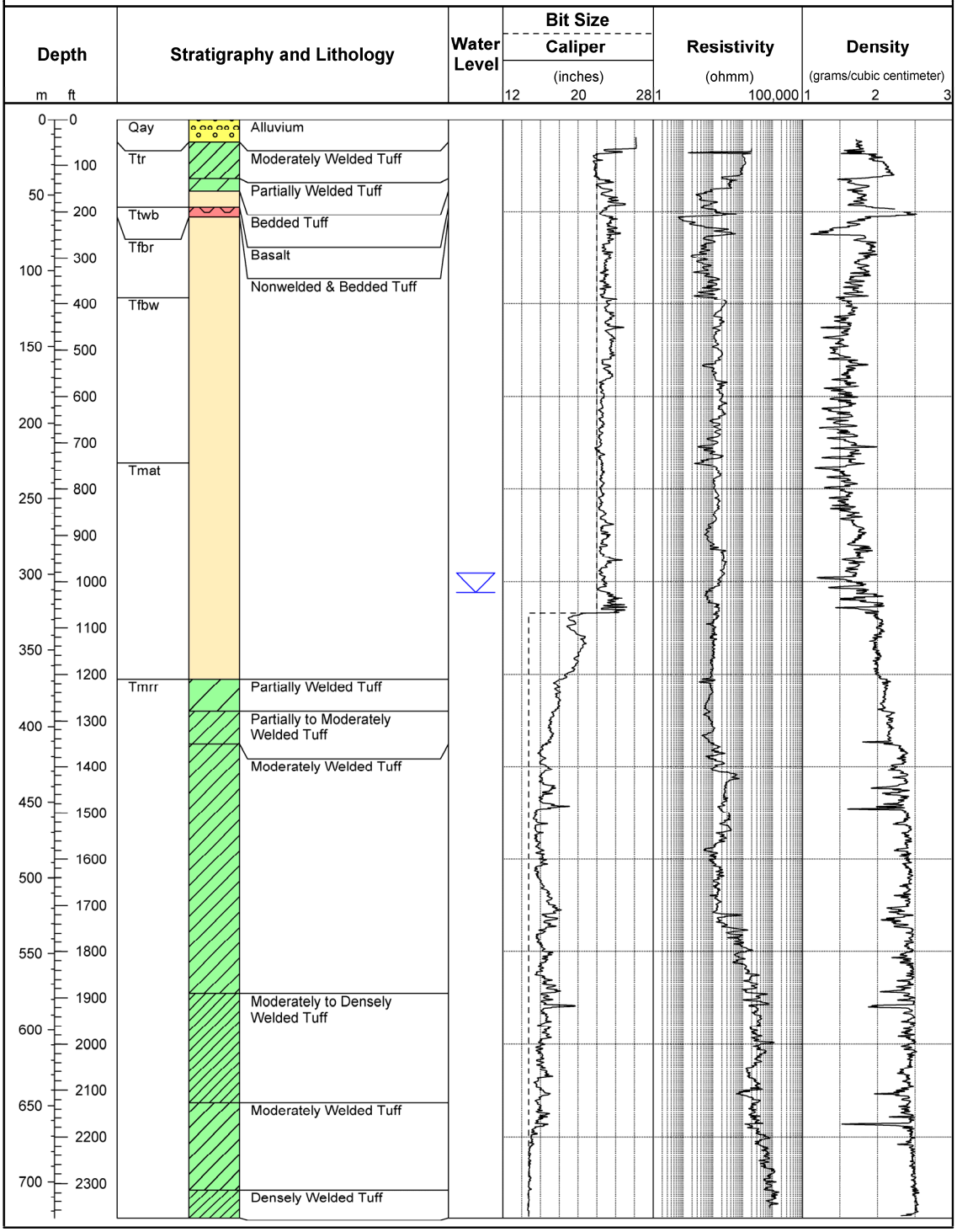
Table E-1
Well ER-EC-14 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval	
			meters	feet
Caliper	CA6-1 CA6-2	10/3/2012 10/11/2012	21.6–322.5 307.8–719.9	71–1,058 1,010–2,362
X-Multipole Array Acoustilog (sonic)	XMAC-1	10/12/2012	307.8–716.3	1,010–2,350
Gamma Ray	GR-3 GR-6	10/3/2012 10/11/2012	0–315.2 289.6–711.7	0–1,034 950–2,335
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2	10/3/2012 10/11/2012	0–315.2 289.6–711.7	0–1,034 950–2,335
High Definition Induction and R_t Explorer (resistivity)	HDIL-1 RTEX-1	10/3/2012 10/11/2012	21.6–321.9 307.8–716.9	71–1,056 1,010–2,352
Density	ZDL-1 ZDL-2	10/3/2012 10/11/2012	21.6–324.6 228.6–722.1	71–1,065 750–2,369
Compensated Neutron	CN-1 CN-2	10/3/2012 10/11/2012	21.6–324.6 228.6–722.1	71–1,065 750–2,369
Temperature	TL-1 TL-2	10/3/2012 10/11/2012	184.7–325.4 206.7–722.8	606–1,067.5 678–2,371.5

