DOE/NV--1180

Nevada
Environmental
Restoration
Project

Completion Report for Well ER-16-1

Corrective Action Unit 99: Rainier Mesa - Shoshone Mountain

December 2006

Environmental Restoration Project

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

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COMPLETION REPORT FOR WELL ER-16-1

CORRECTIVE ACTION UNIT 99: RAINIER MESA - SHOSHONE MOUNTAIN, NEVADA

Approved by: *Kent C. Thompson* Date: *13 Dec 06*

Kent C. Thompson
Acting Federal Sub-Project Director
Underground Test Area Project

Approved by: *Wilhelm R. Wilborn* Date: *12/13/2006*

Wilhelm R. Wilborn
Acting Federal Project Director
Environmental Restoration Project

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Abstract

Well ER-16-1 was drilled for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, in support of the Nevada Environmental Restoration Project at the Nevada Test Site, Nye County, Nevada. The well was drilled in June and July 2005 as part of a hydrogeologic investigation program for the Rainier Mesa-Shoshone Mountain Corrective Action Unit, Number 99. The overall purpose of the well was to gather subsurface data to better characterize the hydrogeology of the Shoshone Mountain area, especially in the older Tertiary and pre-Tertiary strata. The main 46.99-centimeter hole was drilled to a depth of 702.9 meters and cased with 33.97-centimeter casing to 663.7 meters. The hole diameter was then decreased to 31.1 centimeters, and the well was drilled to total depth of 1,220.7 meters. A completion string set at the depth of 1,162.4 meters consisted of 13.97-centimeter stainless-steel casing, with one continuous slotted interval open to the lower carbonate aquifer.

The fluid level in the borehole soon dropped, so the borehole was deepened in July 2006. To deepen the borehole, the slotted section was cemented and a 12.1-centimeter hole was drilled through the bottom of the completion string to the new total depth of 1,391.7 meters, which is 171.0 meters deeper than the original borehole. A string of 6.03-centimeter carbon-steel tubing with one continuous slotted interval at 1,361.8 to 1,381.4 meters, and open to the lower carbonate aquifer, was installed in the well with no gravel packing or cement, to serve as a monitoring string.

Data gathered during and shortly after hole construction include composite drill cuttings samples collected every 3 meters (extra cuttings samples were collected from the Paleozoic rocks for paleontological analyses), sidewall core samples from 37 depths, various geophysical logs, and water level measurements. These data indicate that the well penetrated 646.8 meters of Tertiary volcanic rocks and 744.9 meters of Paleozoic dolomite, quartzite, shale, and limestone. Three weeks after the monitoring string was installed, the water level was tagged at the drill hole depth of 1,271.9 meters, which equates to an estimated elevation of 761.7 meters, accounting for the borehole angle.

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List of Acronyms and Abbreviations

BHA	bottom-hole assembly
BN	Bechtel Nevada
C	analysis complete
CAU	Corrective Action Unit
cm	centimeter(s)
DC	drill cuttings
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
E	east
FAWP	Field Activity Work Plan
FMP	Fluid Management Plan
ft	foot (feet)
HES	Halliburton Energy Services
in.	inch(es)
LANL	Los Alamos National Laboratory
LCA	lower carbonate aquifer
m	meter(s)
Ma	million years (ago)
N	north
NAD	North American Datum
NARA	National Archives and Records Administration
NP	not planned
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSA/NV	U.S. Department of Energy, National Nuclear Security Administration Nevada Operation Office
NSTec	National Security Technologies, LLC
NTS	Nevada Test Site
pCi/L	picocuries per liter
RM-SM	Rainier Mesa - Shoshone Mountain
SNJV	Stoller-Navarro Joint Venture
SWC	sidewall coring tool
TD	total depth
UCA	upper carbonate aquifer

List of Acronyms and Abbreviations (continued)

UCCU	upper clastic confining unit
UGTA	Underground Test Area
UDI	United Drilling, Inc.
USGS	U.S. Geological Survey
XRD	x-ray diffraction
XRF	x-ray fluorescence

1.0 Introduction

1.1 Project Description

Well ER-16-1 was drilled for the U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Site Office (NNSA/NSO) in support of the Nevada Environmental Restoration Project at the Nevada Test Site (NTS), Nye County, Nevada. Well ER-16-1 was the third of three wells drilled as part of a hydrogeologic investigation program for the Rainier Mesa-Shoshone Mountain (RM-SM) Corrective Action Unit (CAU) 99.

The RM-SM CAU and the associated well drilling program are part of the NNSA/NSO Environmental Restoration Project's Underground Test Area (UGTA) sub-project at the NTS. The goals of the UGTA sub-project include evaluating the nature and extent of contamination in groundwater due to underground nuclear testing, and establishing a long-term groundwater monitoring network. As part of the UGTA sub-project, scientists are developing computer models to predict groundwater flow and contaminant migration within and near the NTS. To build and test these models, it is necessary to collect geologic, geophysical, and hydrologic data from new and existing wells to define groundwater quality, migration pathways, and migration rates. Data from these wells will allow for more accurate modeling of groundwater flow and radionuclide migration in the region. Some of the wells may also function as long-term monitoring wells.

This hydrogeologic investigation well program is also part of the Corrective Action Investigation Plan (U.S. Department of Energy, National Nuclear Security Administration Nevada Operations Office [NNSA/NV], 2004) for the RM-SM CAU. This plan is a requirement of the *Federal Facility Agreement and Consent Order* (1996), agreed to by the DOE, the Nevada Division of Environmental Protection, and the U.S. Department of Defense.

Well ER-16-1 was drilled in 2005 as part of the RM-SM CAU Phase I drilling initiative. The well is located on top of Shoshone Mountain in the southern part of NTS Area 16, and the borehole collar is positioned above the workings of U16a Tunnel on Tippipah Point (Figure 1-1). The well was planned to provide geologic and hydrogeologic information for Tertiary volcanic rocks within which the U16a Tunnel drifts were mined, and for the underlying Paleozoic rocks.

Stoller-Navarro Joint Venture (SNJV) was the principal environmental contractor for the project, and SNJV personnel collected geologic and hydrologic data during drilling. The drilling

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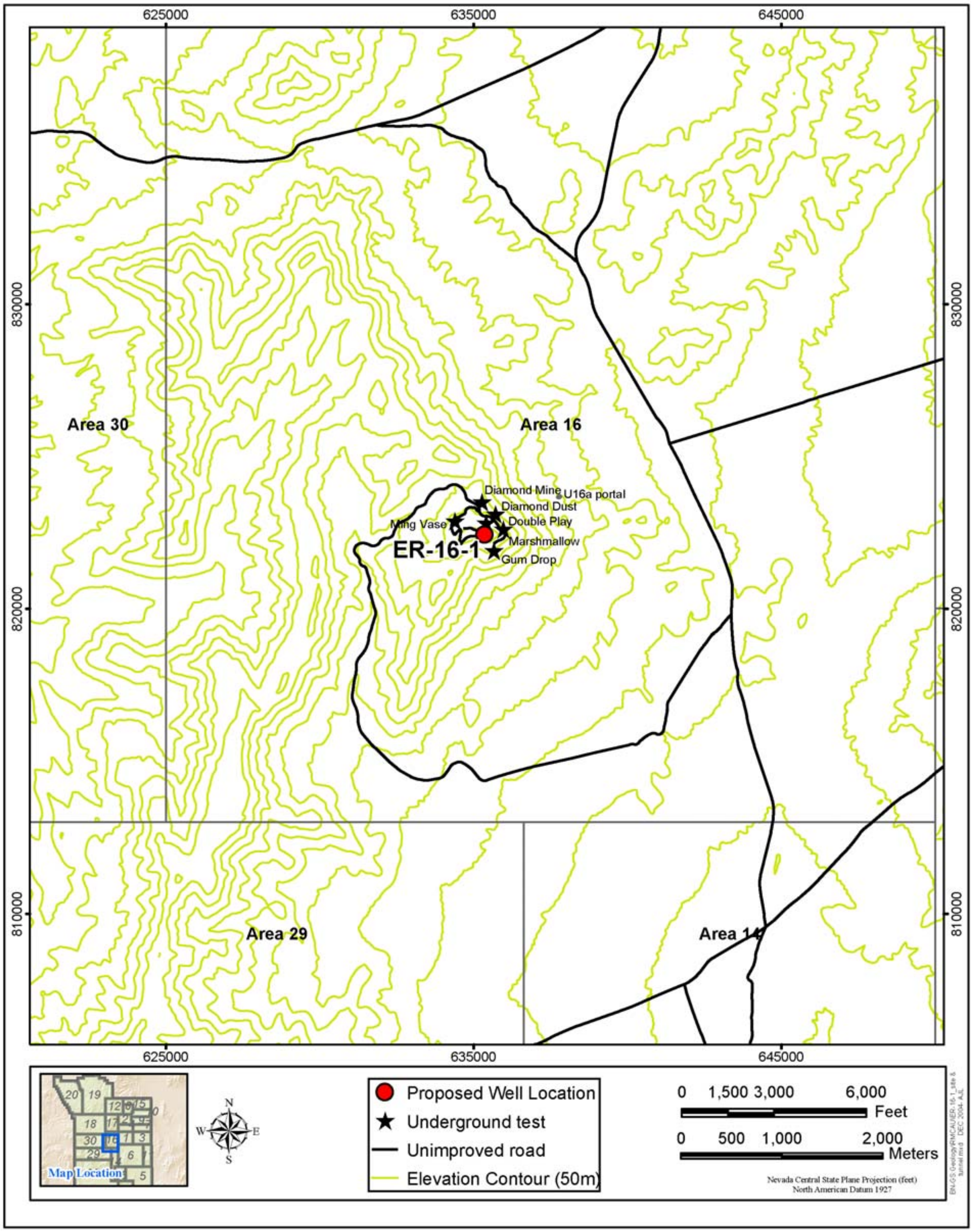

Figure 1-1
Reference Map Showing Location of Well ER-16-1

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company was United Drilling, Incorporated (UDI), a subcontractor to Bechtel Nevada (BN), the NTS management and operating contractor to DOE at the time. The well was deepened in 2006 by drillers employed by the new NTS management and operating contractor, National Security Technologies, LLC (NSTec). Site supervision, engineering, construction, inspection, and geologic support were provided by BN and NSTec. The roles and responsibilities of these and other contractors involved in the project are described in BN subcontract number 31874, and in Field Activity Work Plans (FAWPs) number D-005-002.05 and D-006-001.06 (BN, 2005; 2006). The UGTA Technical Working Group, a committee of scientists and engineers from NNSA/NSO, Lawrence Livermore National Laboratory, Los Alamos National Laboratory (LANL), and various contractors, provided additional technical advice during drilling, design, and construction of the well. See *Rainier Mesa-Shoshone Mountain Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2005a) for descriptions of the general plan and goals of the RM-SM drilling initiative project, as well as specific goals for each well.

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/NV, 2002). Estimates of expected production of fluid and drill cuttings for the RM-SM holes are given in Appendix D of the drilling and completion criteria document for the drilling project (SNJV, 2005a), along with sampling requirements and contingency plans for management of any hazardous waste produced. All activities were conducted according to the BN FAWPs (BN, 2005; 2006) and the UGTA Project Health and Safety Plan (BN, 2004).

This report presents construction data and summarizes scientific data gathered during the original drilling and the deepening of Well ER-16-1. Some of the information in this report is preliminary and unprocessed, but is being released with the drilling and completion data for convenient reference. Well data reports prepared by SNJV contain additional information on fluid management, waste management, and environmental compliance for the original drilling (SNJV, 2005b) and for the deepening of the well (SNJV, 2006). Updated geologic information for this area (including any changes in the geologic interpretation) is compiled in the data documentation package for the RM-SM hydrostratigraphic framework model in preparation by NSTec. Information on well development, aquifer testing, and groundwater analytical sampling (outside the scope of this report) will be compiled and disseminated separately.

1.2 Location and Significant Nearby Features

Well ER-16-1 is located on Shoshone Mountain in NTS Area 16 (Figure 1-1) near the workings of the U16a Tunnel. The U16a Tunnel was the site of six underground nuclear tests conducted in the mined horizontal drifts. The drill site is located 120 meters (m) (393 feet [ft]) north of the surface ground zero of the closest test, U16a.03 DOUBLE PLAY, and14.6 m (48 ft) northwest of the exploratory core hole UE-16a#1.

1.2.1 Location

Well ER-16-1 is located on Tippipah Point, a high volcanic mesa that is part of the larger dissected volcanic plateau known as Shoshone Mountain. The surface topography at the wellhead is relatively flat, but drops away steeply in all directions from the drill site. The elevation of the construction pad is 2,009.1 m (6,591.5 ft). Additional information about Well ER-16-1 is provided in Table 1-1.

Table 1-1
Well ER-16-1 Site Data Summary

Well Designation	ER-16-1
Site Coordinates [a]	Nevada State Plane (central zone) (NAD 83): N 6,250,672.9 m (N 20,507.416.1 ft) E 541,177.1 m (E 1,775,511.9 ft) Nevada State Plane (central zone) (NAD 27): N 822,414.1 ft E 635,354.3 ft Universal Transverse Mercator (Zone 11)(NAD 83): N 4,096,113.4 m E 570,820.7 m
Surface Elevation [a, b]	2,009.1 m (6,591.5 ft)
Drilled Depth	1,220.7 m (4,005 ft) on June 28, 2005 1,391.7 m (4,566 ft) on July 31, 2006
Fluid-Level Depth	1,271.9 m (4,173 ft) [c] 1,247.5 m (4,093 ft) [d]
Fluid-Level Elevation [e]	761.7 m (2,499 ft)

a Measurement made by BN Survey. NAD = North American Datum (National Archives and Records Administration [NARA], 1989; U.S. Coast and Geodetic Survey, 1927)
b Measurement made by BN Survey. Elevation at top of construction pad. National Geodetic Vertical Datum, 1929 (NARA, 1973).
c Measured drilled depth. Measured by SNJV on August 25, 2006 (SNJV, 2006).
d Estimated true vertical depth after correction for borehole deviation.
e Estimated elevation after correction for borehole deviation.

1.2.2 Underground Nuclear Tests in the Vicinity of Well ER-16-1

Six underground nuclear tests were conducted in U16a Tunnel, all in mined horizontal drifts, and all sponsored by the U.S. Department of Defense. Four were weapons effects tests and two were Vela Uniform seismic verification tests; all were less than 20 kilotons in yield (U.S. Department of Energy, Nevada Operations Office [DOE/NV], 2000). All six tests were sited in zeolitized bedded tuff of the Tunnel Formation (lower tuff confining unit), at elevations ranging from 1,652.6 to 1,657.2 m (5,423 to 5,437 ft) above sea level. Available mining records include nothing to indicate the presence of significant quantities of water encountered during mining or exploratory drilling. The regional static water level is estimated to be more than 893 m (2,931 ft) below the average working point elevation for U16a Tunnel tests. Severe cracking of the ground surface was observed after several of the tests, but none collapsed to the surface (Grasso, 2003). Additional information pertaining to the U16a Tunnel tests is provided in Table 1-2.

Table 1-2
Selected Information for Underground Nuclear Tests Relevant to Well ER-16-1

Tunnel Drift Designation	**Test Name** [a]	**Test Date** [a]	**Surface Elevation** (meters)	**Depth of Burial** (meters)	**Distance from Well ER-16-1** [b] (meters)
U16a.01	MARSHMALLOW	06/28/1962	1,968	315	189
U16a.02	GUM DROP	04/21/1965	1,967	314	180
U16a.03	DOUBLE PLAY	06/15/1966	1,981	327	120
U16a.04	MING VASE	11/20/1968	1,961 [c]	306 [c]	329
U16a.05	DIAMOND DUST	05/12/1970	1,920 [c]	264 [c]	231
U16a.06	DIAMOND MINE	07/01/1971	1,920 [c]	263 [c]	329

a Source: DOE/NV, 2000.
b Approximate horizontal distance from surface ground zero of test to wellhead of Well ER-16-1.
c Approximate.

All yields less than 20 kilotons (DOE/NV, 2000).
All tests conducted within the lower tuff confining unit.

1.3 Objectives

The overall purpose of constructing Well ER-16-1 was to obtain information that will help characterize the hydrogeology of the Shoshone Mountain area, particularly for the lower Tertiary volcanic rocks and for the underlying Paleozoic sedimentary rocks. In addition, the well was planned to facilitate detection and sampling of any perched water near the tunnel elevation and to determine the depth to the regional static water level. Ultimately, data from this well will help improve the understanding of the hydrogeology in the southern part of the RM-SM CAU and help reduce uncertainties in the hydrostratigraphic framework model for the RM-SM CAU.

As described in Appendix C of the drilling and completion criteria document for the RM-SM wells (SNJV, 2005a), the well-specific objectives for Well ER-16-1 include the following:

a. Obtain geologic samples and geophysical data that will aid in defining hydrostratigraphic units and characterizing any geologic structures encountered. This geologic information is being used to support the development of an UGTA CAU-specific hydrostratigraphic framework model and reduce uncertainties, especially regarding:

   – Hydrogeologic character of the lower Tertiary volcanic section, including the vertical distribution of reactive minerals such as clays, zeolites, and iron oxides.

   – Extent and thickness of the upper carbonate aquifer (UCA) and the upper clastic confining unit (UCCU).

   – Character of structural features such as the syncline at Syncline Ridge and imbricate thrust faults in the UCCU.

   – Detailed fracture data.

b. Obtain detailed water-level data to determine the regional water level and investigate potential local groundwater flow toward Yucca Flat.

c. Investigate the possibility of perched water zones above the regional water level.

d. Obtain aqueous geochemistry samples from the UCA and/or the UCCU to establish water chemistry and age.

Additional data from future hydraulic testing at this well will help characterize the hydrology in the Shoshone Mountain area. Well ER-16-1 is expected to provide the following:

a. Data for determination of vertical and horizontal conductivity.

b. Hydraulic properties of the saturated units penetrated.

Some of these objectives will not be met until additional work, outside the scope of this report, is completed, including installing a pump and conducting hydraulic testing, and analyzing geology and hydrology data from this and other wells in the RM-SM area.

See discussions in Sections 4.0 and 5.0 for more information on the objectives mentioned above.

1.4 Project Summary

This section summarizes Well ER-16-1 construction operations; the details are provided in Sections 2.0 through 7.0 of this report.

A 121.9-centimeter (cm) (48-inch [in.]) diameter surface conductor hole was constructed by drilling to a depth of 16.5 m (54 ft), and installing a string of 30-in. conductor casing to the depth of 15.9 m (52 ft). Drilling of the main hole with an 18½-in. tri-cone bit, using a foam/polymer fluid in conventional circulation, began on June 12, 2005. A suitable place to set the surface casing was reached at 703.2 m (2,307 ft), and drilling was suspended, as planned, for geophysical logging prior to installing the casing. A string of 13⅜-in. casing was set at 663.7 m (2,177.6 ft) on June 22, 2005. The main hole was drilled with a 12¼-in. bit using air-foam to a total depth (TD) of 1,220.7 m (4,005 ft), which was reached on June 28, 2005.

The well was completed with 5½-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing. The completion casing was landed at 1,162.4 m (3,813.5 ft). The 5½-in. casing was slotted in the interval 1,109.4 to 1,148.5 m (3,639.9 to 3,768.0 ft), which allowed access to the lower carbonate aquifer (LCA). No piezometer strings were installed in the well.

The water level within the wellbore dropped several months after installation of the completion string, and it became necessary to deepen the well. The lower, slotted portion of the completion string was perforated to accommodate cementing of the bottom of the borehole, and thus stabilize the casing during drilling. NSTec drillers began drilling out cement and fill with a 4¾-in. bit on July 10, 2006, and continued drilling into the formation on July 13, 2006. The new TD of 1,391.7 m (4,566 ft) was reached on July 31, 2006. A string of 2⅜-in. tubing was landed at 1,381.4 m (4,532.3 ft), which is slotted in the interval 1,361.8 to 1,381.4 m (4,467.8 to 4,532.3 ft).

Composite drill cuttings were collected every 3 m (10 ft) from the depth of 16.5 m (54 ft) to TD, and 37 percussion sidewall core samples were taken at various depths between 189.0 and 1,177.4 m (620 and 3,863 ft). Open-hole geophysical logging of the well was conducted to help verify the geology and characterize the hydrologic properties of the rocks; some logs also aided in the construction of the well by indicating borehole volume and condition. The well penetrated 646.8 m (2,122 ft) of Tertiary volcanic rocks and 744.9 m (2,444 ft) of Paleozoic shale, quartzite, limestone, and dolomite.

1.5 Project Director

Inquiries concerning Well ER-16-1 should be directed to the UGTA Federal Project Director at:

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

2.0 Drilling Summary

2.1 Introduction

This section contains detailed descriptions of the drilling process and fluid management issues. The general drilling requirements for all three 2005 Rainier Mesa-Shoshone Mountain wells were provided in *Rainier Mesa-Shoshone Mountain Hydrogeologic Investigation Wells Drilling and Completion Criteria* (SNJV, 2005a). Specific requirements for Well ER-16-1 were outlined in FAWP number D-005-002.05 (BN, 2005), and requirements for the deepening of the borehole were outlined in FAWP number D-006-001.06 (BN, 2006). Figure 2-1 shows the layout of the drill site. Figure 2-2 is a chart of the drilling and completion history, including deepening and recompletion, for Well ER-16-1. A summary of drilling statistics for the well is given in Table 2-1. The following information was compiled primarily from BN and NSTec daily drilling reports.

2.2 Drilling History for the Original Borehole

Field operations at Well ER-16-1 began on May 9, 2005, when BN drillers, using the CP-750 drill rig, drilled a 121.9-cm (48-in.) hole through the welded tuff caprock to 16.5 m (54 ft). The hole became unstable at about 5.2 m (17 ft) and severe caving of the borehole wall continued to the bottom of the conductor hole. Two intervals, 4.9 to 7.9 m (16 to 26 ft) and 7.6 to 10.7 m (25 to 35 ft), had to be cemented and re-drilled. A hydraulically operated down-hole grappling device mounted on drill pipe (“hydro-grab”) was used to remove from the borehole large boulders that the auger bit could not break up. A string of 30-in. conductor casing was set at the depth of 16.0 m (52.6 ft). The conductor casing was cemented in place on May 23, 2005, with Type II cement, with a rise inside the casing to 14.8 m (48.6 ft).

There was no further activity at the well site until the UDI crews arrived and rigged up the Wilson Mogul 42B drill rig, June 4 to 13, 2005. The drillers tagged the top of cement inside the 30-in. casing at 14.9 m (49 ft), indicating that the cement surface had dropped slightly in the 3 weeks since its emplacement. The drill crew worked through the cement at the bottom of the 30-in. casing with a center-punch assembly consisting of an 18½-in. rotary bit mounted 2.6 m (8.4 ft) below a 26-in. hole opener. The drill fluid was an air/water/soap mix with a polymer additive (“polymer-foam”) in conventional circulation. The hole opener was removed when the hole reached the depth of 18.9 m (62 ft).

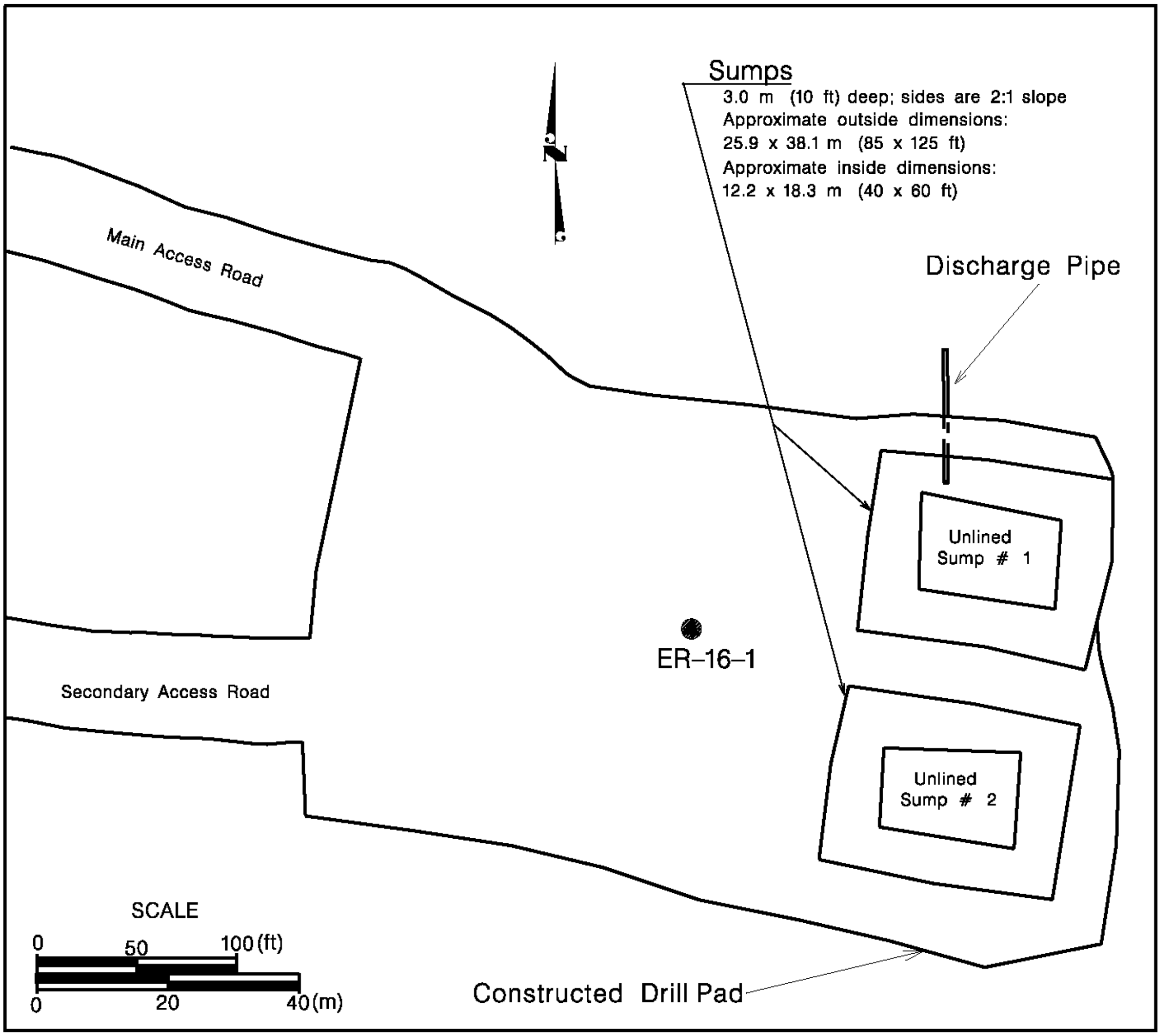

Figure 2-1
Drill Site Configuration for Well ER-16-1

WELL ER–16–1 SUMMARY

Activity	Date
Begin drilling for conductor hole:	05/09/2005
Conductor hole completed and 30–in. casing set to 15.9m (52 ft):	05/23/2005
Begin drilling 18 1/2–in. surface hole:	06/12/2005
13 3/8–in. surface casing set at 663.7 m (2,177.59 ft):	06/22/2005
Begin drilling 31.1–cm (12.25–in.) main hole:	06/23/2005
Reach drilled depth of 1,220.7 m (4,005 ft):	06/28/2005
Well completed:	07/01/2005
Begin recompletion activities:	06/19/2006
Reach final TD of 1,391.7 m (4,566 ft):	07/31/2006
Final completion:	08/04/2006

LEGEND

BHA	bottom hole assembly
BN	Bechtel Nevada
cm	centimeter(s)
DRI	Desert Research Institute
ft	foot (feet)
gpm	gallons per minute
HES	Halliburton Energy Services
in.	inch(es)
lpm	liters per minute
m	meter(s)
NSTec	National Security Technologies (Successor to BN)
SLM	steel line measurement
SNJV	Stoller Navarro Joint Venture
TD	total depth
TIH	trip into hole
TOC	top of cement
TOH	trip out of hole
UDI	United Drilling Inc.

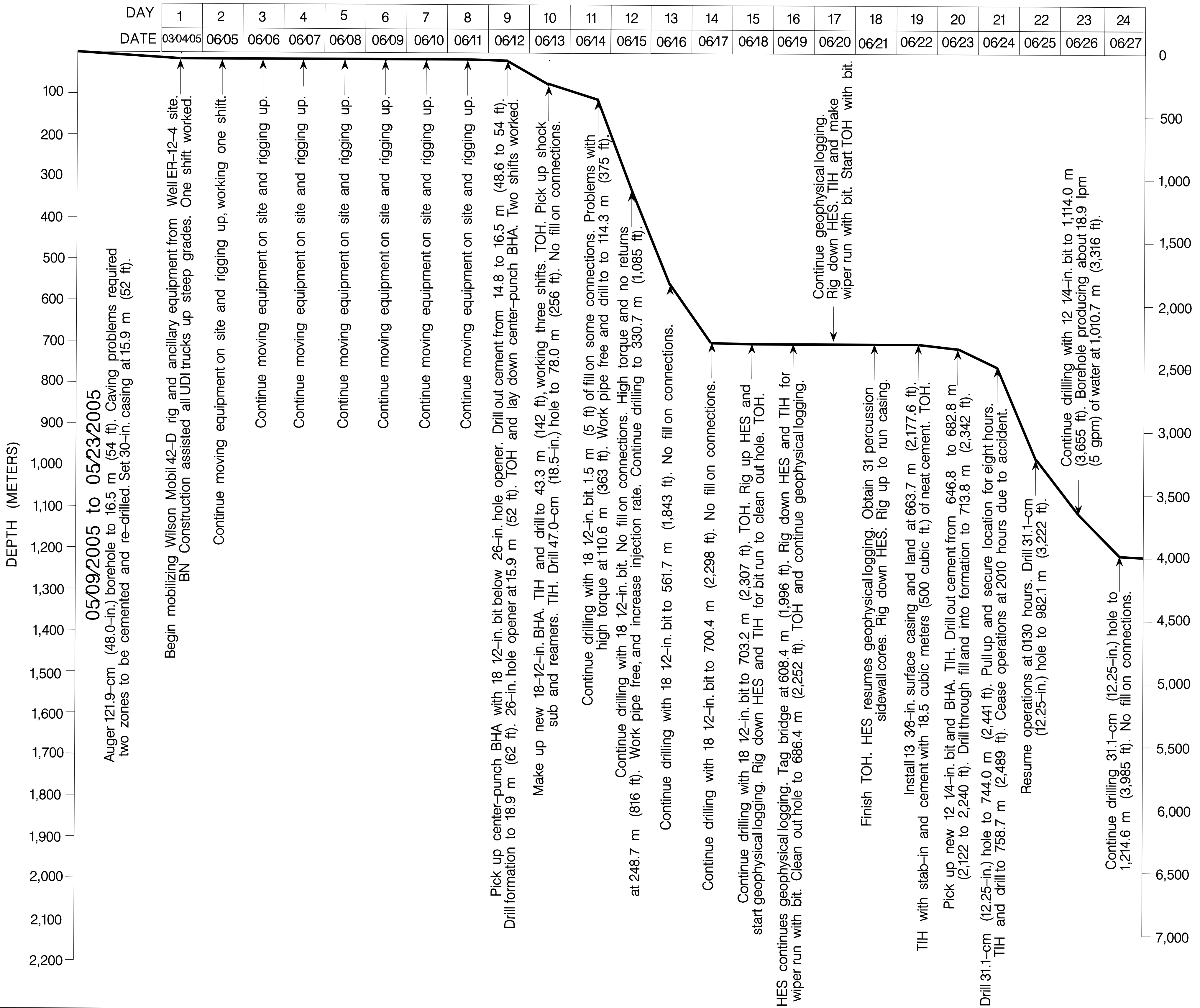

FIGURE 2–2

WELL ER–16–1
DRILLING AND COMPLETION HISTORY
SHEET 1 OF 3

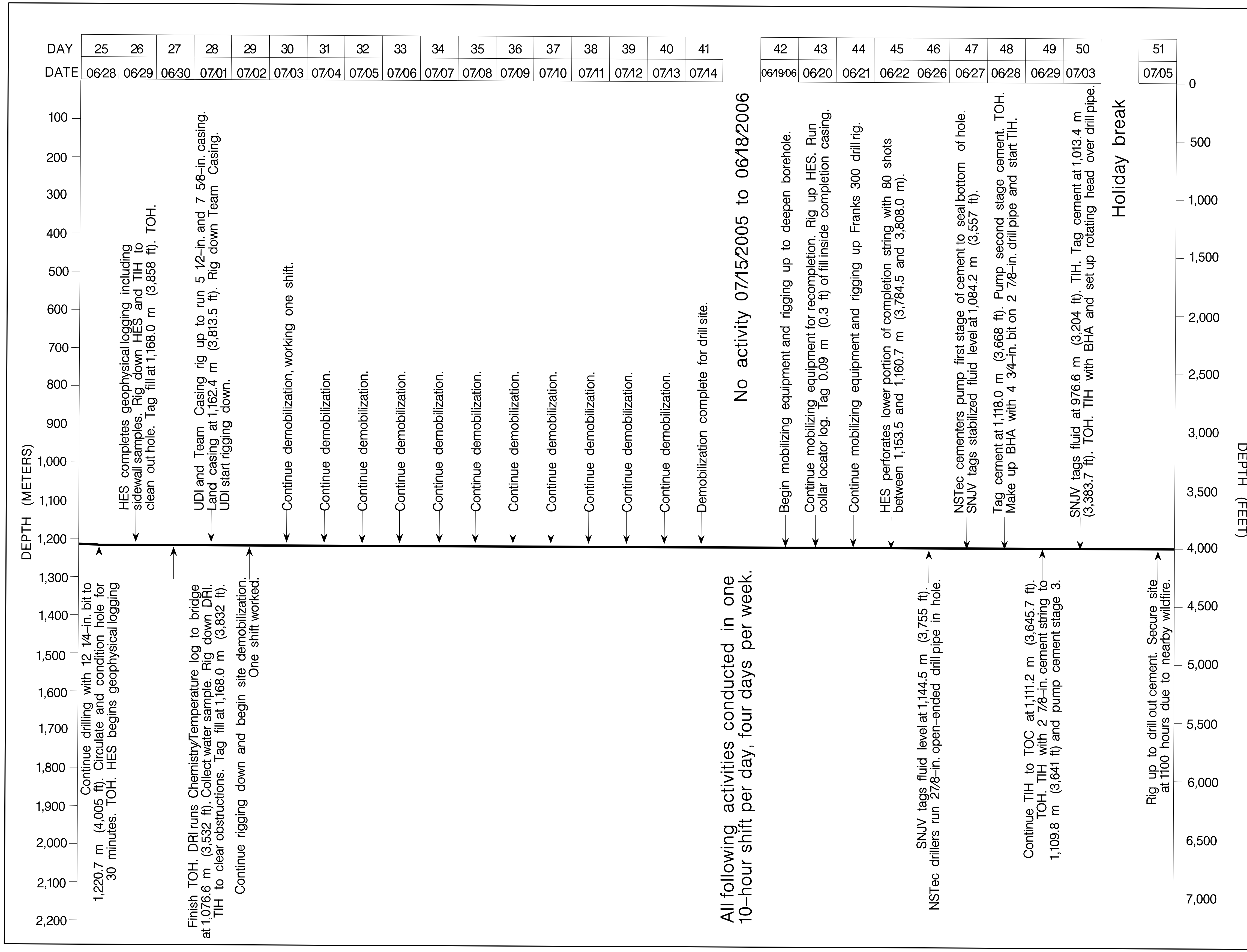

FIGURE 2–2
WELL ER–16–1
DRILLING AND COMPLETION HISTORY
SHEET 2 OF 3

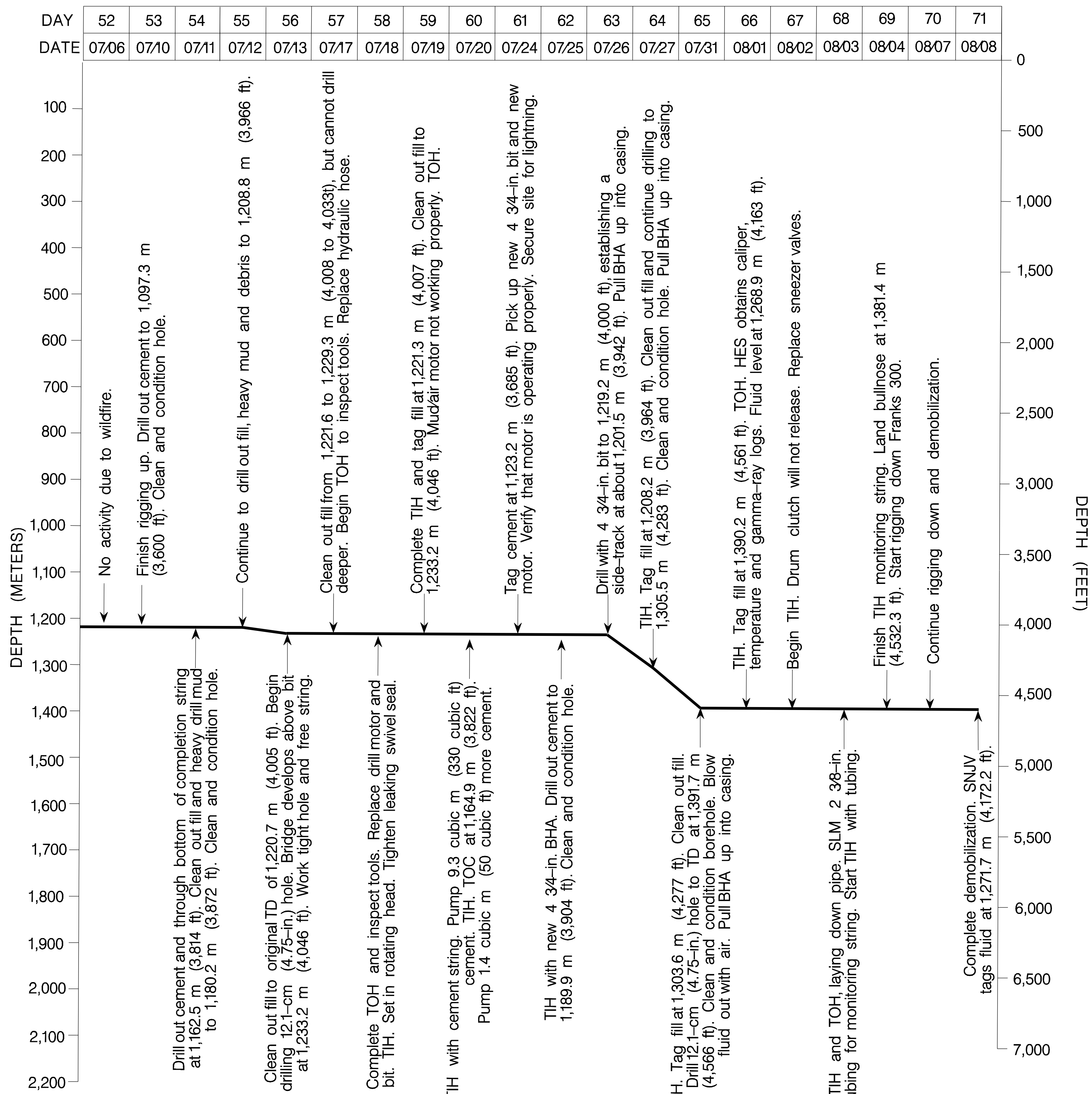

FIGURE 2–2

WELL ER–16–1
DRILLING AND COMPLETION HISTORY

SHEET 3 OF 3

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Table 2-1
Abridged Drill Hole Statistics for Well ER-16-1

LOCATION DATA:	
Coordinates: Nevada State Plane (central zone):	NAD 83: N 6,250,672.9 m E 541,177.1 m NAD 27: N 822,414.1 ft E 635,354.3 ft
Universal Transverse Mercator:	NAD 83: N 4,096,113.4 m E 570,820.7 m
Surface Elevation [a]:	2,009.1 m (6,591.5 ft)
DRILLING DATA:	
Spud Date:	06/12/2005 (main hole drilling with Wilson Mogul 42B rig)
Total Depth (TD):	1,220.7 m (4,005 ft). Deepened to 1,391.7 m (4,566 ft).
Date TD Reached:	06/28/2005. Final TD after deepening was reached on 07/31/2006.
Date Well Completed:	07/02/2005 (date completion string was landed). Recompleted on 08/04/2006
Hole Diameter:	121.9 cm (48 in.) from surface to 16.5 m (54 ft); 47 cm (18.5 in.) from 15.9 to 703.2 m (52 to 2,307 ft); 31.1 cm (12.25 in.) from 703.2 m (2,307 ft) to TD of 1,220.7 m (4,005 ft); 12.1 cm (4.75 in.) from 1,220.7 to 1,391.7 m (4,005 to 4,566 ft).
Drilling Techniques:	Dry-hole auger from surface to 15.9 m (52 ft.); center-punch with 18½-in. tricone bit mounted below a 26-in. hole opener to 18.9 m (62 ft); rotary drill with 18½-in. tricone bit and using air-foam and polymer in direct circulation from 18.9 to 703.2 m (62 to 2,307 ft); rotary drill with 12¼-in. tricone bit to TD of 1,220.7 m (4,005 ft); rotary drill with 4¾-in. button bit to second TD of 1,391.7 m (4,566 ft).
CASING DATA:	30-in. conductor casing to 15.9 m (52 ft); 13⅜-in. surface casing to 663.7 m (2,177.6 ft); 7⅝-in. casing to 1,030.4 m (3,380.5 ft); cross-over sub at 1,030.4 to 1,031.1 m (3,380.5 to 3,382.9 ft); 5½-in. casing 1,031.1 to 1,162.4 m (3,382.9 to 3,813.5 ft).
WELL COMPLETION DATA:	A string of 7⅝-in. carbon-steel casing, connected to 5½-in. stainless-steel casing via a crossover sub was installed in Well ER-16-1 after drilling in 2005. The carbon-steel casing extends through the unsaturated zone approximately 217.0 m (712 ft) above the water table. The 14.0-cm (5.5-in.) outside-diameter casing has an inside diameter of 12.83 cm (5.05 in.). The string was landed at 1,162.4 m (3,813.5 ft); its single slotted interval was cemented in 2006 for deepening of the hole. A string of 2⅜-in. tubing with one slotted interval was inserted inside the 5½-in. casing and landed at 1,381.4 m (4,532.3 ft) to serve as a monitoring string. Detailed data for the completion interval are provided in Section 7.0 of this report.
Depth of Slotted Section:	1,361.8 to 1,380.1 m (4,467.8 to 4,527.8 ft)
Depth of Gravel Pack:	None
Depth of Pump:	Not installed at the time of completion
Water Depth [b]:	Preliminary composite fluid level of 1,271.9 m (4,173.0 ft) measured inside the monitoring string, August 25, 2006, 3 weeks after installation. Estimated true vertical depth is 1,247.5 m (4,093 ft).
DRILLING CONTRACTOR:	United Drilling, Inc. (original hole); BN and NSTec (deepening)
GEOPHYSICAL LOGS BY:	Halliburton Energy Services.
SURVEYING CONTRACTOR:	Bechtel Nevada

a Elevation of ground level at wellhead. National Geodetic Vertical Datum, 1929 (NARA, 1973).
b Fluid level tag by SNJV (SNJV, 2006).