Well ER-EC-14

Logging Company: Baker Atlas
Date Logged: October 3 and 11, 2012
Drilled Depth: 724.8 m (2,378 ft)
Date TD Reached: October 11, 2012
Drill Method: Rotary/Air foam

Surface Elevation: 1,580.7 m (5,185.9 ft)
Coordinates (UTM [NAD 83]): 4,110,534.9 m
543,386.3 m
Water Level: 311.8 m (1,023.0 ft) on November 5, 2012

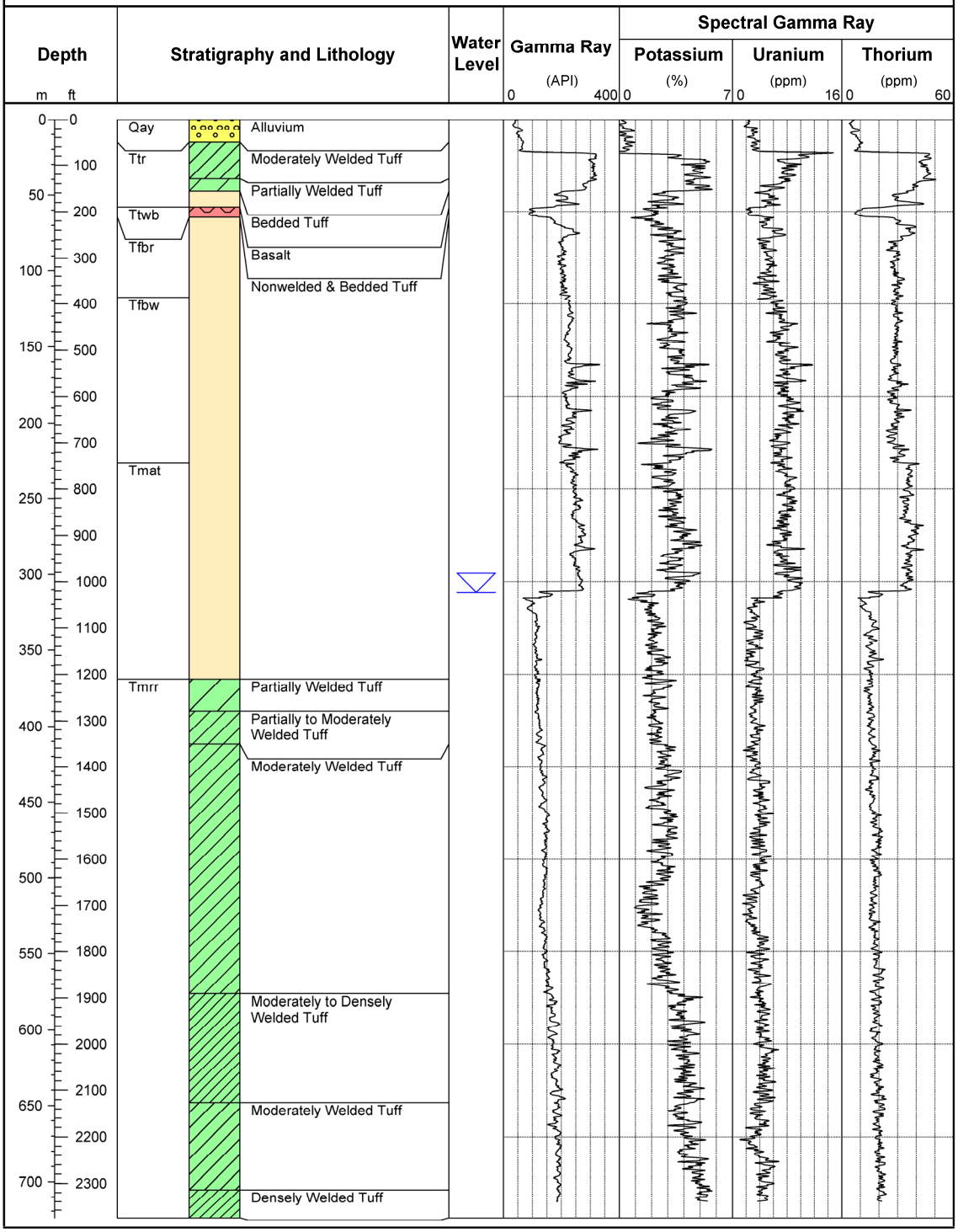


See Table 5-1 for key to stratigraphic symbols.