Drilling of the surface hole with an 18½-in. rotary tricone bit and polymer-foam began June 12, 2005. Drilling continued uneventfully with little or no fill accumulating when drilling was stopped to add drill pipe ("make a connection") to 103.6 m (340 ft), though tight spots were encountered at 104.9 and 248.7 m (344 and 816 ft). Drilling continued to 703.2 m (2,307 ft) with no fill. On June 18, 2005, drilling was stopped for geophysical logging, followed by installation of the 13⅜-in. surface casing. The drillers circulated drill fluid to clean and condition the hole, pulled the drill pipe off the bottom of the hole, and waited about an hour. When they lowered the pipe they encountered fill at the depth of 694.3 m (2,278 ft). As the drill string was removed for geophysical logging, tight conditions were encountered from 633.4 to 640.1 m (2,078 to 2,100 ft).

The Halliburton Energy Services (HES) logging crew encountered a bridge of sloughed material at 619.7 m (2,033 ft) on the first logging attempt, so they rigged down and the drillers cleaned out and conditioned the borehole. After the borehole was cleared, HES rigged back up and resumed logging operations, but hit a bridge at 608.4 m (1,996 ft). The HES loggers again rigged down, and drillers again worked the bit through bridges and fill to the original depth of 703.2 m (2,307 ft). Drillers then pulled the drill pipe a short distance off bottom and let the hole stabilize for an hour before removing the pipe from the hole.

The geophysical logging crew was able to finish the logs that did not require fluid in the hole, then rigged down and departed the location. The UDI drillers mixed 79,450 liters (500 barrels) of 60-viscosity gel mud, and cleaned and conditioned the hole to 703.2 m (2,307 ft). They continued to add fluid (an additional 47,670 liters [300 barrels] of gel mud) as they pulled the pipe from the hole. The HES logging crew returned to the site on June 21, 2005, and completed the logs requiring a fluid-filled hole, successfully logging to the depth of 677.6 m (2,223 ft).

After logging was completed, the casing subcontractor installed a string of 13⅜-in. casing, which was set at the depth of 663.7 m (2,177.6 ft). The bottom of the casing was cemented with 14.2 cubic meters (500 cubic feet) of Type II neat cement on June 23, 2005.

After installation of the casing, the drill crew lowered a bottom-hole assembly (BHA) with a 12¼-in. bit into the hole to drill out the cement and clean out the hole. They tagged the top of cement inside the 13⅜-in. casing at 646.8 m (2,122 ft), and drilled out the cement to 682.8 m (2,240 ft). Drilling of new 31.1-cm (12.25-in.) hole was interrupted at 744.0 m (2,441 ft) on June 24, 2005, when the area was secured for 24 hours to accommodate non-project operations.

Drilling with the 12¼-in. bit commenced on June 25, 2005, but was again interrupted due to an accident with injury. Work was stopped for approximately 5 hours, then continued uneventfully to the TD of 1,220.7 m (4,005 ft), which was reached on June 28, 2005. The drillers worked and reamed an area of tight hole at 1,208.2 m (3,964 ft), then cleaned and conditioned the borehole by circulating the drilling fluid for about 30 minutes. After the hole stabilized for an hour, a depth check tagged approximately 6.1 m (20 ft) of fill, and the crew removed the drill string from the hole for geophysical logging. Logging operations were conducted with no problems by HES on June 28-30, 2005.

The drillers conducted another depth check, tagged fill at 1,175.9 m (3,858 ft), then pulled the drill string from the hole in preparation for logging by Desert Research Institute (DRI) personnel. The DRI crew was unable to lower their logging and sampling tools to the fluid level due to obstructions and/or deviation of the borehole. After DRI was rigged down, the drillers tagged fill at the depth of 1,168.0 m (3,832 ft).

A completion string with one slotted interval was inserted into the hole on July 1, 2005, and landed at a depth of 1,162.4 m (3,813.5 ft). The string was not gravel-packed or cemented. The drillers started demobilizing the rig and drilling equipment on July 2, 2005, and crews worked one shift per day after that until demobilization was completed on July 14, 2005.

A standard gyroscopic survey was not run in the borehole, but the inclination of the borehole was determined from the Electric Micro Imager log run by HES on June 28, 2005, for the interval 11.9 to 1,196.3 m (39 to 3,925 ft). Within this interval the borehole drifted approximately 144.8 m (475 ft) to the southeast (bearing of 154.28 degrees). No abrupt changes in the borehole orientation ("doglegs") are apparent, but the borehole begins to build angle rapidly up-dip to the northwest within the Chainman Shale, starting at the depth of about 762 m (2,500 ft). At the lowest logged depth of 1,196.5 m (3,925.6 ft) the true vertical depth is calculated to be 1,175.0 m (3,855.2 ft).

2.3 Deepening of Well ER-16-1

On June 19, 2006, BN crews mobilized equipment to the Well ER-16-1 drill site and began setting up to deepen the borehole. One drill crew typically worked four 10-hour shifts per week for the duration of the deepening.

On June 22, 2006, HES perforated the lower portion of the completion string to permit cementing to stabilize the bottom of the 5½-in. completion casing. The HES crew made 40 shots in each of two 3.1-m (10-ft) sections of the casing, for a total of 80 shots, with no misfires. The perforated sections were located at the depths of 1,153.5 to 1,156.6 m (3,784.5 to 3,794.5 ft) and 1,157.6 to 1,160.7 m (3,798 to 3,808 ft).

The BN cementing crews pumped three stages of cement over the next three days, and SNJV personnel conducted periodic fluid-level checks. When the drill crew lowered the BHA with a 4¾-in. bit on July 3, 2006, they tagged cement inside the 5½-in. casing at the depth of 1,031.4 m (3,384 ft), just above the top of the 5½-in. casing, at the cross-over to the 7⅝-in. casing. There was no activity at the site for approximately 2½ shifts due to the holiday and a nearby wildfire. Then the crew returned, drilled out the cement, and drilled through the bullnose at the bottom of the 5½-in. casing at 1,162.5 m (3,814 ft). They spent the next few days cleaning out fill, residual heavy drill mud, and debris to the original TD of the borehole at 1,220.7 m (4,005 ft). They began drilling new 12.1-cm (4.75-in.) hole on July 13, 2006, but soon began to encounter equipment problems and tight hole conditions. The crew had to replace a hydraulic hose, the down-hole drill motor, and the bit (worn due to drilling on metal debris at the bottom of the borehole), and to repair the mud/air motor. On July 20, 2006, the crew pumped a total of 10.8 cubic meters (380 cubic feet) of cement in four lifts. After the weekend break they tagged cement at 1,123.2 m (3,685 ft).

Drilling with the 4¾-in. bit, the drillers began trying to "sidetrack" the hole, in an effort to avoid the metal debris in the bottom of the hole and to straighten the deviation that had developed during drilling to the original TD. On July 27, 2006, they established a sidetrack at the depth of approximately 1,200.9 m (3,940 ft), and the next day drilled new hole to the depth of 1,305.5 m (4,283 ft) with no problems. After the weekend break, drilling reached the TD of 1,391.7 m (4,566 ft) on July 31, 2006. On August 1, 2006, when the HES crew arrived for geophysical logging, the drillers tagged fill at the depth of 1,390.2 m (4,561 ft) and the water level was tagged at 1,268.9 m (4,163 ft).

2.4 Drilling Parameters

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 casing materials. Drilling fluids and cements used in Well ER-16-1 are listed in Appendix A-3.

2.5 Drilling Problems

The most significant delays during construction of the original well occurred when the auger crew had to cement and re-drill two problem zones while drilling the hole for the conductor casing. Although borehole sloughing was not a major problem during drilling of the 47.0-cm (18.5-in.) diameter main hole, problems were caused by bridges and fill that obstructed the borehole during logging operations prior to running the 13⅜-casing. It was necessary to stop geophysical logging and run the bit in the hole twice to clean it out. The drilling of the 31.1-cm (12.25- in.) borehole was accomplished without significant delays, but as a result of borehole deviation, DRI was unable to run its chemistry tool or to collect discrete bailer samples.

While deepening the borehole, the main problems encountered were related to the presence of metal debris in the bottom of the original hole, equipment failures, and work stoppages due to lightning and nearby wildfires. Once the sidetrack was established, the final 170.0 m (561 ft) of the borehole were drilled in two work shifts.

2.6 Fluid Management

During both phases of drilling, the drilling effluent was monitored according to the methods prescribed in the UGTA FMP (NNSA/NV, 2002) and the associated state-approved, well-specific, fluid management strategy letter (Murphy, 2005). The air-foam/polymer drill fluid was circulated down the inside of the drill string and back up the hole through the annulus (conventional or direct circulation) and then discharged into a sump. Bentonite mud drill fluid was also used during cleaning the hole. Water used to prepare drilling fluids came from Water Well UE-16d, located in Area 16. Lithium bromide was added to the drill fluid as a tracer to provide a means of estimating groundwater production. The rate of water production was estimated from the dilution of the tracer in the drill fluid returns.

To manage the anticipated water production, two sumps were constructed prior to drilling (Figure 2-1). No contaminants were expected during drilling at this site, so neither sump was lined. Samples of drilling effluent were collected hourly by SNJV and analyzed onsite by BN Radiation Operations personnel for the presence of tritium. As detailed in the SNJV data report (SNJV, 2005b), the onsite monitoring results for the first phase of drilling indicate that tritium levels measured in the drilling fluid remained at or below background levels as measured by field instruments throughout the drilling operations, ranging from 0 to 4,487 picocuries per liter (pCi/L). Drilling fluids generated at Well ER-16-1 were not analyzed for lead during drilling to the original TD, according to the approved Well ER-16-1 Fluid Management Strategy (Murphy, 2005).

Although a fluid discharge pipe was installed in sump #1, water volume in the sump remained relatively low and no fluid was discharged to the ground surface during the first phase of drilling in 2005; sump #2 remained inactive. Samples of drilling fluid were collected from the sump at Well ER-16-1 for water quality analyses if necessary during the original drilling operations in 2005. These samples were archived, but were never tested, and were disposed of in the sump after well construction was complete (SNJV, 2005b). A final sample was collected and analyzed from sump #1 on June 30, 2005, after well completion (see Appendix B).

During deepening of the borehole in 2006, drilling effluent was again managed according to the UGTA FMP (NNSA/NV, 2002) and the Well ER-16-1 fluid management strategy letter (Murphy, 2005). SNJV personnel checked all down-hole equipment for lead (none was found), and monitored discharge fluids daily at the rig site for lead. All fluid analyses were below detection limits for lead (SNJV, 2006). SNJV also collected fluid discharge samples hourly for tritium analyses, which were made by NSTec Radiological Operations personnel at the end of each shift. Fluid monitoring results for the deepening of the borehole also remained at or below background levels as measured by field instruments, ranging from 0 to 583 pCi/L (SNJV, 2006). All fluids were discharged to sump #1, while sump #2 remained inactive; no fluid was discharged to the surface during deepening of the borehole. A final sample was collected and analyzed from sump #1 on July 31, 2006, after recompletion activities were completed (see Appendix B).

All fluid quality objectives were met, as shown on the fluid management reporting form dated September 18, 2006 (Appendix B). The form lists volumes of solids (drill cuttings) and fluids produced during well-construction operations (vadose-zone drilling in 2005 and saturated-zone drilling in 2006; well development and aquifer testing are not addressed in this report). The volume of solids produced was calculated using the diameter of the borehole (from caliper logs) and the depth drilled, and includes added volume attributed to a rock bulking factor. The volumes of fluids listed on the report are estimates of total fluid production, and do not account for any infiltration or evaporation of fluids from the sumps.

3.0 Geologic Data Collection

3.1 Introduction

This section describes the sources of geologic data obtained from Well ER-16-1 and the methods of data collection. Improving the understanding of the subsurface structure, stratigraphy, and hydrogeology in the southern portion of RM-SM CAU was among the primary objectives of Well ER-16-1, so the proper collection of geologic and hydrogeologic data from the borehole was considered fundamental to successful completion of the drilling project.

Geologic data collected at Well ER-16-1 consist of drill cuttings, sidewall core samples, and geophysical logs. Data collection, sampling, transfer, and documentation activities were performed according to applicable contractor procedures, as listed in SNJV (2005a).

3.2 Collection of Drill Cuttings

Composite drill cuttings were collected from Well ER-16-1 at 3-m (10-ft) intervals as drilling progressed from the depth of 16.5 m (54 ft) to the final (deepened) TD of the well at 1,391.7 m (4,566 ft). No samples were collected during construction of the conductor hole, to the depth of 16.5 m (54 ft). Below that depth, SNJV personnel collected triplicate samples, each consisting of approximately 550 cubic centimeters of material, from 449 intervals. These samples are stored under environmentally controlled, secure conditions at the U.S. Geological Survey (USGS) Geologic Data Center and Core Library in Mercury, Nevada. One of each triplicate sample set was sealed with custody tape at the rig site and remains sealed as an archive sample; one set was left unsealed in the original sample containers; and the third set was washed and stored according to standard USGS Core Library procedures. The washed set was used by NSTec geologists to construct the detailed lithologic log presented in Appendix C. The SNJV field representative collected an additional two sets of reference drill cuttings samples from each of the cuttings intervals. One set was examined at the drill site for use in preparing field lithologic descriptions, and remains in the custody of SNJV. The other set is held by SNJV for future petrographic, mineralogic, and chemical analyses at LANL, if needed.

In addition, 3.8-liter (1-gallon) samples of composite drill cuttings were collected at 15.2-m (50-ft) intervals while drilling the pre-Tertiary section. These samples were collected for paleontologic analysis. Samples not sent for analysis are stored at the USGS Geologic Data Center and Core Library in Mercury, Nevada.

3.3 Sidewall Core Samples

Sidewall core samples were collected from Well ER-16-1 to verify the stratigraphy and lithology at selected locations. Sample locations were selected by the SNJV field representative on the basis of field lithologic logs, with consideration of borehole conditions determined from caliper logs. HES used a percussion gun tool to collect core samples between the depths of 189.0 and 1,148.8 m (620 and 3,769 ft) (no samples were collected after the borehole was deepened). A total of 61 sample depths was attempted, with 37 cores recovered. Table 3-1 summarizes the results of sidewall coring operations at Well ER-16-1.

3.4 Sample Analysis

Five samples of drill cuttings from various depths in Well ER-16-1 were submitted to the Hydrology, Geochemistry, and Geology Group of the Earth and Environmental Sciences Division at LANL for petrographic, mineralogic, and chemical analyses to aid in stratigraphic identification and for characterization of mineral alteration (WoldeGabriel, 2006a; 2006b). Nine conventional core samples from nearby core hole UE-16a #1 and three samples from nearby outcrops were also submitted to LANL for analysis to help characterize correlative intervals in Well ER-16-1. Biostratigraphic analyses were performed on four samples of drill cuttings from the Paleozoic carbonate section in Well ER-16-1 (Harris, 2005). Table 3-2 lists the sample depths and the status of laboratory analyses.

3.5 Geophysical Log Data

Geophysical logs were run in the borehole to further characterize the lithology, structure, and hydrologic properties of the rocks encountered, and to evaluate borehole conditions. Geophysical logging was conducted in three stages during drilling: prior to installation of the 13⅜-in. casing at 663.7 m (2,177.6 ft), after the original TD was reached at 1,220.7 m (4,005 ft), and in the deepened portion of the borehole. A complete listing of the logs, dates run, depths, and service companies is provided in Table 3-3. The logs are available from NSTec in Mercury, Nevada, and copies are on file at the office of SNJV in Las Vegas, Nevada, and at the USGS Geologic Data Center and Core Library in Mercury, Nevada. Preliminary geophysical data from the logs are reproduced in Appendix D.

Table 3-1
Sidewall Samples from Well ER-16-1

Core Depth [a] meters (feet)	**Tool Used** [b]	**Recovery** centimeters (inches)	**Formation**	**Lithology**
189.0 (620)	SWC-1	3.18 (1.25)	Bullfrog Tuff, Crater Flat Group	Ash-flow tuff, nonwelded, vitric
208.8 (685)	SWC-2	1.91 (0.75)	Bullfrog Tuff, Crater Flat Group	Ash-flow tuff, nonwelded, vitric
209.4 (687)	SWC-2	4.45 (1.75)	Bullfrog Tuff, Crater Flat Group	Ash-flow tuff, nonwelded, vitric
231.0 (758)	SWC-1	3.81 (1.50)	Crater Flat Group	Ash-flow tuff, nonwelded, vitric
254.2 (834)	SWC-2	4.14 (1.63)	Lithic Ridge Tuff	Ash-flow tuff, nonwelded to partially welded, zeolitic
254.8 (836)	SWC-2	4.14 (1.63)	Lithic Ridge Tuff	Ash-flow tuff, nonwelded to partially welded, zeolitic
274.3 (900)	SWC-1	2.54 (1.00)	Lithic Ridge Tuff	Ash-flow tuff, nonwelded to partially welded, zeolitic
316.7 (1,039)	SWC-2	1.27 (0.50)	Lithic Ridge Tuff	Ash-flow tuff, nonwelded to partially welded, zeolitic
317.3 (1,041)	SWC-2	1.60 (0.63)	Lithic Ridge Tuff	Ash-flow tuff, nonwelded to partially welded, zeolitic
329.2 (1,080)	SWC-1	2.87 (1.13)	Lithic Ridge Tuff	Ash-flow tuff, nonwelded to partially welded, zeolitic
350.5 (1,150)	SWC-1	3.51 (1.38)	Tunnel Formation	Bedded tuff, zeolitic
364.5 (1,196)	SWC-1	3.51 (1.38)	Tunnel Formation	Bedded tuff, zeolitic
396.2 (1,300)	SWC-1	2.54 (1.00)	Tunnel Formation	Ash-flow tuff, nowelded to partially welded, zeolitic
420.6 (1,380)	SWC-1	3.18 (1.25)	Tunnel Formation	Bedded tuff, zeolitic
481.0 (1,578)	SWC-1	3.18 (1.25)	Tunnel Formation	Ash-flow tuff, nowelded to partially welded, zeolitic
520.9 (1,709)	SWC-2	3.51 (1.38)	Yucca Flat Tuff	Ash-flow tuff, nowelded to partially welded, zeolitic
533.4 (1,750)	SWC-1	3.51 (1.38)	tunnel bed 1	bedded tuff, zeolitic
547.1 (1,795)	SWC-2	3.51 (1.38)	tunnel bed 1	bedded tuff, zeolitic
547.7 (1,797)	SWC-2	4.45 (1.75)	tunnel bed 1	bedded tuff, zeolitic
577.3 (1,894)	SWC-1	3.81 (1.50)	tunnel bed 1	bedded tuff, zeolitic
581.9 (1,909)	SWC-2	0.64 (0.25)	Redrock Valley Tuff	Ash-flow tuff, partially welded, devitrified
582.5 (1,911)	SWC-2	0.64 (0.25)	Redrock Valley Tuff	Ash-flow tuff, partially welded, devitrified

Table 3-1 (continued)
Sidewall Samples from Well ER-16-1

Core Depth [a] meters (feet)	**Tool Used** [b]	**Recovery** centimeters (inches)	**Formation**	**Lithology**
594.4 (1,950)	SWC-1	3.18 (1.25)	Redrock Valley Tuff	Ash-flow tuff, partially welded, devitrified
596.8 (1,958)	SWC-1	1.27 (0.50)	Redrock Valley Tuff	Ash-flow tuff, partially welded, devitrified
599.2 (1,966)	SWC-1	1.27 (0.50)	Redrock Valley Tuff	Ash-flow tuff, partially welded, devitrified
647.4 (2,124)	SWC-2	3.18 (1.25)	Chainman Shale	Shale
648.0 (2,126)	SWC-2	3.18 (1.25)	Chainman Shale	Shale
658.7 (2,161)	SWC-2	3.18 (1.25)	Chainman Shale	Shale
665.4 (2,183)	SWC-2	3.18 (1.25)	Chainman Shale	Shale
666.0 (2,185)	SWC-2	1.27 (0.50)	Chainman Shale	Shale
739.8 (2,427)	SWC-2	5.08 (2.00)	Chainman Shale	Shale
820.8 (2,693)	SWC-2	5.08 (2.00)	Chainman Shale	Shale
851.9 (2,795)	SWC-2	3.81 (1.50)	Chainman Shale	Shale
897.6 (2,945)	SWC-2	3.81 (1.50)	Chainman Shale	Shale
916.8 (3,008)	SWC-2	2.54 (1.00)	Chainman Shale	Shale
987.2 (3,239)	SWC-2	1.91 (0.75)	Chainman Shale	Shale
1,148.8 (3,769)	SWC-2	1.91 (0.75)	Guilmette Formation	Limestone

a All depths are drilled depths, not corrected for borehole angle.
b SWC-1 = percussion-gun sidewall coring tool; core diameter: 24 millimeters (0.94 in.)
SWC-2 = percussion-gun sidewall coring tool; core diameter: 16 millimeters (0.63 in.).

Table 3-2
Status of Rock Sample Analyses for Well ER-16-1

Depth [a, b] meters	(feet)	Sample Type [c]	Analyses Performed [d]			
			Petrographic	Mineralogic (XRD)	Chemical (XRF)	Biostratigraphic
405.4	(1,330)	DC	C	C	C	NP
475.5	(1,560)	DC	C	C	C	NP
512.1	(1,680)	DC	C	C	C	NP
557.8	(1,830)	DC	C	C	C	NP
603.5	(1,980)	DC	C	C	C	NP
1,112.5	(3,650)	DC	NP	NP	NP	C
1,143.0	(3,750)	DC	NP	NP	NP	C
1,173.5	(3,850)	DC	NP	NP	NP	C
1,204.0	(3,950)	DC	NP	NP	NP	C

a All depths are drilled depths, not corrected for borehole angle.

b Depths for petrographic, mineralogic, and chemical analyses represent base of 3.0-m (10-ft) sample interval for drill cuttings samples. Depths for biostratigraphic analyses represent base of 15.2-m (50-ft) sample interval.

c Sample type: DC = Drill cuttings

d Status of analyses: **C** = analysis complete; **NP** = analysis not planned.
Analysis type: **XRD** = x-ray diffraction; **XRF** = x-ray fluorescence.

Table 3-3
Well ER-16-1 Geophysical Log Summary

Geophysical Log Type [a]	Log Purpose	Logging Service [b]	Date Logged	Run Number	Bottom of Logged Interval [c] meters (feet)	Top of Logged Interval [c] meters (feet)
* Natural Gamma Ray Spectroscopy / Gamma Ray	Stratigraphic and depth correlation, mineralogy, and natural and man-made radiation determination	HES	6/19/2005 6/21/2005 6/28/2005	SGR-1 / GR-3 SGR-2 / GR-5 SGR-3 / GR-9	585.8 (1,922) 665.1 (2,182) 1,176.8 (3,861)	15.9 (52) 495.6 (1,626) 663.6 (2,177)
* Six-Arm Caliper / Gamma Ray	Borehole conditions, cement volume calculation / stratigraphic correlation	HES	6/18/2005 6/19/2005 6/21/2005 6/28/2005	CA6-1 / GR-1 CA6-2 / GR-2 CA6-3 / GR-4 CA6-4 / GR-8	626.4 (2,055) 665.4 (2,183) 678.8 (2,214) 1,185.4 (3,889)	15.9 (52) 15.9 (52) 459.6 (1,626) 663.6 (2,177)
* Four-Arm Caliper / Gamma Ray	Borehole conditions, cement volume calculation / stratigraphic correlation	HES	8/01/2006	CA4-1 / GR-12	1,388.4 (4,555)	1,143.0 (3,750)
* High-Resolution Induction Log	Lithologic determination / saturation of formations / stratigraphic and depth correlation	HES	6/19/2005 6/21/2005 6/28/2005	HRI-1 / GR-3 HRI-2 / GR-5 HRI-3 / GR-9 / SP-2	616.9 (2,024) 674.5 (2,213) 1,186.3 (3,892)	15.9 (52) 495.6 (1,626) 663.6 (2,177)
* Epithermal Neutron / Density / Gamma Ray / Caliper	Total water content / rock porosity / stratigraphic correlation / borehole conditions	HES	6/21/2005 6/29/2005	DSEN-1 / SDL-1 / GR-6 DSEN-2 / SDL-2 / GR-10 / CAL-2	672.7 (2,207) 1,187.2 (3,895)	15.9 (52) 487.7 (1,600)
Electric Micro Imager / Caliper / Gamma Ray	Saturated zone: lithologic characterization, fracture and void analysis.	HES	6/21/2005	EMI-1 / CA6-3 / GR-4	674.8 (2,214)	495.6 (1,626)
* Temperature / Gamma Ray	Saturated zone: groundwater temperature / stratigraphic correlation	HES	6/21/2005 6/28/2005 8/01/2006	TL-1 / GR-6 TL-2 / GR-7 TL-3 / GR-11	672.7 (2,207) 1,185.4 (3,889) 1,388.4 (4,555)	519.1 (1,703) 663.6 (2,177) 1,127.8 (3,700)
Percussion Gun Sidewall Tool / Gamma Ray	Geologic samples	HES	6/21/2005 6/29/2005	SWC-1 / SP-1 SWC-3 and SWC-4	664.5 (2,180) 1,187.8 (3,897)	15.9 (52) 1,127.8 (3,700)
True Vertical Depth (calculated from EMI logs)	Borehole deviation	HES	6/28/2005	TVD Plot	1,196.3 (3,925)	11.9 (39)

a Logs presented in geophysical log summary, Appendix D, are indicated by *.
b HES = Halliburton Energy Services.
c Drilled depth, not corrected for borehole angle.

4.0 Geology and Hydrogeology

4.1 Introduction

This section describes the geology and hydrogeology of Well ER-16-1. The basis for the discussions here is the detailed lithologic log of Well ER-16-1 presented in Appendix C. The detailed lithologic log was developed using drill cuttings and sidewall core samples, geophysical logs, and drilling parameters. Information from petrographic, mineralogic, and chemical analyses on select lithologic samples from Well ER-16-1 (WoldeGabriel, 2006a; 2006b) was incorporated into the detailed lithologic log. Additional information was obtained from biostratigraphic analyses (Harris, 2005) and borehole image analysis (Leavitt, 2005).

All depths listed in this section are drilled depths, uncorrected for borehole angle, unless otherwise stated.

4.2 Geology

This section is divided into three discussions relating to the geology of Well ER-16-1. Section 4.2.1 describes the geologic setting of the Shoshone Mountain area and Well ER-16-1. The stratigraphic and lithologic units penetrated at the well are discussed in Section 4.2.2. Because of the significant influence some alteration products have on the hydraulic properties of certain rocks, alteration of the rocks encountered at the well is discussed separately in Section 4.2.3. More detailed descriptions of the stratigraphy, lithology, and alteration of the rocks encountered are provided in the detailed lithologic log presented in Appendix C.

4.2.1 Geologic Setting

Well ER-16-1 was drilled from Tippipah Point, a high volcanic mesa that is part of the larger dissected volcanic plateau called Shoshone Mountain (Figure 4-1). Shoshone Mountain consists geologically of a thick sequence of Miocene volcanic rocks erupted between 11.45 and 15.90 million years ago (Ma) from large calderas located nearby to the west and northwest (Sawyer et al., 1994). The volcanic rocks consist mainly of nonwelded ash-fall and welded ash-flow tuffs of generally rhyolitic composition (Orkild, 1963).

The volcanic rocks unconformably overlie Paleozoic sedimentary rocks (Orkild, 1963). These older rocks are exposed extensively north and east of Tippipah Point where they show complex structural relationships associated with generally east-directed contractional deformation. The nearest Paleozoic exposures include Devonian carbonate rocks, Mississippian siliciclastic rocks,

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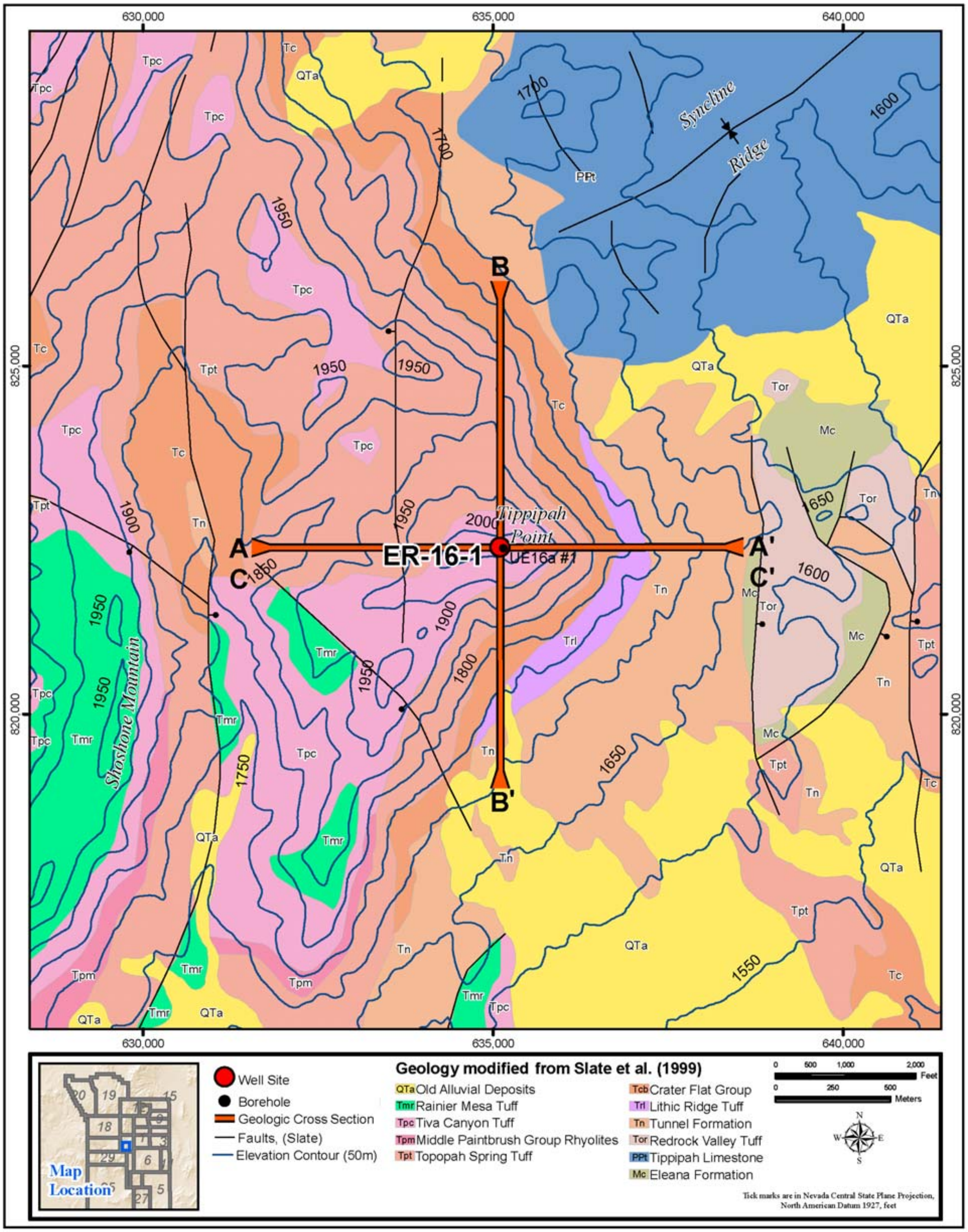

Figure 4-1
Surface Geologic Map of the Well ER-16-1 Site

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and Pennsylvanian and late Permian carbonate rocks. The Mississippian, Pennsylvanian, and late Permian rocks exposed at the surface are folded into a northeast-trending syncline at Syncline Ridge northeast of Tippipah Point.

4.2.2 Stratigraphy and Lithology

The stratigraphic and lithologic units penetrated at Well ER-16-1 are illustrated in Figure 4-2, and the distribution of stratigraphic units in the vicinity of the well is shown in cross section in Figures 4-3 and 4-4. The determination of the volcanic stratigraphic and lithologic units penetrated by Well ER-16-1 was greatly aided by examination of, and correlation with, nearby core hole UE-16a #1 drilled in 1973 to explore geologic conditions in the vicinity of the U16a Tunnel. Core hole UE-16a #1 is located 14.6 m (48 ft) east of Well ER-16-1. The exploratory hole was continuously cored to a depth of 364.8 m (1,197 ft) and thus provides excellent lithologic samples for the upper portion of the volcanic section in the immediate vicinity of Well ER-16-1. Geophysical well logs available from both Well ER-16-1 and hole UE-16a #1 allowed correlation of contacts between the drill holes.

Because of the greater stratigraphic detail described in Well ER-16-1 than that mapped at the surface in the area, many of the stratigraphic units in Well ER-16-1 are included within larger, more general stratigraphic groupings depicted in Figure 4-1.

Drilling at Well ER-16-1 began in densely welded ash-flow tuff of the Tiva Canyon Tuff which forms the ground surface in the vicinity of the well (Figure 4-1). The Tiva Canyon Tuff was encountered to a depth of 47.5 m (156 ft). The upper 15.2 m (50 ft) of the formation consists of densely welded, devitrified ash-flow tuff, and the basal 32.3 m (106 ft) consists of vitric bedded tuff. The stratigraphic assignment of Tiva Canyon Tuff is based mainly on surface mapping (Orkild, 1963), and the absence of quartz in drill cuttings samples from Well ER-16-1 is consistent with this assignment. The Tiva Canyon Tuff was erupted 12.7 Ma from the Claim Canyon caldera complex located west of the well location (Sawyer et al., 1994).

The Topopah Spring Tuff was encountered below the Tiva Canyon Tuff, from 47.5 to 108.5 m (156 to 356 ft). The Topopah Spring Tuff consists of 54.9 m (180 ft) of densely welded, devitrified ash-flow tuff that overlies 6.1 m (20 ft) of vitric nonwelded ash-flow tuff. The stratigraphic assignment of Topopah Spring Tuff is based on surface mapping (Orkild, 1963), stratigraphic position below the Tiva Canyon Tuff, densely welded ash-flow tuff lithology, and

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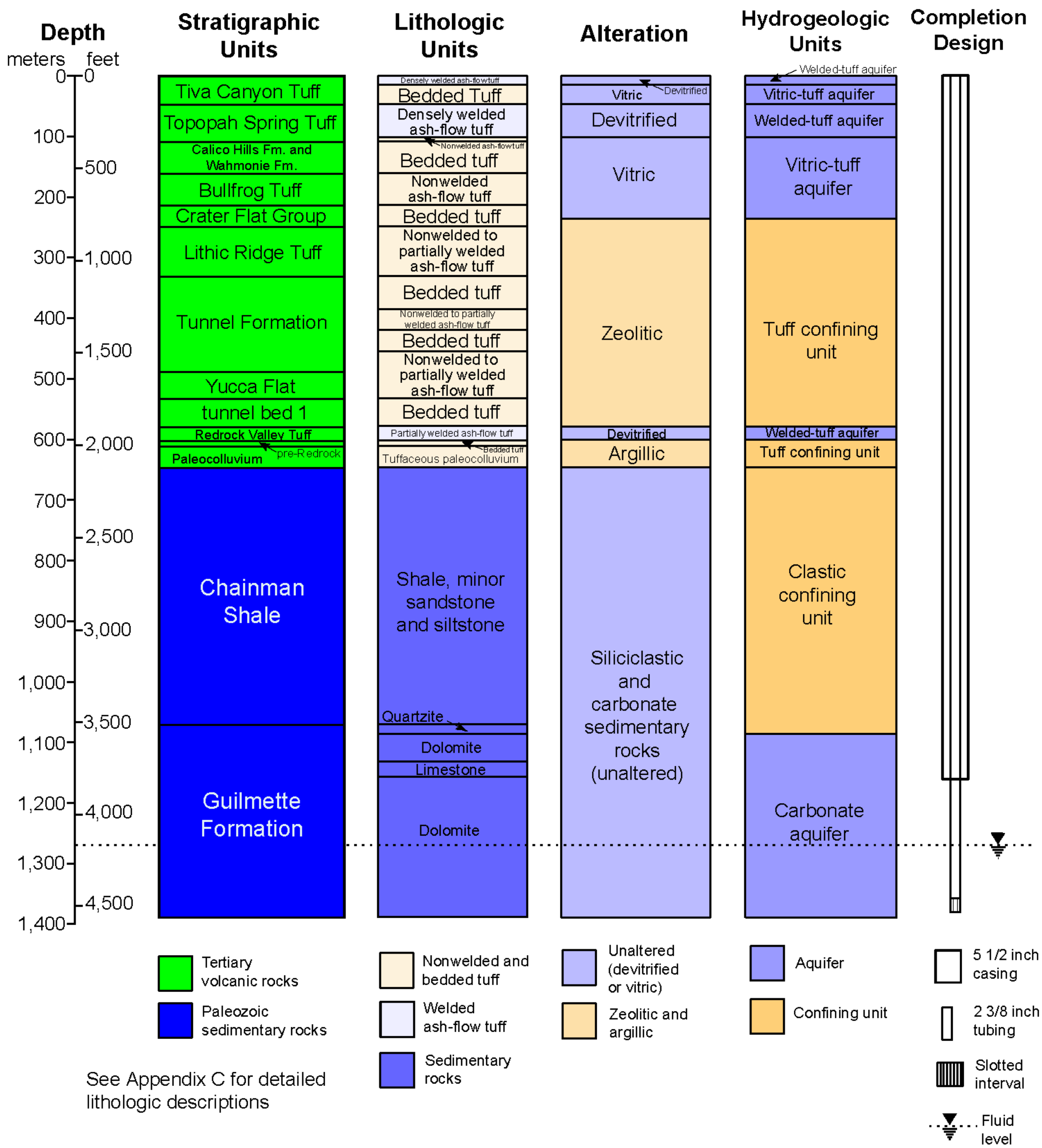

Figure 4-2
Geology and Hydrogeology of Well ER-16-1

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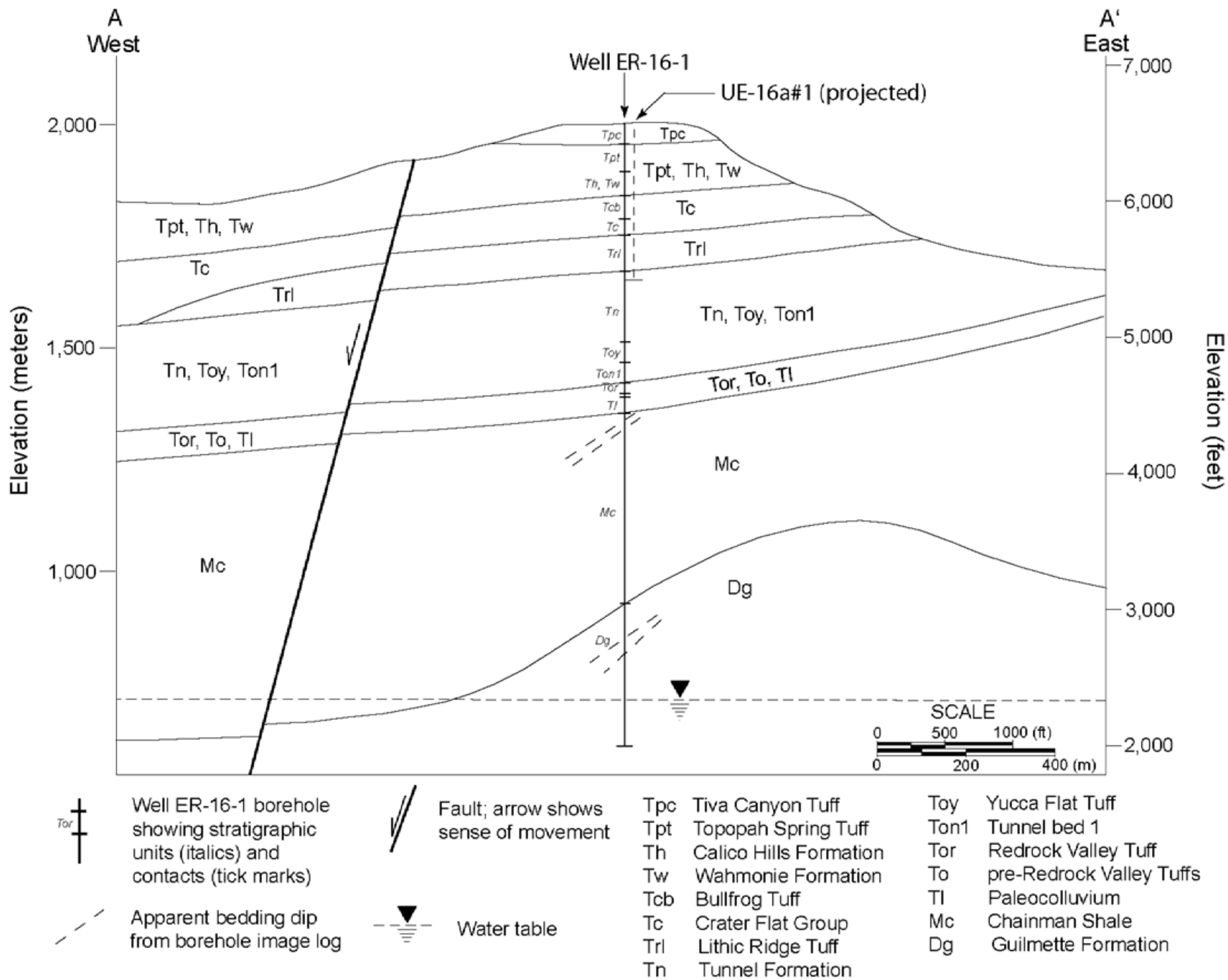