Well ER-EC-14

Logging Company: Baker Atlas
Date Logged: October 3 and 11, 2012
Drilled Depth: 724.8 m (2,378 ft)
Date TD Reached: October 11, 2012
Drill Method: Rotary/Air foam

Surface Elevation: 1,580.7 m (5,185.9 ft)
Coordinates (UTM [NAD 83]): 4,110,534.9 m
543,386.3 m
Water Level: 311.8 m (1,023.0 ft) on November 5, 2012

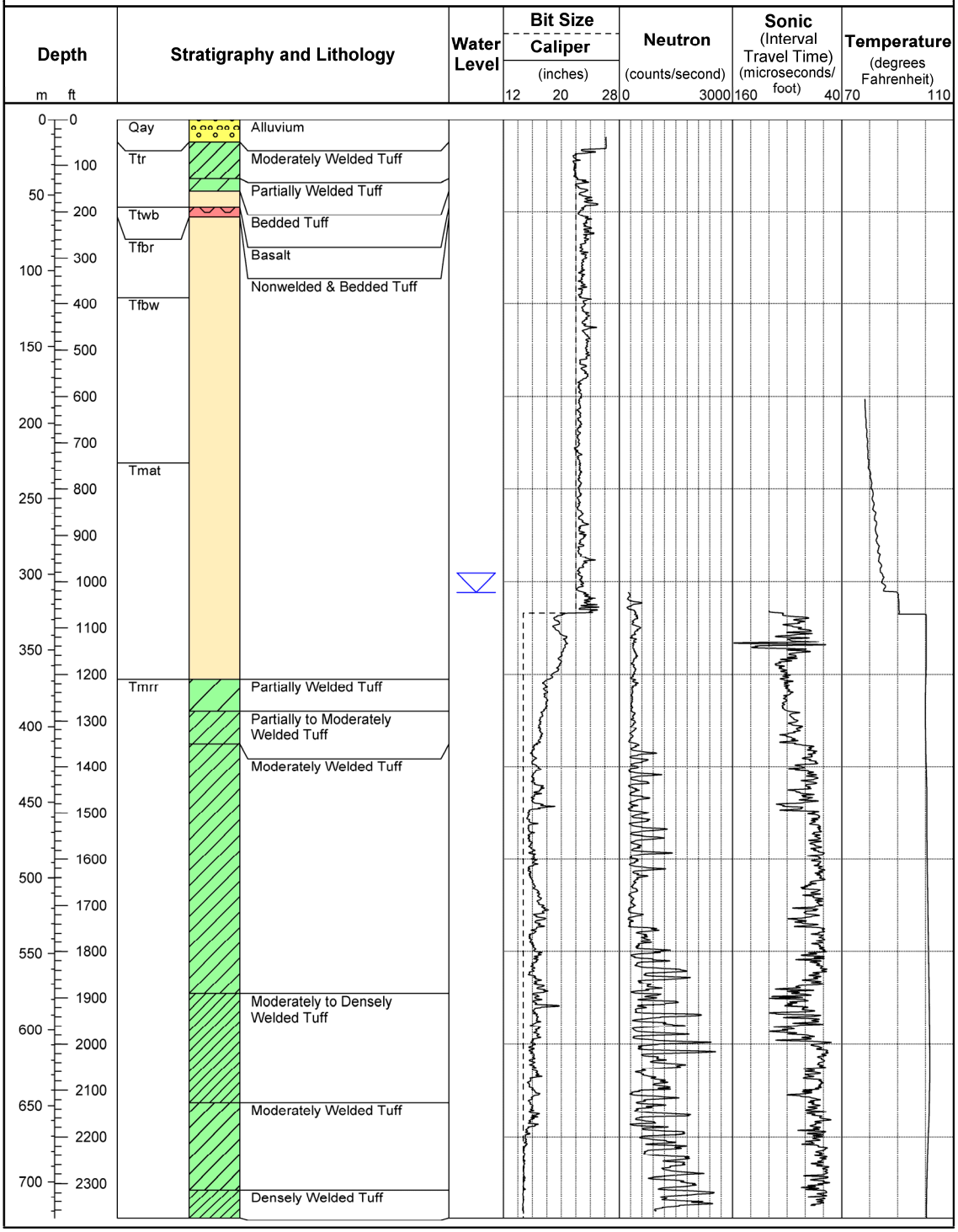


See Table 5-1 for key to stratigraphic symbols. .

Well ER-EC-14

Logging Company: Baker Atlas
Date Logged: October 3, 11, and 12, 2012
Drilled Depth: 724.8 m (2,378 ft)
Date TD Reached: October 11, 2012
Drill Method: Rotary/Air foam

Surface Elevation: 1,580.7 m (5,185.9 ft)
Coordinates (UTM [NAD 83]): 4,110,534.9 m
543,386.3 m
Water Level: 311.8 m (1,023.0 ft) on November 5, 2012



See Table 5-1 for key to stratigraphic symbols.

Appendix F
Water Production Data for Well ER-EC-14

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Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-EC-14 (two pages)

Date	Time	Depth below Ground Surface		Bromide Concentration (milligrams/liter)		Injection Rate		Water Production	
		meters	feet	Mixing Tank	Discharge Line	liters per hour	barrels per hour	liters per minute	gallons per minute
09/27/2012	21:40	27.4	90	18.4	14.4	2,385	15	11.0	3
09/28/2012	01:40	36.9	121	22.1	17.2	2,385	15	11.3	3
09/28/2012	05:25	58.8	193	25.7	16.5	2,385	15	22.2	6
09/28/2012	09:00	70.7	232	30.6	18.9	2,385	15	24.6	7
09/28/2012	15:00	83.8	275	24.1	28.4	2,385	15	-6.0	-2
09/30/2012	12:00	89.3	293	44.6	37.3	2,385	15	7.8	2
09/30/2012	16:00	116.4	382	15.5	29.9	2,385	15	-19.1	-5
09/30/2012	21:10	138.1	453	33.2	27.1	2,385	15	8.9	2
10/01/2012	00:52	174.3	572	35.3	25.7	2,385	15	14.8	4
10/01/2012	04:52	204.8	672	23.1	21.6	2,385	15	2.8	1
10/01/2012	09:10	240.8	790	30.1	34.5	2,385	15	-5.1	-1
10/01/2012	10:15	250.2	821	29.2	27.1	2,385	15	3.1	1
10/01/2012	11:15	260.9	856	21.3	20.2	2,385	15	2.2	1
10/01/2012	12:15	275.5	904	23.5	27.6	2,385	15	-5.9	-2
10/01/2012	13:15	281.9	925	22.2	24.9	2,385	15	-4.3	-1
10/01/2012	14:15	288.0	945	19.4	21.2	2,385	15	-3.4	-1
10/01/2012	15:15	296.3	972	22.2	20.4	2,385	15	3.5	1
10/01/2012	16:25	307.2	1,008	23.1	21.0	2,385	15	4.0	1
10/01/2012	16:50	311.8	1,023	28.8	27.8	2,385	15	1.4	0
10/01/2012	17:25	315.8	1,036	32.7	25.7	2,385	15	10.8	3
10/01/2012	18:10	319.4	1,048	34.6	23.7	2,385	15	18.3	5
10/01/2012	18:50	324.3	1,064	31.5	35.6	2,385	15	-4.6	-1
10/01/2012	19:00	325.8	1,069	27.2	21.9	2,385	15	9.6	3
10/06/2012	13:30	343.2	1,126	53.0	42.8	2,385	15	9.5	3
10/06/2012	15:30	367.6	1,206	59.0	46.3	2,385	15	10.9	3
10/06/2012	17:30	382.5	1,255	35.4	24.3	2,385	15	18.2	5
10/06/2012	19:30	398.4	1,307	37.6	17.3	2,385	15	46.6	12
10/06/2012	21:30	411.2	1,349	31.3	13.5	2,385	15	52.4	14
10/06/2012	23:30	419.1	1,375	29.6	7.93	2,385	15	108.6	29
10/07/2012	01:25	429.8	1,410	38.6	14.1	2,385	15	69.1	18
10/07/2012	03:30	437.1	1,434	36.8	7.17	2,385	15	164.3	43
10/07/2012	05:45	451.1	1,480	35.0	1.95	2,385	15	673.7	178
10/07/2012	07:45	460.2	1,510	4.72	0.735	2,385	15	215.5	57
10/07/2012	09:55	470.0	1,542	89.2	3.37	2,385	15	1012.3	267
10/07/2012	11:45	480.4	1,576	22.1	1.74	2,385	15	465.1	123
10/07/2012	13:45	496.5	1,629	51.3	2.00	2,385	15	979.8	259
10/07/2012	15:45	509.6	1,672	47.9	2.12	2,385	15	858.3	227
10/07/2012	17:45	522.4	1,714	22.3	1.30	2,385	15	642.1	170
10/07/2012	19:45	533.1	1,749	19.9	0.876	2,385	15	863.2	228
10/07/2012	21:40	539.8	1,771	25.4	0.983	2,385	15	987.3	261
10/07/2012	23:45	548.6	1,800	26.1	1.05	2,385	15	948.2	251
10/08/2012	02:05	560.2	1,838	29.5	0.974	2,385	15	1,164.1	308
10/08/2012	03:45	566.9	1,860	32.6	1.43	2,385	15	866.4	229
10/08/2012	06:00	577.3	1,894	28.5	0.845	2,385	15	1,300.8	344