Figure 4-3
West-East Geologic Cross Section A-A' through Well ER-16-1

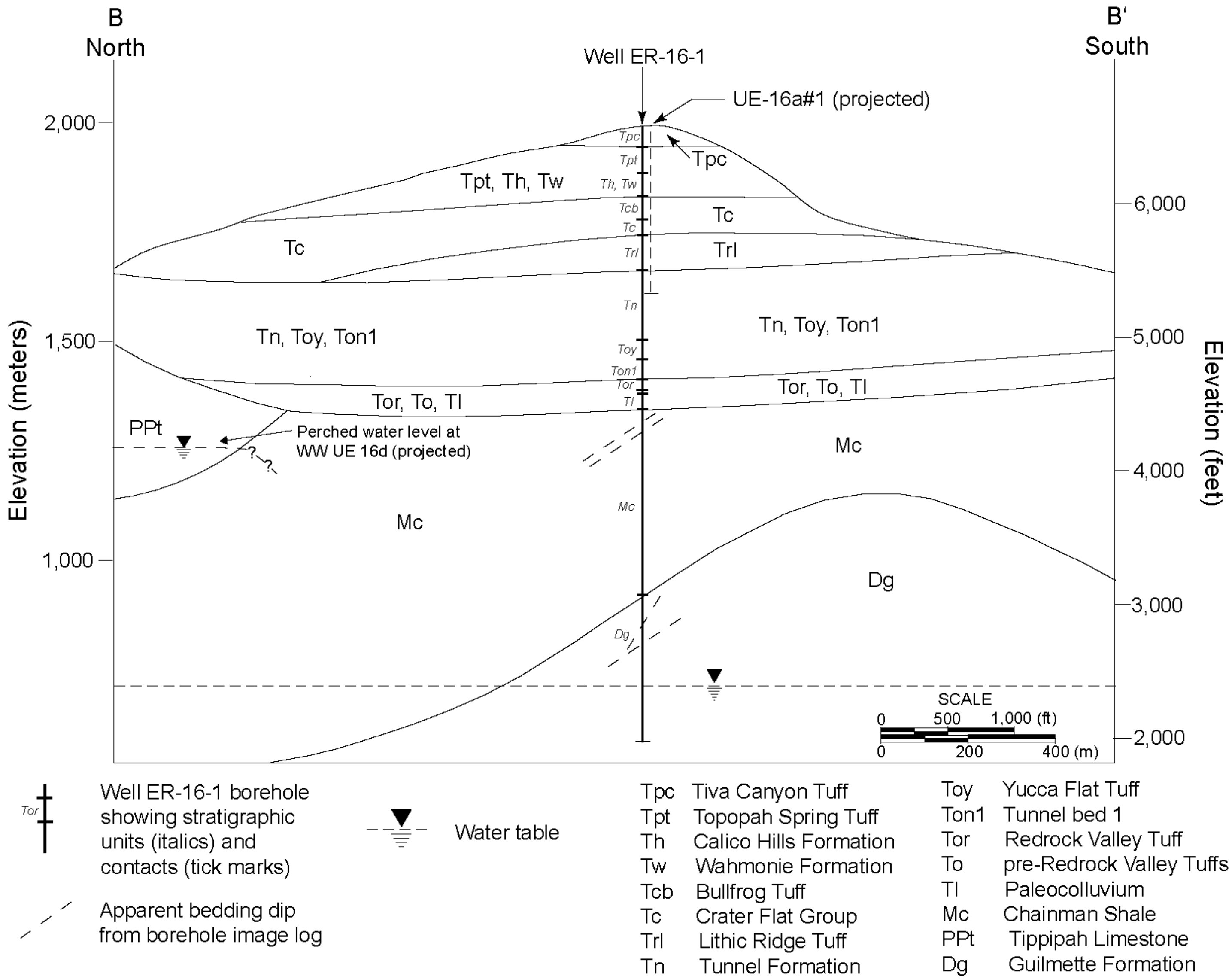

Figure 4-4
North-South Geologic Cross Section B-B' through Well ER-16-1

primary mineralogy that is characterized by a scarcity of quartz phenocrysts. The Topopah Spring Tuff was erupted from an unknown source 12.8 Ma (Sawyer et al., 1994).

Below the Topopah Spring Tuff, Well ER-16-1 penetrated 53.0 m (174 ft) of vitric (i.e., unaltered) bedded tuff from 108.5 to 161.5 m (356 to 530 ft). Although the quality of the drill cuttings samples from this interval is poor, which is typical of samples from poorly indurated to friable vitric tuffs, analyses of correlative core samples from UE-16a #1 and geophysical logs from Well ER-16-1 provide information on the lithologic and stratigraphic units penetrated. The gamma-ray signature from 118.9 to 134.1 m (390 to 440 ft) in Well ER-16-1 is characteristic of the Wahmonie Formation, and mineralogic and petrographic analyses from the correlative interval in UE-16a #1 (WoldeGabriel, 2006a; 2006b) indicate a conspicuous plagioclase- and mafic-rich character that is diagnostic of the Wahmonie Formation (Slate et al., 1999; Warren et al., 2003). Bedded tuffs above and below the Wahmonie Formation are tentatively assigned to the Calico Hills Formation, based on the presence of quartz and the similar ages for these two stratigraphic units. The Calico Hills Formation was erupted 12.9 Ma from an unknown source, and the Wahmonie Formation was erupted 13.0 Ma from the Wahmonie volcanic center located south of the well location (Sawyer et al., 1994). Because the Wahmonie Formation is slightly older than the Calico Hills Formation, the basal portion of the interval may include older units such as the Crater Flat Group. All the units in this interval are included in the Topopah Spring Tuff in Figure 4-1.

Nonwelded ash-flow tuff was penetrated from 161.5 to 213.4 m (530 to 700 ft). The poor quality of the drill cuttings samples from the interval, geophysical log signatures, and character of the correlative interval in UE-16a #1 indicate the interval is vitric. This ash-flow tuff deposit is assigned to the Bullfrog Tuff of the Crater Flat Group, based on its stratigraphic position well below the Wahmonie Formation, ash-flow tuff lithology, and its primary mineralogy which includes both sanidine and plagioclase dominant over quartz, and the absence of sphene. Correlative rocks exposed just east of the well along the slope below Tippipah Point are assigned to the Calico Hills Formation by Slate et al. (1999). However, based on stratigraphic relationships in Well ER-16-1 and nearby core hole UE-16a #1, these rocks have been reassigned in Figure 4-1 to the Crater Flat Group which includes the Bullfrog Tuff. The Bullfrog Tuff was erupted 13.25 Ma from the Silent Canyon caldera complex located northwest of the well location (Sawyer et al., 1994).

Below the Bullfrog Tuff the well penetrated 36.0 m (118 ft) of bedded tuff from 213.4 to 249.3 m (700 to 818 ft). The bedded tuff is vitric to 236.5 m (776 ft), becoming zeolitic below this depth. The interval is also assigned to the Crater Flat Group.

Another interval of partially welded tuff occurs from 249.3 to 330.7 m (818 to 1,085 ft). The interval consists of 81.4 m (276 ft) of zeolitic nonwelded to partially welded ash-flow tuff. Carr et al. (1984) and Slate et al. (1999) assign this ash-flow tuff to the Lithic Ridge Tuff. Mineralogical data from Well ER-16-1 are consistent with this assignment, particularly the scarcity of quartz and the presence of sphene. The Lithic Ridge Tuff was erupted 14.0 Ma from an unknown source (Sawyer et al., 1994).

Below the Lithic Ridge Tuff, the well penetrated a 157.6-m (517-ft) thick section of zeolitic bedded tuff and partially welded ash-flow tuff all assigned to the Tunnel Formation. This interval probably includes Tunnel 3 and 4 members of the Tunnel Formation, which were erupted between 14.0 and 14.9 Ma from unknown sources (Sawyer et al., 1994).

The Yucca Flat Tuff was penetrated from 488.3 to 533.4 m (1,602 to 1,750 ft), and consists of 45.1 m (148 ft) of zeolitic and partially devitrified, nonwelded to partially welded ash-flow tuff. The stratigraphic assignment is based mainly on stratigraphic position, ash-flow tuff lithology, and a high biotite content. The Yucca Flat Tuff was erupted 15.1 Ma from an unknown source (Sawyer et al., 1994). The Yucca Flat Tuff is included within the Tunnel Formation in Figure 4-1.

Another interval of bedded tuff was penetrated from 533.4 to 579.1 m (1,750 to 1,900 ft). The interval is zeolitic to 552.9 m (1,814 ft), becoming partially argillic below this depth. This bedded tuff is assigned to tunnel bed 1, based on its bedded nature and stratigraphic position between the Yucca Flat Tuff and Redrock Valley Tuff. Tunnel bed 1 was erupted between 15.1 and 15.25 Ma from unknown sources (Sawyer et al., 1994). Tunnel bed 1 is also included within the Tunnel Formation in Figure 4-1.

The Redrock Valley Tuff was penetrated from 579.1 to 602.6 m (1,977 to 2,006 ft). The Redrock Valley Tuff in Well ER-16-1 consists of 23.5 m (77 ft) of devitrified partially welded ash-flow tuff. The stratigraphic assignment is based on the interval’s stratigraphic position near the base of the volcanic section, the welded ash-flow tuff lithology, correlation to nearby surface exposures (Slate et al., 1999), and the primary mineralogy that includes quartz significantly less in abundance than both sanidine and plagioclase. The Redrock Valley Tuff was erupted 15.25 Ma from an unknown source (Sawyer et al., 1994).

The base of the Tertiary section at Well ER-16-1 consists of 8.8 m (29 ft) of argillic bedded tuff that overlies 35.4 m (116 ft) of paleocolluvial material. The paleocolluvium consists of subangular to subrounded clasts of Mississippian siliciclastic rocks within a reddish-brown, argillic and tuffaceous matrix. The bedded tuff and paleocolluvium that occur between the Redrock Valley Tuff and pre-Tertiary surface are included with the Redrock Valley Tuff in Figure 4-1.

Well ER-16-1 encountered pre-Tertiary rocks at a depth of 646.8 m (2,122 ft). The borehole penetrated 424.9 m (1,394 ft) of black shale, with minor siltstone and sandstone, to a depth of 1,071.7 m (3,516 ft). This interval is assigned to the Mississippian Chainman Shale based on the occurrence of thick black shale characteristic of the Chainman Shale and correlation to nearby surface exposures (Cole and Cashman, 1999; Slate et al., 1999). Bedding within the upper portion of the Chainman Shale, from 646.8 to 675.1 m (2,122 to 2,215 ft), dips 43° northwest, as determined from the borehole image log (Leavitt, 2005).

At a depth of 1,071.7 m (3,516 ft), the borehole encountered the top of a 15.2-m (50-ft) thick interval of light-colored, very clean quartzite that is conspicuously different from sandstones within the Chainman Shale. Below the quartzite the borehole penetrated in descending order, 45.7 m (150 ft) of dolomite, 25.0 m (82 ft) of limestone, and another 234.1 m (768 ft) of dolomite. The borehole was terminated in dolomite at 1,391.7 m (4,566 ft). Although no fossils were found in the biostratigraphic samples from this interval, the lithologic composition and stratigraphic position below the Chainman Shale suggest the interval represents the Devonian Guilmette Formation. The dip of bedding in the middle portion of the interval averages 57° to the north-northwest and northwest as determined from the borehole image log (Leavitt, 2005).

4.2.3 Alteration

The volcanic rocks penetrated at Well ER-16-1 are generally unaltered above 236.5 m (776 ft), becoming mostly zeolitic below. Unaltered rocks include nonwelded and bedded tuffs that have retained their original vitric (i.e., glassy) character. The welded portions of the Tiva Canyon Tuff and Topopah Spring Tuff are devitrified as a result of recrystallization of the original glass matrix to microcrystalline quartz and feldspar during cooling and degassing as the welding process proceeded. Below 236.5 m (776 ft), the original glass matrix of the nonwelded and bedded tuffs has been altered mainly to zeolite. The partially welded Redrock Valley Tuff from

579.1 to 602.6 m (1,900 to 1,977 ft) is devitrified. Argillic alteration becomes pervasive below 602.6 m (1,977 ft), which is common for basal volcanic rocks and paleocolluvium in the Yucca Flat vicinity (Prothro, 2005).

The pre-Tertiary rocks penetrated below 646.8 m (2,122 ft) are generally unaltered. However, local alteration associated with secondary mineralization along fractures may be present.

4.3 Predicted and Actual Geology

The geology encountered at Well ER-16-1 differs from that predicted prior to drilling (SNJV, 2005a), particularly with regard to the pre-Tertiary rocks encountered (Figure 4-5). This is mainly due to the lack of deep subsurface control (e.g., other deep drill holes) in the area and the difficulty in interpreting subsurface geology on the basis of surface exposures of highly deformed pre-Tertiary rocks in the area. Well ER-16-1 encountered the top of pre-Tertiary rocks at a depth of 646.8 m (2,122 ft), which is 67.7 m (222 ft) deeper than predicted. It was predicted that approximately 183 m (600 ft) of Pennsylvanian Tippipah Limestone would be penetrated above the underlying Mississippian Chainman Shale. However, below the volcanic section the borehole first encountered Chainman Shale, indicating that the Tippipah Limestone was eroded off at the well location. It was also predicted that the well would reach TD within the Chainman Shale at 1,219 m (4,000 ft) after penetrating approximately 457 m (1,500 ft) of the formation. However, after penetrating 424.9 m (1,394 ft) of Chainman Shale (at the depth of 1,071.7 m [3,516 ft]), the borehole encountered the top of the Guilmette Formation which stratigraphically underlies the Chainman Shale in the region. The Chainman Shale penetrated at Well ER-16-1 is thinner than regional estimates, indicating that the upper portion of the formation has also been eroded off at the well location, although the possibility that faulting in the area is responsible for some of the thinning, as well as other stratigraphic relationships observed, can not be ruled out.

Differences in the volcanic rocks encountered at Well ER-16-1 versus that predicted prior to drilling mainly result from the more detailed stratigraphy described for the well than the general geology depicted on geologic maps of the area that were utilized for pre-drill predictions as discussed Section 4.2.2.

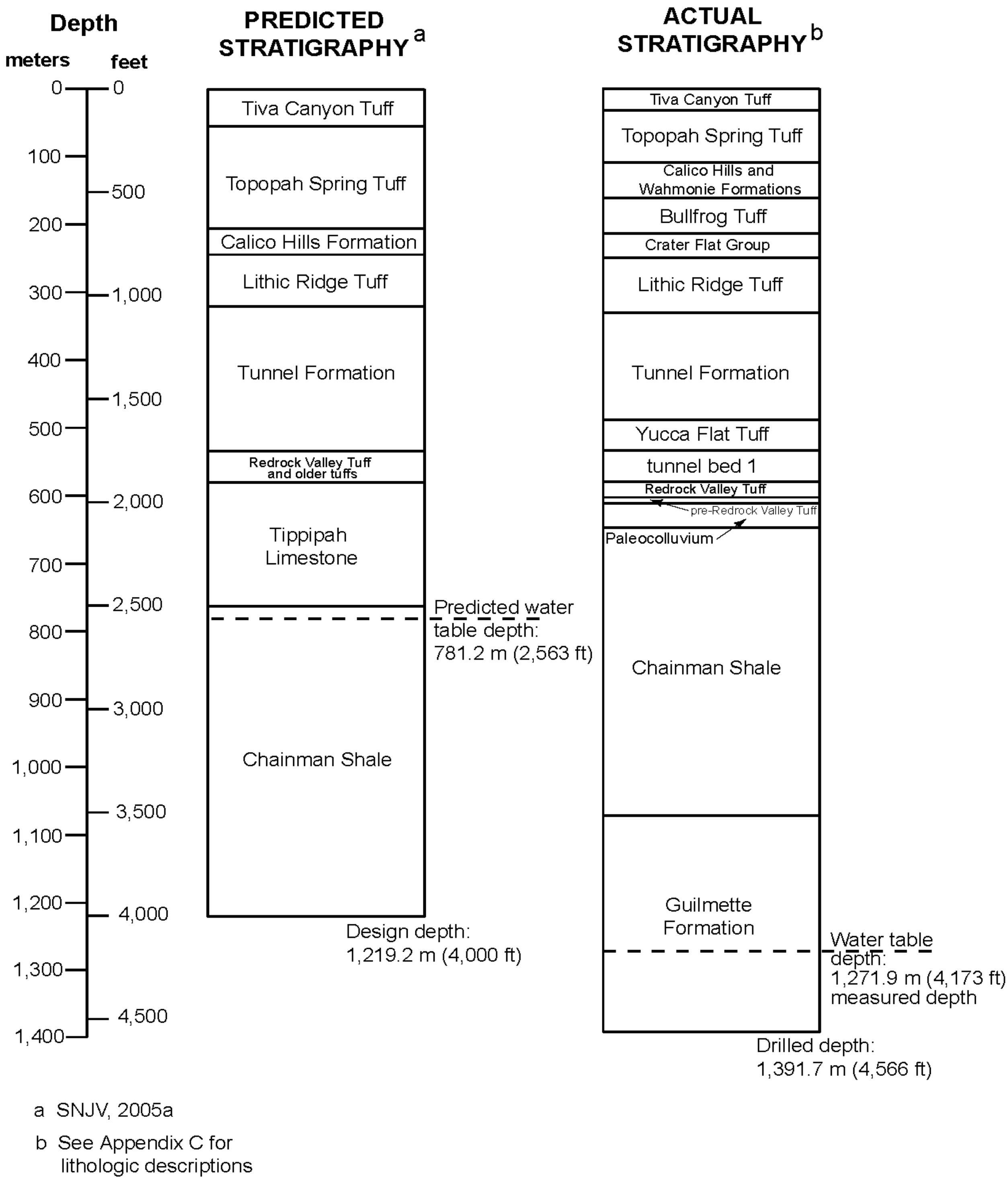

Figure 4-5
Predicted and Actual Stratigraphy at Well ER-16-1

4.4 Hydrogeology

Welded Tiva Canyon Tuff and Topopah Spring Tuff penetrated in the upper portion of Well ER-16-1 are classified hydrogeologically as welded-tuff aquifers due to the dense and brittle nature of welded ash-flow tuffs which tend to support well-developed fracture sets (Winograd and Thordarson, 1975; Laczniak et al., 1996). The vitric nonwelded and bedded tuffs encountered above 236.5 m (776 ft) are classified as vitric-tuff aquifers because of the relatively high effective matrix porosity of these low-density rocks.

The mostly zeolitic nonwelded to partially welded ash-flow tuffs and bedded tuffs, including the argillic paleocolluvium encountered below 236.5 m (776 ft), are classified as tuff confining units because of the low effective porosity associated with zeolitic and argillic alteration. The welded Redrock Valley Tuff, penetrated from 579.1 to 602.6 m (1,900 to 1,977 ft), forms a relatively thin welded-tuff aquifer intercalated near the base of the much thicker section of tuff confining unit.

The Chainman Shale is classified as a clastic confining unit. These fine-grained rocks have low effective porosity and do not typically support open fractures (Winograd and Thordarson, 1975; Laczniak et al., 1996). The quartzite at the top of the Guilmette Formation is also classified as a clastic confining unit, whereas the dolomite and limestone are classified as carbonate aquifer because of the fractured and transmissive character of carbonate rocks in the region (Winograd and Thordarson, 1975; Laczniak et al., 1996). An interpretation of the possible distribution of hydrogeologic units at Well ER-16-1 is shown in cross section on Figure 4-6.