Table F-1
Bromide Concentrations and Calculated Water Production during Drilling at Well ER-EC-14 (two pages)

Date	Time	Depth below Ground Surface		Bromide Concentration (milligrams/liter)		Injection Rate		Water Production	
		meters	feet	Mixing Tank	Discharge Line	liters per hour	barrels per hour	liters per minute	gallons per minute
10/08/2012	08:00	587.7	1,928	41.7	1.69	2,385	15	941.0	249
10/08/2012	10:00	598.3	1,963	46.4	1.34	2,385	15	1,336.6	353
10/08/2012	12:00	608.7	1,997	43.6	1.18	2,385	15	1,428.9	377
10/08/2012	15:00	613.9	2,014	45.8	0.855	2,385	15	2,089.4	552
10/08/2012	17:00	621.5	2,039	42.1	1.04	2,385	15	1,569.2	415
10/08/2012	18:00	624.2	2,048	56.1	0.771	2,385	15	2,852.3	754
10/08/2012	20:05	631.5	2,072	61.9	0.783	2,385	15	3,102.4	820
10/08/2012	22:40	635.2	2,084	70.5	0.739	2,385	15	3,752.1	991
10/09/2012	00:30	639.2	2,097	70.3	0.759	2,385	15	3,641.7	962
10/09/2012	02:30	644.0	2,113	68.2	0.753	2,385	15	3,560.2	940
10/09/2012	04:20	646.8	2,122	70.9	1.29	2,385	15	2,144.8	567
10/09/2012	06:00	649.8	2,132	65.6	0.768	2,385	15	3,355.3	886
10/09/2012	08:10	655.6	2,151	76.9	0.808	2,385	15	3,743.1	989
10/09/2012	10:10	662.0	2,172	73.1	0.601	2,385	15	4,794.7	1,267
10/09/2012	12:10	668.7	2,194	83.4	0.819	2,385	15	4,007.7	1,059
10/09/2012	14:10	673.0	2,208	68.5	0.842	2,385	15	3,193.8	844
10/09/2012	16:10	677.0	2,221	80.5	0.883	2,385	15	3,583.8	947
10/10/2012	03:00	678.2	2,225	13.7	0.606	2,385	15	858.8	227
10/10/2012	05:00	683.1	2,241	14.4	0.793	2,385	15	682.0	180
10/10/2012	07:30	687.9	2,257	60.8	1.03	2,385	15	2,306.5	609
10/10/2012	09:30	694.0	2,277	80.9	1.06	2,385	15	2,993.8	791
10/10/2012	11:30	697.7	2,289	76.6	0.758	2,385	15	3,976.9	1,051
10/10/2012	13:30	702.9	2,306	92.3	1.03	2,385	15	3,522.0	930
10/10/2012	15:30	707.1	2,320	95.4	0.978	2,385	15	3,837.4	1,014
10/10/2012	17:30	709.6	2,328	81.5	1.35	2,385	15	2,359.8	623
10/10/2012	19:30	714.1	2,343	80.2	1.46	2,385	15	2,143.6	566
10/10/2012	21:30	716.0	2,349	69.4	0.914	2,385	15	2,978.2	787
10/10/2012	23:30	721.8	2,368	75.4	1.65	2,385	15	1,776.6	469

Data from N-I (2013)

Notes:

1. Calculated water production values above the water table are not indicative of water yield from the formation.
2. Water-production data listed in this table were used to develop groundwater production estimates listed in Table F-2 and plotted in Appendix A-1-1.

Table F-2
Estimated Water Production during Drilling of Well ER-EC-14 Based on Bromide Tracer Data and Visual Observations (4 pages)

Date	Time	Drilled Depth Below Ground Surface				Estimated Water Production	
		Top (meters)	**Base** (meters)	**Top** (feet)	**Base** (feet)	Liters per minute	Gallons per minute
9/27/2012	21:30	26.8	27.4	88	90	0	0
9/27/2012	22:45	28.7	29.3	94	96	0	0
9/27/2012	23:30	30.2	30.8	99	101	0	0
9/28/2012	01:00	35.1	35.7	115	117	0	0
9/28/2012	02:15	39.6	40.2	130	132	0	0
9/28/2012	03:30	45.7	46.3	150	152	0	0
9/28/2012	04:55	54.3	54.9	178	180	0	0
9/28/2012	05:45	58.8	59.4	193	195	0	0
9/28/2012	07:35	61.9	62.5	203	205	0	0
9/28/2012	08:30	67.4	68.0	221	223	0	0
9/28/2012	12:55	71.0	71.6	233	235	0	0
9/28/2012	13:45	76.8	77.4	252	254	0	0
9/28/2012	14:50	82.3	82.9	270	272	0	0
9/30/2012	12:00	88.4	89.0	290	292	0	0
9/30/2012	13:00	96.3	96.9	316	318	0	0
9/30/2012	14:00	100.9	101.5	331	333	0	0
9/30/2012	15:00	106.4	107.0	349	351	0	0
9/30/2012	16:00	116.1	116.7	381	383	0	0
9/30/2012	17:00	124.1	124.7	407	409	0	0
9/30/2012	18:00	135.3	135.9	444	446	0	0
9/30/2012	21:20	138.4	139.0	454	456	0	0
9/30/2012	22:20	146.9	147.5	482	484	0	0
9/30/2012	23:30	163.1	163.7	535	537	0	0
10/1/2012	00:20	168.9	169.5	554	556	0	0
10/1/2012	01:25	175.0	175.6	574	576	0	0
10/1/2012	02:35	185.6	186.2	609	611	0	0
10/1/2012	03:35	193.5	194.2	635	637	0	0
10/1/2012	04:18	200.3	200.9	657	659	0	0
10/1/2012	05:00	205.1	205.7	673	675	0	0
10/1/2012	05:50	213.4	214.0	700	702	0	0
10/1/2012	07:30	228.0	228.6	748	750	0	0
10/1/2012	08:30	234.7	235.3	770	772	0	0
10/1/2012	09:40	246.3	246.9	808	810	0	0
10/1/2012	10:30	255.4	256.0	838	840	0	0
10/1/2012	11:50	269.7	270.4	885	887	0	0
10/1/2012	13:05	277.7	278.3	911	913	0	0
10/1/2012	14:30	289.9	290.5	951	953	0	0
10/1/2012	15:10	295.4	296.0	969	971	0	0
10/1/2012	16:00	303.3	303.9	995	997	0	0
10/1/2012	17:00	313.0	313.6	1,027	1,029	11.4	3
10/1/2012	17:55	317.9	318.5	1,043	1,045	7.6	2
10/1/2012	18:30	321.3	321.9	1,054	1,056	18.9	5
10/6/2012	12:05	323.1	323.7	1,060	1,062	11.4	3
10/6/2012	12:25	328.0	328.6	1,076	1,078	11.4	3
10/6/2012	12:45	332.5	333.1	1,091	1,093	11.4	3

Table F-2
Estimated Water Production during Drilling of Well ER-EC-14 Based on Bromide Tracer Data and Visual Observations (4 pages)