The depth to the regional water table at Well ER-16-1 was estimated at 781.2 m (2,563 ft) prior to drilling (SNJV, 2005a). On July 8, 2005, a few days after the original TD of the well was reached, the fluid level at Well ER-16-1 was at a depth of 1,137.8 m (3,732 ft) within dolomite of the Guilmette Formation (SNJV, 2005b). On August 25, 2006, three weeks after the final TD of 1,391.7 m (4,566 ft) was reached, the fluid level was measured at the drilled depth of 1,271.9 m (4,173 ft). Correcting for the borehole angle, the true vertical depth to fluid at Well ER-16-1 is 1,247.5 m (4,093 ft), which is 466.3 m (1,530 ft) deeper than predicted prior to drilling. The difference is due to the well penetrating through the Chainman Shale, a confining unit, and into the Guilmette Formation, a carbonate aquifer. The predicted water level (SNJV, 2005a) was based on data from nearby drill holes that terminate in the Chainman Shale or higher stratigraphic units. Because the well was predicted also to reach TD within the Chainman Shale, it was believed that the water level would be similar to nearby wells. However, the well

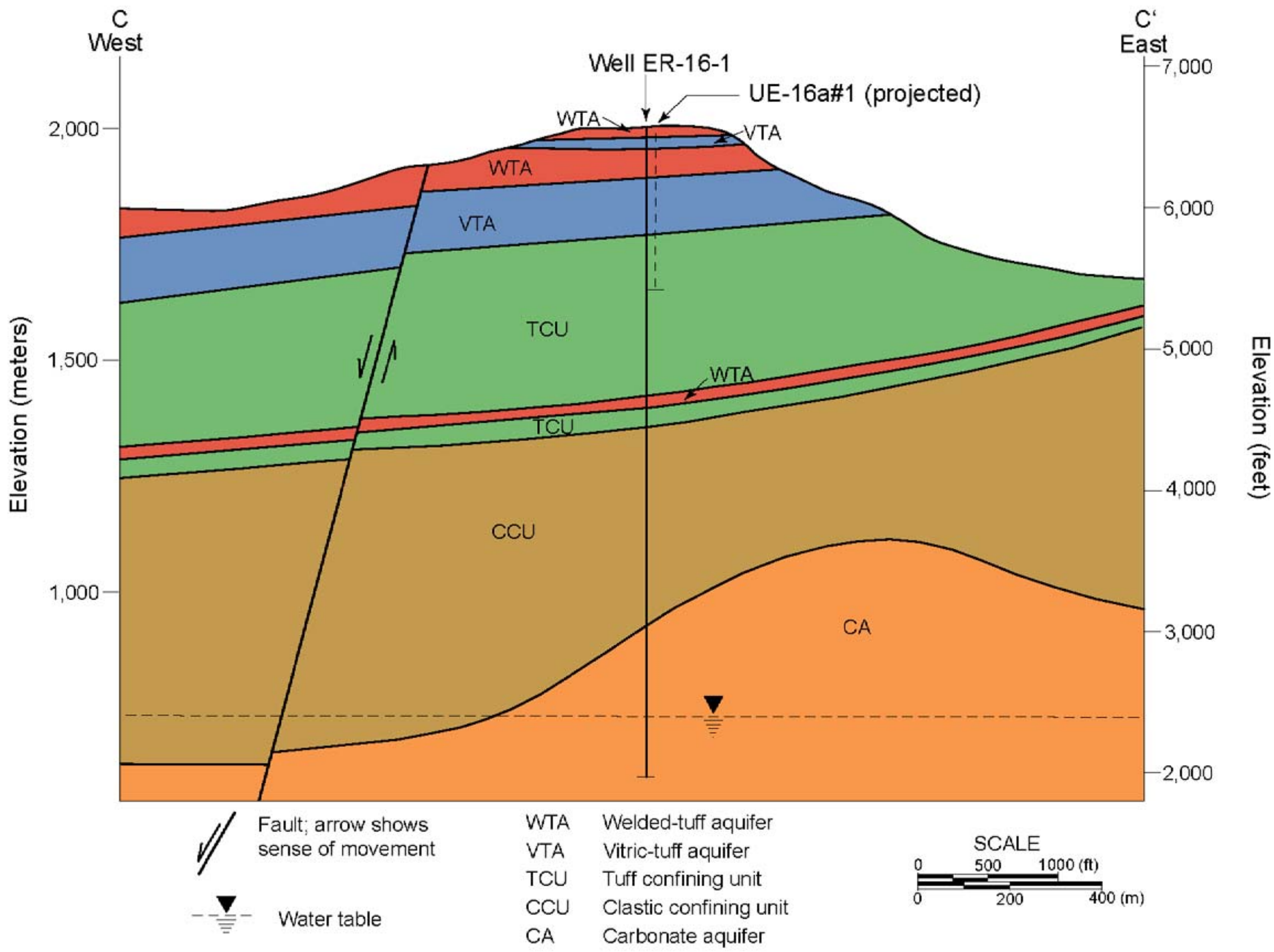

Figure 4-6
West-East Hydrogeologic Cross Section C-C' through Well ER-16-1

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penetrated completely through the Chainman Shale, which resulted in a much lower (regional) water level. This confirms that the Chainman Shale is a viable confining unit in the area and that perched water may be present where an aquifer such as the Tippipah Limestone is positioned above the Chainman Shale. This is illustrated on Figure 4-4 by the difference in water level between Wells UE-16d and ER-16-1. Well UE-16d was completed in the Tippipah Limestone, and groundwater encountered there is perched above the Chainman Shale.

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5.0 Hydrology

5.1 Preliminary Water-Level Information

Prior to drilling, the water level at Well ER-16-1 was estimated to be 781.3 m (2,563 ft) below ground surface, within the UCCU (Chainman Shale), with a possibility that perched water might be present in the volcanic rocks above a depth of 579.1 m (1,900 ft) (SNJV, 2005a). Perched water was not encountered in the volcanic section, and the saturated UCA (Tippipah Limestone), expected above the Chainman Shale, was not present at this location as predicted. Well ER-16-1 terminated in saturated LCA after drilling through a thinner section of UCCU than expected. Measurements made after the well was deepened indicate that the potentiometric surface associated with the LCA is much lower than predicted within the UCCU, and more closely aligned with water levels for LCA completions in Yucca Flat.

On July 8, 2005, 11 days after the original TD of the well was reached, the fluid level was measured at 1,137.5 m (3,731.9 ft) by SNJV. However, this turned out not to be a stable water level, and the fluid level in Well ER-16-1 dropped over the next few months. The fluid level in the well was measured by SNJV at the depth of 1,148.5 m (3,768.0 ft) on March 20, 2006, prior to deepening of the borehole. A fluid level of 1,268.9 m (4,163 ft) was measured during geophysical logging on August 1, 2006, after the new TD of 1,391.7 m (4,566 ft) had been reached. The fluid level depth of 1,271.9 m (4,173 ft) measured by SNJV on August 25, 2006, is believed to be a stable level. This equates to a true vertical depth (correcting for borehole angle) of 1,247.5 m (4,093 ft), or a water level elevation of 761.7 m (2,499 ft).

5.2 Water Production

Water production was estimated during drilling of Well ER-16-1 on the basis of dilution of a lithium-bromide tracer, as measured by SNJV field personnel. Water production was first detected at the depth of about 1,003.1 m (3,291 ft) within the Chainman Shale. Estimated water production ranged from 0 to 38 liters per minute (0 to 10 gallons per minute) until the original TD of 1,220.7 m (4,005 ft) was reached. During deepening of the borehole, estimated water production ranged from about 57 to 64 liters per minute (15 to 17 gallons per minute). Estimated water production rates during drilling are presented graphically in Appendix A-1.

5.3 Preliminary Flow Meter Data

Flow meter data, along with temperature, electrical conductivity, and pH measurements, are typically used in UGTA wells to characterize borehole fluid variability, which may indicate inflow and outflow zones. DRI personnel attempted to run their chemistry log to obtain temperature, electrical conductivity, and pH measurements within the LCA, shortly after the first TD was reached, but could not lower their tool to the fluid level due to borehole deviation. These logs were not run after deepening of the borehole.

5.4 Preliminary Groundwater Characterization Samples

Following geophysical logging, on June 30, 2005, DRI also attempted to collect preliminary groundwater characterization samples within the open borehole, but because of the above-mentioned borehole deviation, discrete samples could not be collected. DRI did not obtain water samples after the well was deepened.

6.0 Precompletion and Open-Hole Development

The only precompletion development conducted in Well ER-16-1 consisted of circulating fluid for 30 minutes to clean the borehole prior to the final logging operation, after the original TD was reached. The drillers also cleaned and conditioned the borehole for 30 minutes after the final TD was reached, prior to geophysical logging.

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7.0 Well Completion

7.1 Introduction

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

For the original completion, the proposed design for Well ER-16-1 was presented in SNJV (2005a); the recompletion design is described in FAWP number D-006-001.06 (BN, 2006). The completion and recompletion plans are summarized here in Section 7.2.1, and the actual well completion and recompletion designs, based on the hydrogeology encountered in the borehole, are presented in Section 7.2.2. The rationale for differences between the planned and actual designs is discussed in Section 7.2.3, and the completion methods are presented in Section 7.3. Figure 7-1 is a schematic diagram of the original well-completion design, and Figure 7-2 is a detail of the lower portion of the well, showing the recompletion. Figure 7-3 shows a plan view and profile of the final wellhead surface completion. Table 7-1 is a construction summary for the completion strings.

7.2 Well Completion Design

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

7.2.1 Proposed Completion Design

The original completion design (presented in SNJV, 2005a) was based on the assumption that Well ER-16-1 would penetrate the Tippipah Limestone (UCA) and reach TD within the Chainman Shale (UCCU). The 13⅜-in. casing was intended to extend to the depth of approximately 670.6 m (2,200 ft) and isolate the UCA from the overlying volcanic section (tuff confining unit). A piezometer tube was to be positioned outside the 13⅜-in. intermediate casing, to monitor perched water zones within the tuff confining unit, if any were encountered. The bottom portion of this tubing string would not necessarily be gravel-packed or cemented in place.

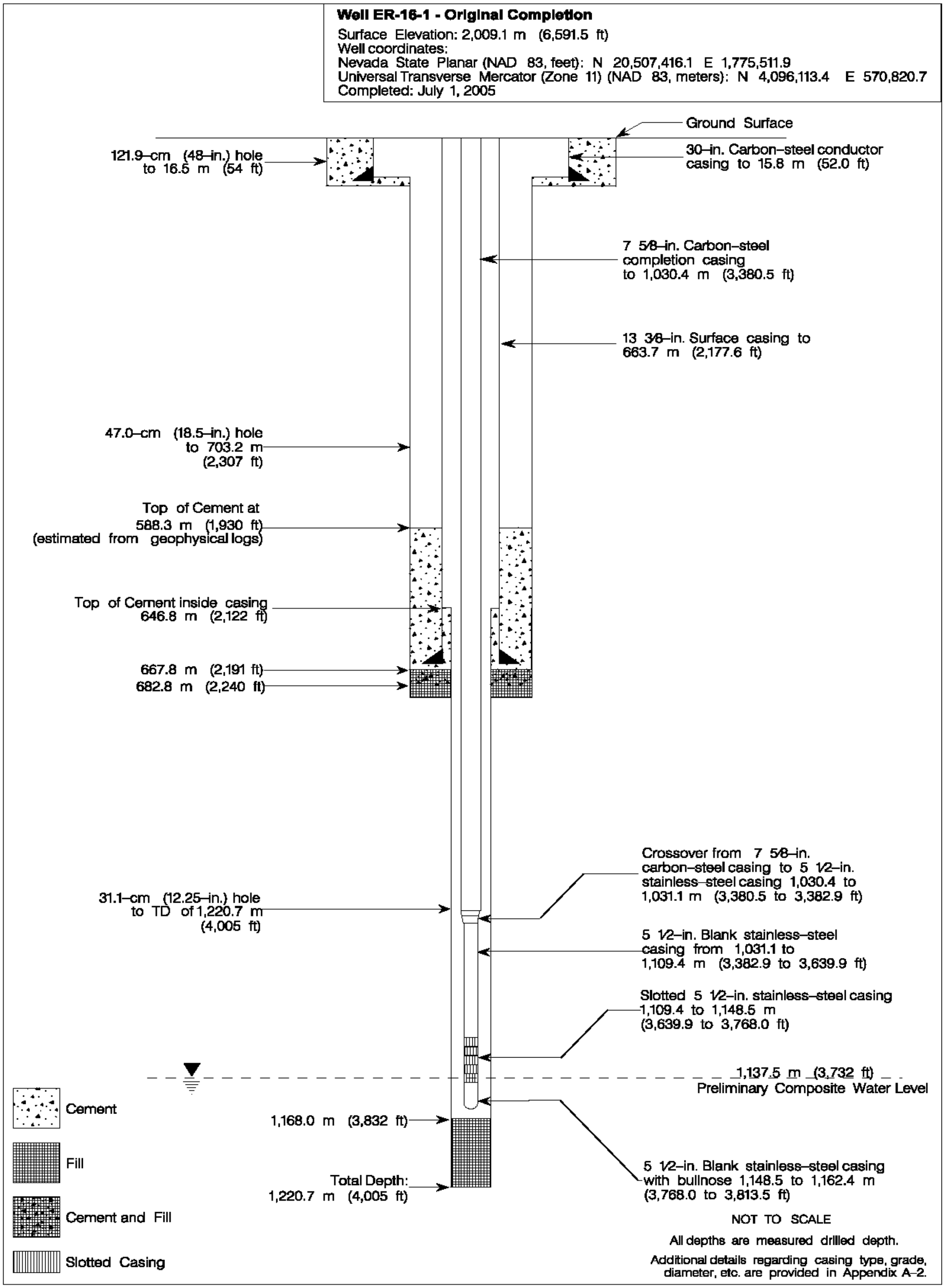

Figure 7-1
As-Built Completion Schematic for Well ER-16-1 – Original

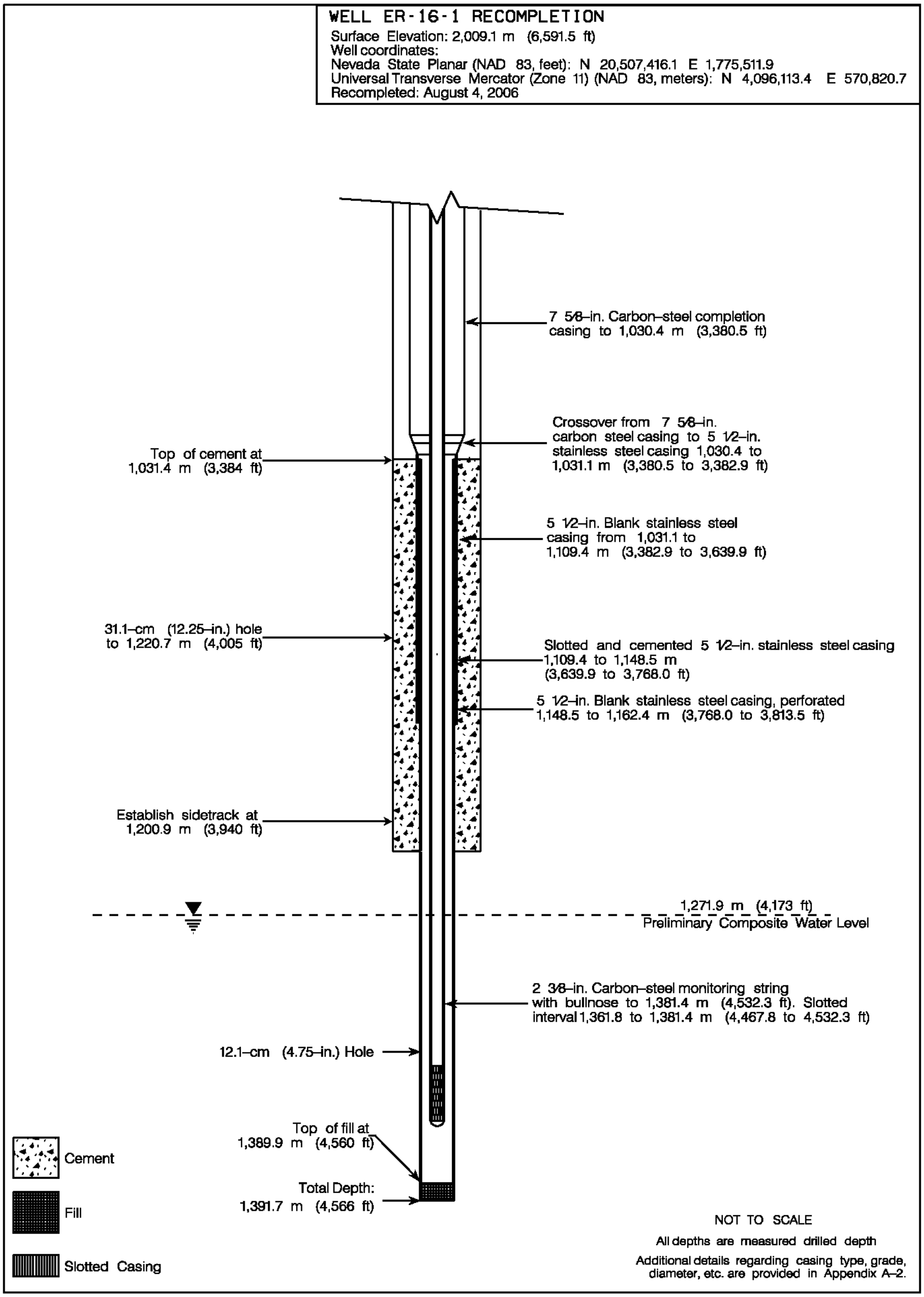

Figure 7-2
Detail of Lower Portion of Completion Zone for Well ER-16-1 – Recompletion

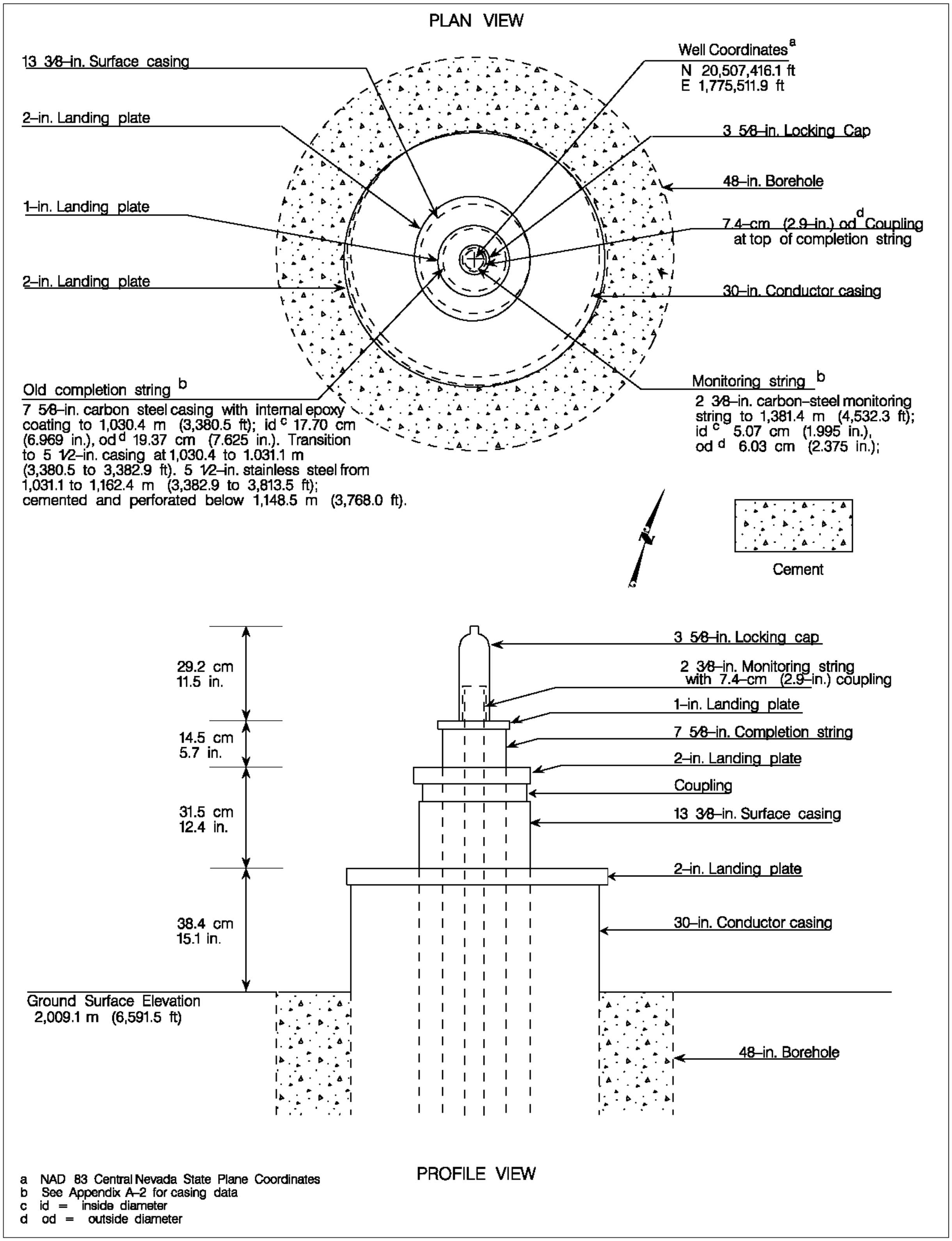

Figure 7-3
Wellhead Diagram for Well ER-16-1

Table 7-1
Well ER-16-1 Completion String Construction Summary

Casing and Tubing	Configuration meters (feet)		Cement	Sand/Gravel
7⅝-in. carbon-steel production casing	0 to 1,030.4 (0 to 3,380.5)	Blank	None	None
7⅝-in. to 5½-in. crossover sub, carbon-steel, with stainless-steel double pin	1,030.4 to 1,031.1 (3,380.5 to 3,382.9)	Blank		
5½-in. stainless-steel production casing Installed July 2005 Cemented June 2006 [b]	1,031.1 to 1,162.4 (3,382.9 to 3,813.5)	Blank 1,031.1 to 1,109.4 (3,382.9 to 3,639.9)	1,031.4 to 1,220.7 m (3,384 to 4,005 ft)	
		3 consecutive slotted joints [a] 1,109.4 to 1,148.5 (3,639.9 to 3,768.0)		
		Blank and bull-nosed 1,161.6 to 1,162.4 (3,811.1 to 3,813.5)		
2⅜-in. carbon-steel tubing	0 to 1,381.4 (0 to 4,532.3)	Blank 0 to 1,361.8 (0 to 4,467.8)	None	
		Slotted and bull-nosed 1,361.8 to 1,381.4 [c] (4,467.8 to 4,532.3)		

a Slots were 0.159 cm (0.0625 in.) wide and 5.1 cm (2.0 in.) long, arranged in 18 rings, on staggered 15.2-cm (6.0-in.) centers.

b The lower part of the slotted casing and the underlying blank casing were perforated in two intervals (1,156.6 to 1,153.5 m [3,794.5 to 3,784.5 ft] and 1,157.6 to 1,160.7 m [3,798 to 3,808 ft]) in June 2006, prior to cementing, in preparation for deepening of the borehole.

c Torch-cut slots are 0.476 cm (0.1875 in.) wide and 15.2 cm (6.0 in.) long, arranged in rings on staggered 90-degree angles, 30.5 cm (12 in.) apart. Care should be taken not to insert tools below 1,361.5 m (4,467 ft) at the top of the slotted zone due to obstructions present.