Date	Time	Drilled Depth Below Ground Surface				Estimated Water Production	
		Top (meters)	**Base** (meters)	**Top** (feet)	**Base** (feet)	Liters per minute	Gallons per minute
10/6/2012	13:10	340.2	340.8	1,116	1,118	11.4	3
10/6/2012	13:43	344.4	345.0	1,130	1,132	11.4	3
10/6/2012	14:30	355.7	356.3	1,167	1,169	11.4	3
10/6/2012	15:15	363.9	364.5	1,194	1,196	11.4	3
10/6/2012	16:00	371.9	372.5	1,220	1,222	11.4	3
10/6/2012	16:40	375.8	376.4	1,233	1,235	11.4	3
10/6/2012	18:00	386.2	386.8	1,267	1,269	18.9	5
10/6/2012	19:30	398.1	398.7	1,306	1,308	18.9	5
10/6/2012	20:15	402.3	402.9	1,320	1,322	18.9	5
10/6/2012	20:40	404.8	405.4	1,328	1,330	37.9	10
10/6/2012	21:30	410.9	411.5	1,348	1,350	45.4	12
10/6/2012	22:00	413.0	413.6	1,355	1,357	56.8	15
10/6/2012	22:30	414.8	415.4	1,361	1,363	56.8	15
10/6/2012	23:00	417.6	418.2	1,370	1,372	56.8	15
10/6/2012	23:30	418.8	419.4	1,374	1,376	56.8	15
10/7/2012	00:20	421.2	421.8	1,382	1,384	94.6	25
10/7/2012	01:00	425.5	426.1	1,396	1,398	94.6	25
10/7/2012	02:10	431.3	431.9	1,415	1,417	94.6	25
10/7/2012	03:00	434.6	435.3	1,426	1,428	94.6	25
10/7/2012	03:50	438.0	438.6	1,437	1,439	94.6	25
10/7/2012	04:30	441.7	442.3	1,449	1,451	151.4	40
10/7/2012	04:45	445.6	446.2	1,462	1,464	189.3	50
10/7/2012	05:25	451.4	452.0	1,481	1,483	340.7	90
10/7/2012	06:00	454.8	455.4	1,492	1,494	492.1	130
10/7/2012	07:00	457.5	458.1	1,501	1,503	529.9	140
10/7/2012	07:20	458.7	459.3	1,505	1,507	529.9	140
10/7/2012	08:20	460.9	461.5	1,512	1,514	567.8	150
10/7/2012	09:15	467.9	468.5	1,535	1,537	567.8	150
10/7/2012	10:10	470.3	470.9	1,543	1,545	643.5	170
10/7/2012	11:05	476.7	477.3	1,564	1,566	757.0	200
10/7/2012	11:55	481.9	482.5	1,581	1,583	757.0	200
10/7/2012	13:15	491.3	491.9	1,612	1,614	757.0	200
10/7/2012	13:55	496.8	497.4	1,630	1,632	870.6	230
10/7/2012	14:45	501.4	502.0	1,645	1,647	946.3	250
10/7/2012	15:20	507.5	508.1	1,665	1,667	946.3	250
10/7/2012	16:00	509.9	510.5	1,673	1,675	946.3	250
10/7/2012	16:50	516.9	517.6	1,696	1,698	946.3	250
10/7/2012	17:45	521.5	522.1	1,711	1,713	946.3	250
10/7/2012	19:10	528.2	528.8	1,733	1,735	946.3	250
10/7/2012	19:30	530.0	530.7	1,739	1,741	946.3	250
10/7/2012	20:00	533.7	534.3	1,751	1,753	946.3	250
10/7/2012	20:30	535.2	535.8	1,756	1,758	946.3	250
10/7/2012	21:30	537.7	538.3	1,764	1,766	946.3	250
10/7/2012	22:00	539.2	539.8	1,769	1,771	946.3	250
10/7/2012	22:30	541.9	542.5	1,778	1,780	946.3	250

Table F-2
Estimated Water Production during Drilling of Well ER-EC-14 Based on Bromide Tracer Data and Visual Observations (4 pages)