The well was planned to be completed with a single casing string of 7⅝-in. carbon-steel extending into the UCA. The 7⅝-in. casing within the UCA would be slotted and would be isolated from other slotted intervals with cement. The primary goal of the proposed completion design was to provide groundwater production data from the UCA if it were saturated, and to provide access to groundwater, if present, within the lower tuff confining unit and the UCCU for monitoring and sampling.

7.2.2 As-Built Completion Design - Original

The design of the Well ER-16-1 completion was determined after the initial TD of 1,220.7 m (4,005 ft) was reached, through consultation with members of the UGTA Technical Working Group, on the basis of onsite evaluation of data such as lithology and water production, drilling data, and data from various geophysical logs.

As shown in Figure 7-1, only the main completion string was installed in Well ER-16-1. The piezometer tubes were not placed in the annular space between the 13⅜-in. surface casing and the borehole wall or deeper within the UCCU as originally planned.

The main completion string, a single casing string of 5½-in. stainless-steel casing suspended from 7⅝-in. carbon-steel casing, was set at the depth of 1,162.4 m (3,813.5 ft), and was slotted in the interval from 1,190.4 to 1,148.5 m (3,639.9 to 3,768.0 ft), within the LCA. The slotted section consisted of three consecutive slotted joints, and was terminated with 13.1 m (43 ft) of blank stainless-steel casing and a 0.73 m (2.41 ft) stainless-steel bullnose. The openings in each slotted casing joint were 0.159 cm (0.0625 in.) wide and 5.08 cm (2.0 in.) long. The slots were arranged in rows of 18, with rows staggered 10 degrees on 7.62-cm (3-in.) centers. The production casing was installed in the open borehole with no gravel pack or cementing; therefore, the slotted interval was not isolated from the formation immediately above. The slotted interval accessed the entire open borehole from the bottom of the cement associated with the 13⅜-in. casing at 702.9 m (2,306.1 ft) to the bottom of the hole at 1,220.7 m (4,005 ft).

7.2.3 As-Built Recompletion Design

Prior to deepening Well ER-16-1, the 5½-in. casing was cemented to stabilize it within the borehole. The lower part of the slotted casing and the underlying blank casing were perforated in two intervals (1,156.6 to 1,153.5 m [3,794.5 to 3,784.5 ft] and 1,157.6 to 1,160.7 m [3,798 to 3,808 ft]) to facilitate cementing. The entire string of 5½-in. casing was cemented into the borehole; cement was tagged inside the casing at the depth of 1,031.4 m (3,384 ft), at the cross-over from the 5½-in. casing to the 7⅝-in. casing.

The 12.01-cm (4.75-in.) diameter hole was drilled through the cemented section and the bullnose of the original completion string. A string of 2⅜ carbon-steel tubing, slotted in the interval 1,361.8 to 1,381.4 m (4,467.8 to 4,532.3 ft), was installed in the open borehole. No gravel pack or cement was used, so the slotted interval is open to the entire borehole from the bottom of the cement used to stabilize the bottom of the original borehole at 1,220.7 m (4,005 ft) to the bottom of the hole at 1,391.7 m (4,566 ft) (Figure 7-2). Slots were cut onsite in the lowest two joints of tubing with a welding torch. The slots are 0.476 cm (0.1875 in.) wide and 15.2 cm (6.0 in.) long, arranged in rings on staggered 90-degree angles, 30.5 cm (12 in.) apart. When the inside of the tubing string was checked for obstructions it was found that the 4.763-cm (1.875-in.) tool used to check the string would not pass through the lower joint of slotted tubing. Care should be taken not to insert tools below 1,361.5 m (4,467 ft) at the top of the slotted zone.

7.2.4 Rationale for Differences between Planned and Actual Well Design

The original proposed well completion design for Well ER-16-1 was based on the expectation that the well might encounter a water-producing interval within the UCA or perched water within the overlying tuffs. However, because the saturated UCA was not encountered as expected, perched water was not detected within the tuffs, and the UCCU also was unsaturated, only a single completion zone was required at the bottom of the drill hole (within the LCA). Only one water producing zone was encountered, so gravel-packing and cementing of the production casing was not necessary, and the completion string was left un-stemmed. Though the fluid level in the well dropped after the original completion string was installed, the slotted tubing string installed to the depth of 1,381.4 m (4,532.3 ft) now provides access for monitoring the groundwater level within the pre-Tertiary rocks, and the objective of constructing Well ER-16-1 has been achieved.

7.3 Well Completion Method

The original well completion activities began on July 2, 2005, when the casing crew landed the production casing at 1,162.4 m (3,813.5 ft). No gravel pack or cement was used with this casing string (Figure 7-1), and the UDI drill rig was released after the production casing was installed. Hydrologic testing was planned as a separate effort, so a pump was not installed in the well, and no well-development or pumping tests were conducted immediately after completion.

Well recompletion activities began on August 4, 2006, and concluded the next day, when the casing crew landed the 2⅜-in. carbon-steel monitoring string at 1,381.4 m (4,532.3 ft). This monitoring string was also left un-stemmed. Hydrologic testing is planned as a separate effort, so a pump was not installed in the well, and no well-development or pumping tests were conducted immediately after completion.

All well construction materials used for the original completion and the recompletion were inspected according to relevant procedures, as listed in SNJV (2005a). Standard decontamination procedures were employed to prevent the introduction of contaminants into the well.

8.0 Planned and Actual Costs and Scheduling

The cost and schedule for the original construction of Well ER-16-1 and for its deepening are presented in the following paragraphs.

8.1 Original Construction

The original BN cost model developed for Well ER-16-1 was based on drilling to the planned TD of 1,219.2 m (4,000 ft). The drilling program baseline projected that it would require 35 days to drill and complete the well.

It took 32 days to drill the surface and main holes, and complete Well ER-16-1. The surface hole was drilled 108.8 m (357 ft) deeper than the original estimated depth (594.4 m [1,950 ft]) to reach a good casing point. However, two days less than planned were then required to reach the planned TD. A graphical comparison, by day, of planned and actual well-construction activities is presented in Figure 8-1.

The cost analysis for the original drilling of Well ER-16-1 to 1,220.7 m (4,005 ft) begins with construction of the conductor hole by BN and the cost of mobilizing the UDI drill rig to the Well ER-16-1 site. The cost of building roads, the drill pad, and sumps is not included, and the cost of well-site support by SNJV is not included. The total construction cost for Well ER-16-1 includes all drilling costs: charges by the drilling subcontractor; charges by other support subcontractors (including compressor services, drilling fluids, bits, casing services, down-hole tools, and geophysical logging); and charges by BN for mobilization and demobilization of equipment, construction of the conductor hole, cementing services, the production casing string, radiation technicians, inspection services, and geotechnical consultation.

The total planned cost for the original construction of Well ER-16-1, was $2,548,802. The actual cost was $2,065,901, or 18.9 percent less than the planned cost. Figure 8-2 presents a comparison of the planned and actual costs, by day, for the original construction of Well ER-16-1.

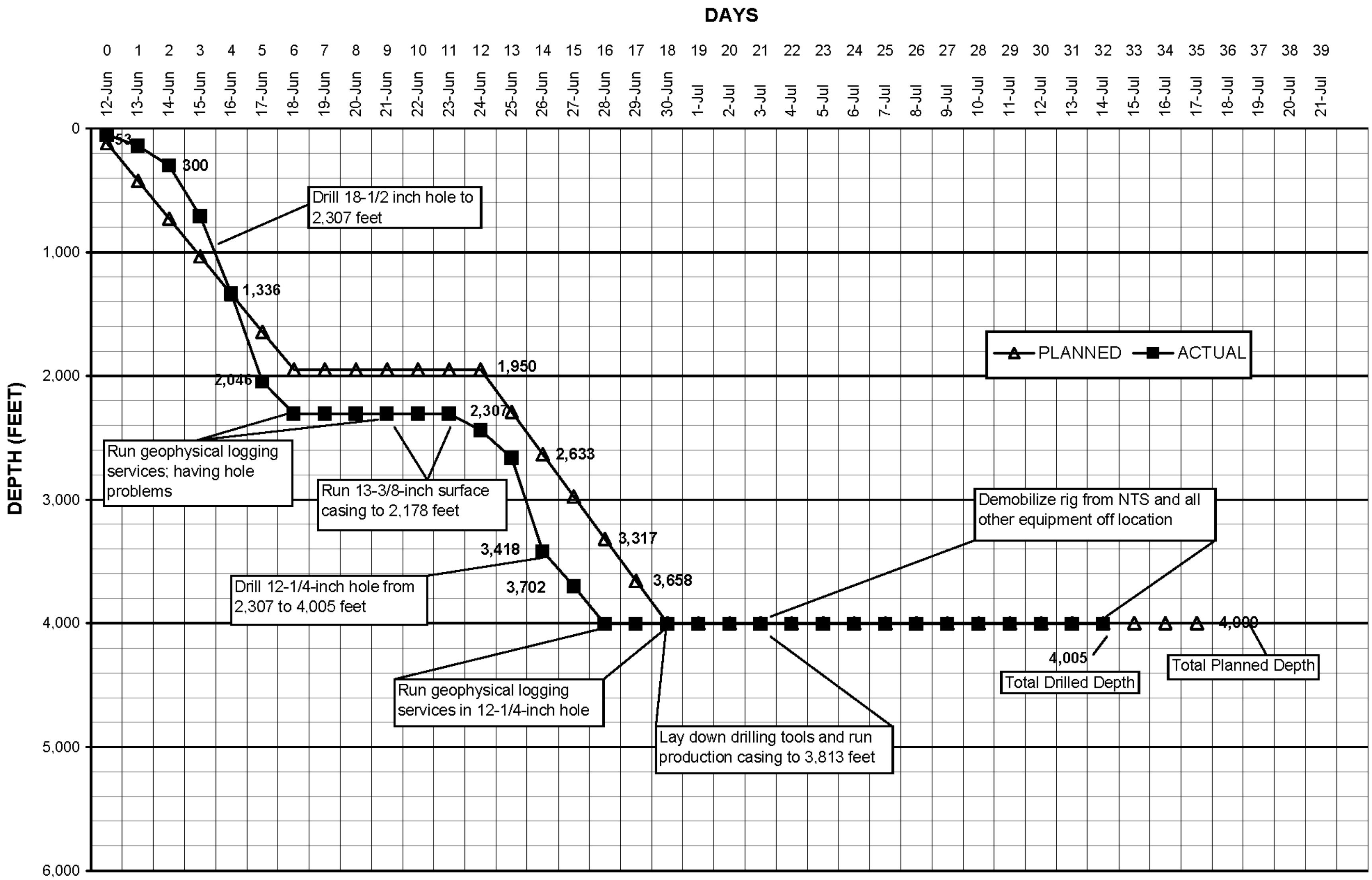

Figure 8-1
Planned and Actual Construction Progress for Well ER-16-1 – Original

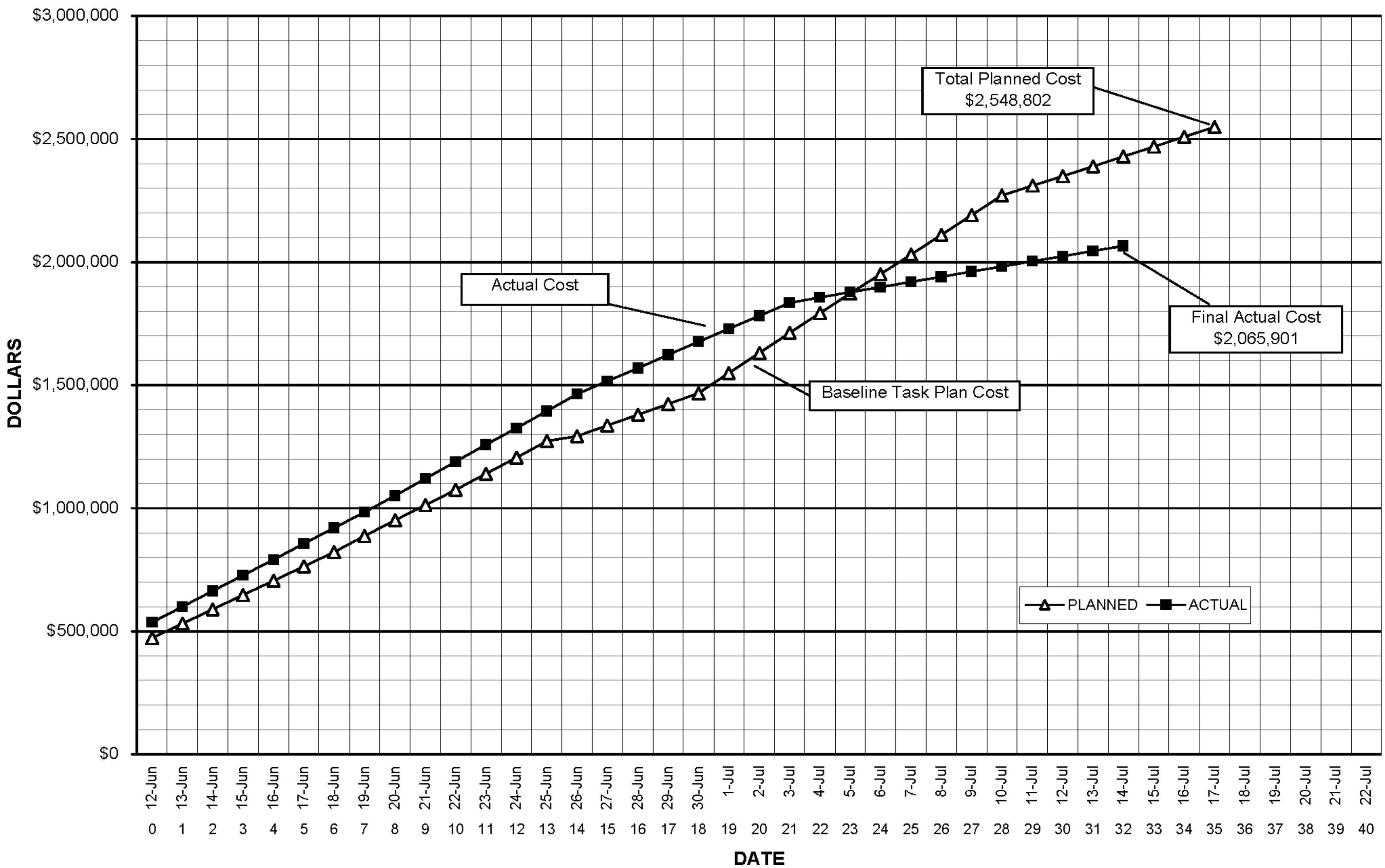

Figure 8-2
Planned and Actual Cost of Constructing Well ER-16-1 – Original

8.2 Deepening

The cost model for deepening the well included perforating and cementing the original production casing, drilling to a planned depth of 1,373.1 m (4,505 ft), geophysical logging, and installing the monitoring string. The drilling program baseline projected that it would require 17 work days to deepen the borehole and recomplete the well.

It took 30 work days to recomplete Well ER-16-1. The presence of fill and debris in the bottom of the original borehole required additional effort, including cementing and redrilling before drilling of new borehole could be accomplished. The borehole was drilled to a TD of 1,391.7 m (4,566 ft), 18.6 m (61 ft) deeper than planned. A graphical comparison, by day, of planned and actual well deepening and recompletion activities is presented in Figure 8-3.

The cost analysis for recompleting Well ER-16-1 begins with mobilizing equipment and personnel to the Well ER-16-1 site. The total construction cost for recompleting Well ER-16-1 includes all drilling costs: charges by support subcontractors (including compressor services, drilling fluids, bits, casing services, down-hole tools, and geophysical logging), and charges by BN and NSTec for mobilization and demobilization of equipment, drilling of the 12.1-cm (4.75-in.) hole, cementing services, the monitoring string, radiation technicians, inspection services, and geotechnical consultation. The cost of well-site support by SNJV is not included.

The total planned cost for the recompletion of Well ER-16-1 was $302,245. The actual cost was $884,577, or 192 percent more than the planned cost. Figure 8-4 presents a comparison of the planned and actual costs, by day, for the recompletion of Well ER-16-1.

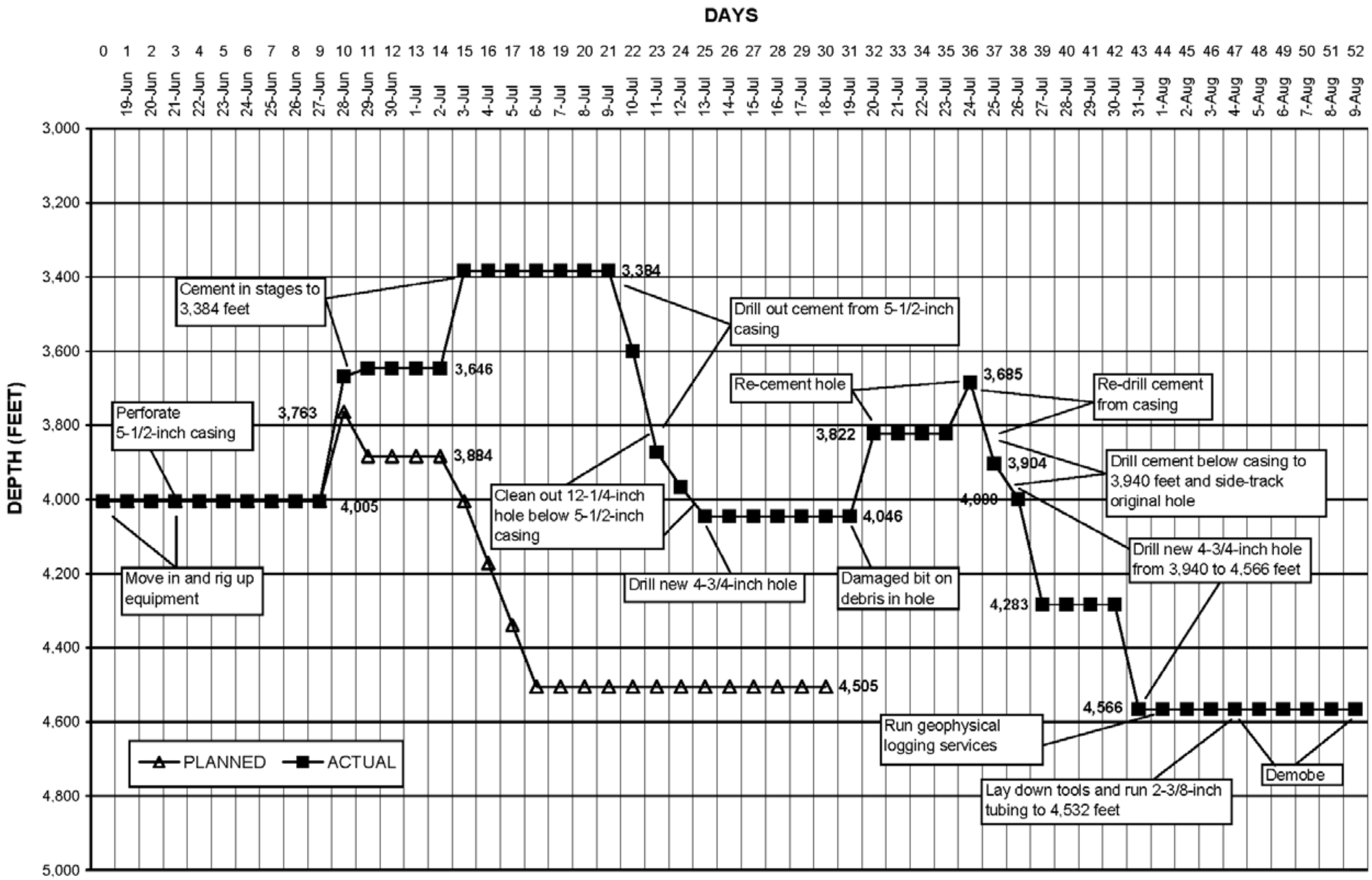

Figure 8-3
Planned and Actual Construction Progress for Recompleting Well ER-16-1