Date	Time	Drilled Depth Below Ground Surface				Estimated Water Production	
		Top (meters)	**Base** (meters)	**Top** (feet)	**Base** (feet)	Liters per minute	Gallons per minute
10/7/2012	23:00	545.3	545.9	1,789	1,791	946.3	250
10/8/2012	00:05	549.6	550.2	1,803	1,805	946.3	250
10/8/2012	00:30	552.6	553.2	1,813	1,815	1,059.8	280
10/8/2012	01:30	556.9	557.5	1,827	1,829	1,059.8	280
10/8/2012	02:00	558.7	559.3	1,833	1,835	1,059.8	280
10/8/2012	02:30	561.1	561.7	1,841	1,843	1,059.8	280
10/8/2012	03:00	563.0	563.6	1,847	1,849	1,059.8	280
10/8/2012	03:30	564.8	565.4	1,853	1,855	1,059.8	280
10/8/2012	04:30	568.1	568.8	1,864	1,866	1,059.8	280
10/8/2012	05:00	572.7	573.3	1,879	1,881	1,059.8	280
10/8/2012	05:20	575.8	576.4	1,889	1,891	1,059.8	280
10/8/2012	06:20	578.2	578.8	1,897	1,899	1,135.5	300
10/8/2012	07:00	581.6	582.2	1,908	1,910	1,135.5	300
10/8/2012	07:30	585.5	586.1	1,921	1,923	1,135.5	300
10/8/2012	08:15	590.1	590.7	1,936	1,938	1,135.5	300
10/8/2012	10:00	598.0	598.6	1,962	1,964	1,135.5	300
10/8/2012	11:30	606.2	606.9	1,989	1,991	1,324.8	350
10/8/2012	12:30	609.3	609.9	1,999	2,001	1,324.8	350
10/8/2012	14:50	612.6	613.3	2,010	2,012	1,514.0	400
10/8/2012	16:15	618.4	619.0	2,029	2,031	1,703.3	450
10/8/2012	16:45	620.3	620.9	2,035	2,037	1,703.3	450
10/8/2012	17:40	623.0	623.6	2,044	2,046	1,703.3	450
10/8/2012	18:15	624.2	624.8	2,048	2,050	1,703.3	450
10/8/2012	19:00	626.7	627.3	2,056	2,058	1,703.3	450
10/8/2012	19:30	628.8	629.4	2,063	2,065	1,703.3	450
10/8/2012	20:00	630.6	631.2	2,069	2,071	1,892.5	500
10/8/2012	20:30	631.5	632.2	2,072	2,074	1,892.5	500
10/8/2012	21:00	632.5	633.1	2,075	2,077	2,081.8	550
10/8/2012	21:30	633.4	634.0	2,078	2,080	2,271.0	600
10/8/2012	22:30	634.3	634.9	2,081	2,083	2,271.0	600
10/8/2012	23:00	635.2	635.8	2,084	2,086	2,271.0	600
10/8/2012	23:30	637.0	637.6	2,090	2,092	2,271.0	600
10/9/2012	00:00	637.6	638.3	2,092	2,094	2,271.0	600
10/9/2012	00:20	637.9	638.6	2,093	2,095	2,271.0	600
10/9/2012	01:00	638.9	639.5	2,096	2,098	2,271.0	600
10/9/2012	01:30	640.4	641.0	2,101	2,103	2,460.3	650
10/9/2012	02:00	641.3	641.9	2,104	2,106	2,460.3	650
10/9/2012	04:10	645.3	645.9	2,117	2,119	2,460.3	650
10/9/2012	05:00	646.8	647.4	2,122	2,124	2,460.3	650
10/9/2012	06:30	650.4	651.1	2,134	2,136	2,460.3	650
10/9/2012	07:10	653.2	653.8	2,143	2,145	2,460.3	650
10/9/2012	08:10	655.3	655.9	2,150	2,152	2,649.5	700
10/9/2012	09:40	659.3	659.9	2,163	2,165	2,649.5	700
10/9/2012	10:17	662.0	662.6	2,172	2,174	2,649.5	700
10/9/2012	11:20	666.0	666.6	2,185	2,187	2,838.8	750

Table F-2
Estimated Water Production during Drilling of Well ER-EC-14 Based on Bromide Tracer Data and Visual Observations (4 pages)

Date	Time	Drilled Depth Below Ground Surface				Estimated Water Production	
		Top (meters)	**Base** (meters)	**Top** (feet)	**Base** (feet)	Liters per minute	Gallons per minute
10/9/2012	12:35	669.0	669.6	2,195	2,197	2,838.8	750
10/9/2012	13:45	670.9	671.5	2,201	2,203	3,028.0	800
10/9/2012	14:32	673.0	673.6	2,208	2,210	3,028.0	800
10/9/2012	15:35	675.1	675.7	2,215	2,217	3,028.0	800
10/10/2012	03:00	677.6	678.2	2,223	2,225	1,892.5	500
10/10/2012	04:00	679.4	680.0	2,229	2,231	1,892.5	500
10/10/2012	05:00	682.4	683.1	2,239	2,241	2,271.0	600
10/10/2012	05:45	684.3	684.9	2,245	2,247	2,649.5	700
10/10/2012	07:40	687.6	688.2	2,256	2,258	3,028.0	800
10/10/2012	08:43	688.5	689.2	2,259	2,261	3,028.0	800
10/10/2012	09:45	693.4	694.0	2,275	2,277	3,028.0	800
10/10/2012	11:37	696.8	697.4	2,286	2,288	3,028.0	800
10/10/2012	12:28	699.2	699.8	2,294	2,296	3,028.0	800
10/10/2012	13:49	702.3	702.9	2,304	2,306	3,028.0	800
10/10/2012	15:15	705.3	705.9	2,314	2,316	3,028.0	800
10/10/2012	16:45	708.1	708.7	2,323	2,325	3,028.0	800
10/10/2012	17:30	709.0	709.6	2,326	2,328	3,028.0	800
10/10/2012	18:28	711.4	712.0	2,334	2,336	3,028.0	800
10/10/2012	19:30	713.5	714.1	2,341	2,343	3,028.0	800
10/10/2012	21:08	714.8	715.4	2,345	2,347	3,028.0	800
10/10/2012	22:08	717.5	718.1	2,354	2,356	3,028.0	800
10/10/2012	22:59	719.6	720.2	2,361	2,363	3,028.0	800
10/11/2012	00:05	722.7	723.3	2,371	2,373	3,028.0	800

Source: Unpublished data from N-I, January 18, 2013

Note: Data in this table were used to make the water-production plot shown in Appendix A-1.

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