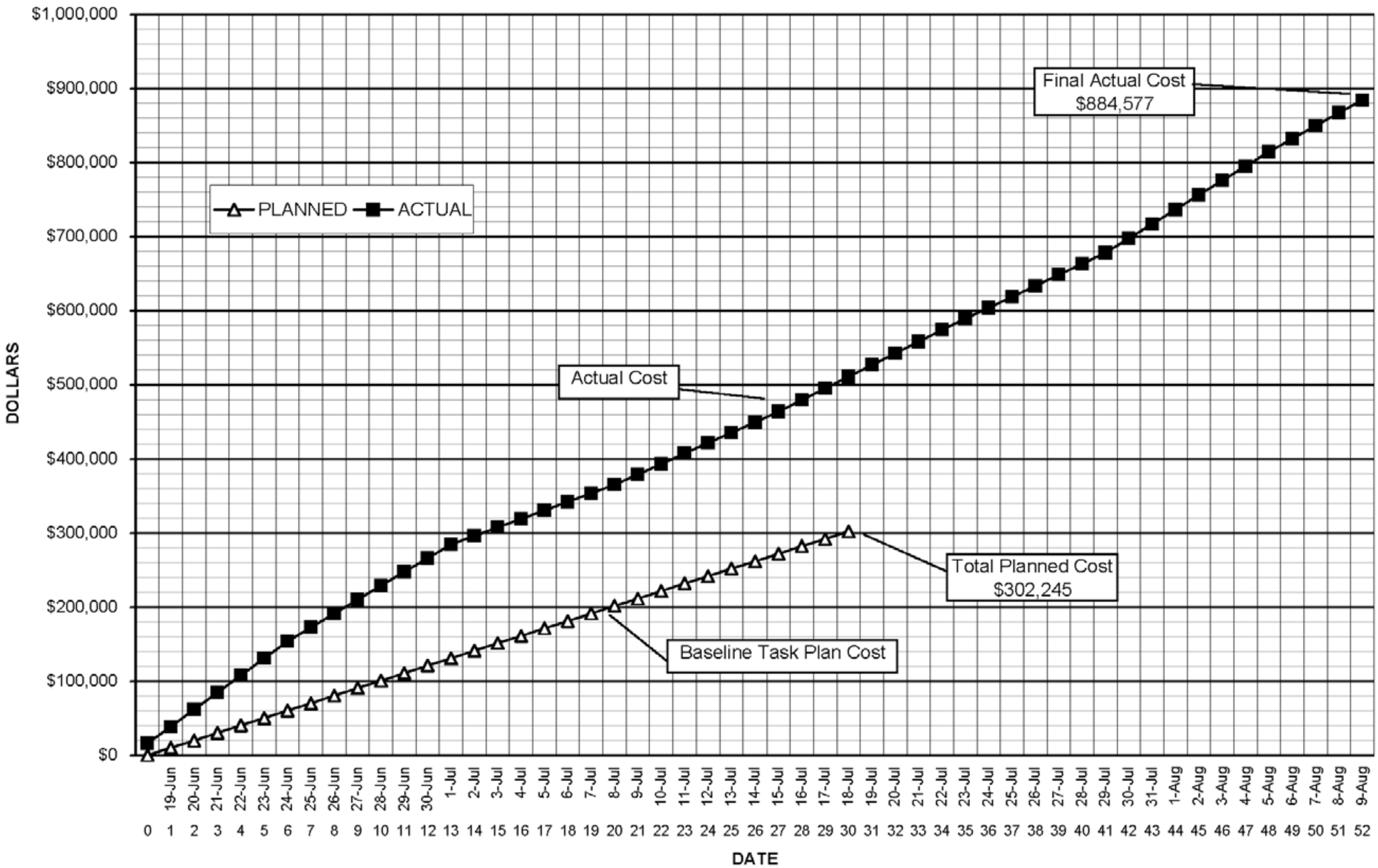

Figure 8-4
Planned and Actual Cost of Recompleting Well ER-16-1

9.0 Summary, Recommendations, and Lessons Learned

9.1 Summary

Main hole drilling at Well ER-16-1 commenced on June 12, 2005, and concluded on June 28, 2005, at a total drilled depth of 1,220.7 m (4,005 ft). Few problems were encountered during drilling, but the geophysical logging series run prior to installation of the surface casing was interrupted by numerous bridges encountered that had to be cleaned out. One of the two primary hydrogeologic target zones expected (the UCA) was not encountered, and the second target zone (the UCCU) was unsaturated and thinner than predicted; therefore, the borehole was completed within the LCA encountered in the bottom portion of the drill hole.

The fluid level was not stable, and dropped over the next few months, so the well was deepened to the final TD of 1,391.7 m (4,566 ft). This work started on June 19, 2006, and was completed on August 9, 2006. To prepare for drilling, the lower part of the original production casing was cemented to stabilize it in the borehole. A 2⅜-in. monitoring string was set at the depth of 1,381.4 m (4,532.3 ft) in the open hole.

Geologic data collected during drilling included composite drill cuttings samples collected every 3 m (10 ft) from 15.2 m (50 ft) to TD. In addition, 38 sidewall core samples were collected in the interval 189.0 to 1,177.4 m (620 to 3,863 ft). Geophysical logging was conducted in the upper portion of the borehole before installation of the surface casing, after the original TD of the well was reached, and after deepening. Some of these logs were used to aid in construction of the well, while others help to verify the geology and determine the hydrologic characteristics of the rocks.

Well ER-16-1 is collared in densely welded Tiva Canyon Tuff, and penetrated 646.8 m (2,122 ft) of Tertiary volcanic rocks, consisting largely of bedded and nonwelded tuff. Below the volcanic rocks the borehole penetrated 424.9 m (1,394 ft) of Mississippian siliciclastic rocks and 149.0 m (489 ft) of Devonian carbonate rocks before reaching the final TD at 1,391.7 m (4,566 ft). A lower Permian and Pennsylvanian-age limestone that outcrops northeast of the borehole was not encountered as expected above the carbonate rocks. An apparently stabilized water level was measured in the well at 1,271.9 m (4,173 ft) on August 25, 2006. This equates to a true vertical depth of 1,247.5 m (4,093 ft) (corrected for borehole angle) or an elevation of 761.7 m (2,499 ft).

Throughout both phases of drilling, tritium levels in the drilling fluid were at or below background levels, as measured by field instruments. No other radionuclides above background were encountered in the drilling fluids from Well ER-16-1.

9.2 Recommendations

All the geologic and hydrologic data and interpretations from Well ER-16-1 should be integrated into the Rainier Mesa - Shoshone Mountain hydrostratigraphic framework model. This will allow for more precise characterization of groundwater flow direction and velocity in the Rainier Mesa area.

9.3 Lessons Learned

The efficiency of drilling and constructing wells to obtain hydrogeologic data in support of the UGTA project continues to improve as experience is gained with each new well. Sometimes difficult drilling conditions are encountered and challenges are confronted. Several new lessons were learned during the construction of Well ER-16-1, the third well in the 2005 Rainier Mesa - Shoshone Mountain drilling initiative.

a. Access to the well site was via a narrow, steep road, which required personnel to be extremely cautious and watch for oncoming vehicles on blind curves. A system was put in place in which drivers at the bottom of the road called the onsite supervisor to find out what vehicles were ahead of them, which reduced the potential for crashes and delays.

b. When drilling in dipping formations care must be taken to reduce the potential for developing borehole deviation. Bottom-hole drilling assemblies that produce very little deviation under normal conditions, tend to deviate up-dip in steeply dipping formations.

c. Loss of even small metal items in a borehole can cause problems later if a smaller diameter hole must be drilled below the original hole and the debris is not retrieved or "cased off." The sidewall core barrels lost in the original 31.1-cm (12.25-in.) production hole became "junk" that was encountered and caused problems while drilling the 12.1-cm (4.75-in.) hole during deepening of Well ER-16-1.

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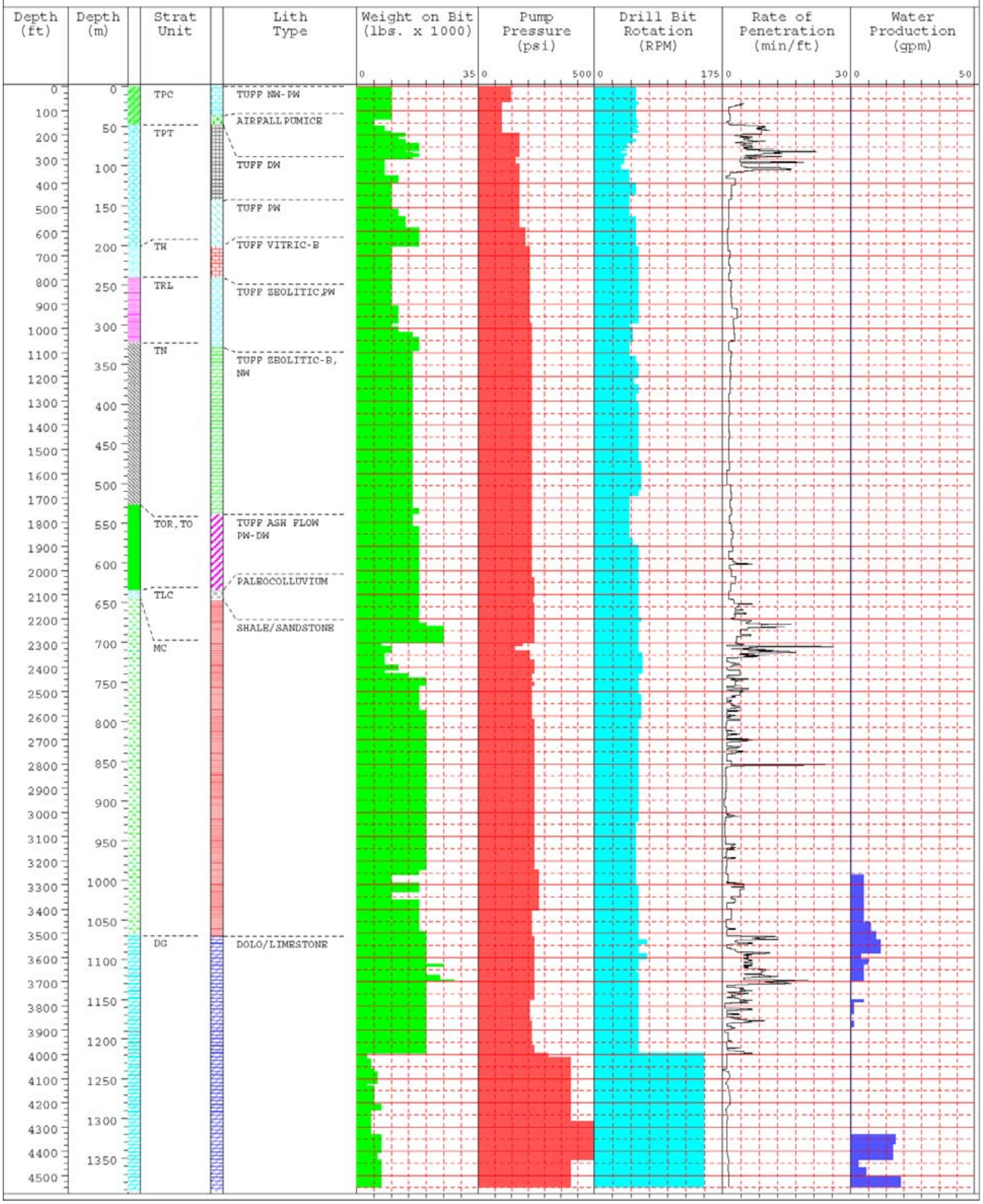
Appendix A
Drilling Data

Appendix A-1
Drilling Parameter Log for Well ER-16-1

Well Name: ER-16-1	Rainier Mesa/Shoshone Mtn Drilling Program	Northing:4096113.4 m
Date: 09/20/06	Start Date: 06/12/05 / Stop Date: 08/04/06	Easting:570820.7 m
Environmental Contractor: UGTA/SNJV	Proj. No. UG06-850	Surface Elevation:6591.5 ft
Drilling Contractor: UDI/NSTec	Drilling Method: Air Foam	Depth: 4566 ft



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Appendix A-2
Tubing and Casing Data for Well ER-16-1

Table A-2
Tubing and Casing Data for Well ER-16-1

Casing and Tubing	Depth Interval meters (feet)	Type	Grade	Outside Diameter centimeters (inches)	Inside Diameter centimeters (inches)	Wall Thickness centimeters (inches)	Weight per foot (pounds)
Conductor Casing	0 to 15.9 (0 to 52.0)	Carbon Steel PE Weld	A	76.20 (30)	74.295 (29.250)	0.953 (0.375)	157.0
Surface Casing	to 663.7 (0 to 2,177.6)	Carbon Steel	J55	33.97 (13.375)	32.042 (12.615)	0.965 (0.380)	61.0
Completion (with crossover)	0 - 1,031.1 (0 - 3,382.9)	Carbon Steel	K55	19.37 (7.625)	17.701 (6.969)	0.833 (0.328)	26.4
Completion Casing	1,031.1 to 1,162.4 (3,382.9 to 3,813.5)	Stainless Steel	L304	13.97 (5.5)	12.825 (5.049)	0.573 (0.226)	14.6
Monitoring String	0 to 1,381.4 (0 to 4,532.3)	Carbon Steel	J55	6.03 (2.375)	5.07 (1.995)	0.483 (0.190)	4.6

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Appendix A-3
Well ER-16-1 Drilling Fluids and Cement Composition

Table A-3-1
Drilling Fluids Used in Well ER-16-1

Typical Air-Foam/Polymer Mix	Typical Bentonite Mud Mix [a]
37.8 to 94.6 liters (10 to 25 gallons) Acrylafoam ® [a] 7.6 liters (2 gallons) Acrylavis ® [b] 0.5 to 1.0 liters of Lithium Bromide per 7,949 liters (50 barrels) water	60 to 70 viscosity bentonite [c]

a Acrylafoam ® foaming agent is a product of Hinkle Chemical Corp.

b Acrylavis ® polymer additive is a product of Cytec Manufacturing Corp.

c The bentonite gel additive was supplied by Western Clay.

NOTES:
1. All water used to mix drilling fluids for Well ER-16-1 came from Water Well UE-16d.

2. A concentrated solution of lithium bromide was added to all introduced fluids to make up a final concentration of approximately 10 to 20 milligrams per liter.

Table A-3-2
Well ER-16-1 Cement Composition

Cement Composition	30-inch Conductor Casing	13⅜-inch Surface Casing	5½-inch Completion Casing
Type II	0 to 16.5 m [a] (0 to 54 ft [b])	588.3 to 667.8 m (1,930 to 2,191 ft)	1,031.4 to 1,220.7 m (3,384 to 4,005 ft)

a meter(s) b foot (feet)

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Appendix B
Well ER-16-1 Fluid Management Data

Table B-1
Well ER-16-1 Fluid Disposition Reporting Form

Site Identification: ER-16-1	Report Date: September 18, 2006
Site Location: Nevada Test Site	NNSA/NSO Project Manager: Bill Wilborn
Site Coordinates: N-4,095,916.2 , E-570,900.3 m	SNJV Project Manager: John McCord
Well Classification: ER Hydrogeologic Investigation Well	SNJV Site Representative: Jeff Wurtz
SNJV Project No: UG06-850	SNJV Field Task Manager: Jeff Wurtz

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) [c]		Infiltration Area (m^3)	Other (m^3) [d]	Fluid Quality Objective Met?
	From	To				Solids [b]	Liquids	Solids	Liquids	Liquids		
Phase I: Vadose-Zone Drilling	3/26/2005	7/31/2006	21	1,335	1,156	243	729	0	0	0	N/A	Yes
Phase I: Saturated-Zone Drilling	7/31/2006	8/1/2006	1	57	14	1	17.3	0	0	0	N/A	Yes
Phase II: Initial Well Development	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Aquifer Testing	-	-	-	-	-	-	-	-	-	-	-	-
Phase II: Final Development	-	-	-	-	-	-	-	-	-	-	-	-
Cumulative Production Totals to Date:			22	1,392	1,170	244	746	0	0	0	N/A	-

[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 factorof 1.5.

[c] Optional fluid management devices not installed for this well site.

[d] Other refers to fluid conveyance to other fluid management locations or facilities away from the well site, such as vacuum truck transport to another well site.

NA = Not Applicable; m = meters; m^3 = cubic meters;

Total Facility Capacities: Sump #1 = 1,165 m^3 Sump #2 = 1,165 m^3

Infiltration Area (assuming very low/no infiltration) = N/A m^3

Remaining Facility Capacity as of 8/2/2006: Sump #1 = 921 m^3 (79%), Sump #2 = 1,165 m^3 (100%)

Current Average Tritium = Natural Background pCi/L

Notes: This report supercedes the previos report dated September 2005.

SNJV Authorizing Signature/Date: 9-18-06

Table B-2
Preliminary Analytical Results for Fluid Management Samples from Well ER-16-1 – Original

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act* Metals (mg/L)							
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
ER-161-063005-1	06/30/2005	Sample from Sump #1	Total	0.378 U	0.468 J	0.00804	0.0593	0.0184 J+	0.00966 U	0.01 U	0.00302
			Dissolved	0.00637 J	0.021	0.00308 J	0.0123	0.00536 J+	0.00942 U	0.01 U	0.000289 U
ER-161-063005-2	06/30/2005	Duplicate sample from Sump #1	Total	0.0384	0.646	0.00712	0.0684	0.0258 J+	0.00873 U	0.01 U	0.00272
			Dissolved	0.00709 J	0.175 J	0.00319 J	0.0054 J	0.00486 J+	0.00957 U	0.01 U	0.000346 U
Detection Limit				0.01	0.2	0.005	0.01	0.003	0.005	0.01	0.0002
Nevada Drinking Water Standard				0.05	2.0	0.005	0.1	0.015	0.05	0.1	0.002

Sample Number	Date Collected	Comment		Radiological Indicator Parameters (pCi/L)		
				Tritium	Gross Alpha	Gross Beta
ER-161-063005-1	06/30/2005	Sample from Sump #1	Result	-80	5	13.1 M3
			Error	210	2.1	4.4
			MDC	350	2.6	6
ER-161-063005-2	06/30/2005	Duplicate sample from Sump #1	Result	90	6.2	15.7 M3
			Error	210	2	4
			MDC	350	2.1	4.7
Nevada Drinking Water Standard				15	50	20,000

Data provided by Stoller-Navarro Joint Venture (SNJV, 2005b)

Analyses for metals performed by E-Max Laboratories. Analyses for radionuclides performed by Paragon Analytics, Inc. (filtered prior to analysis).

Notes: U = Result less than the instrument detection limit or the MDC (Minimum Detectable Concentration). MDC varies by matrix, instrument, and count rates.
J = Estimated value   J+ = Result is estimated but may be biased low   mg/L = milligrams per liter   pCi/L = picoCuries per liter

Analytical methods: All metals except mercury: Environmental Protection Agency (EPA) 6010
Mercury: EPA 7470
Tritium: PAI704R7
Gross alpha and gross beta: PAI1724R8

Table B-3
Preliminary Analytical Results for Fluid Management Samples from Well ER-16-1 – Deepening

Sample Number	Date Collected	Comment		*Resource Conservation Recovery Act* Metals (mg/L)							
				Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver	Mercury
161-073106-1	07/31/2006	Sample from Sump #1	Total	0.13	0.44	0.0007 B	0.076	0.0083	0.011	0.01 N	0.00041
			Dissolved	0.0063 B	0.041 B	0.00053 B	0.0095 B	0.0012 B	0.012	0.01 N	0.000049 B
161-073106-2	07/31/2006	Duplicate sample from Sump #1	Total	0.01	0.29	0.00065 B	0.032	0.0046	0.012	0.0012 B	0.00022
			Dissolved	0.0065 B	0.045 B	0.00047 B	0.0088 B	0.003 N	0.013	0.01 N	0.000037 B
Detection Limit				0.01	0.1	0.005	0.01	0.003	0.005	0.01	0.0002
Nevada Drinking Water Standard				0.05	2.0	0.005	0.1	0.015	0.05	0.1	0.002

Sample Number	Date Collected	Comment		Radiological Indicator Parameters (pCi/L)		
				Tritium	Gross Alpha	Gross Beta
161-073106-1	07/31/2006	Sample from Sump #1	Result	-140 U	1.53 LT	9.8
			Error	200	0.7	2
			MDC	340	0.95	1.9
161-073106-2	07/31/2006	Duplicate sample from Sump #1	Result	-80 U	1.82 LT	9.4
			Error	200	0.76	2.1
			MDC	340	0.99	2.2
Nevada Drinking Water Standard				15	50	20,000

Data provided by Stoller-Navarro Joint Venture (SNJV, 2006)

Analyses performed by Paragon Analytics, Inc.

Notes: mg/L = milligrams per liter   pCi/L = picoCuries per liter
N = Analyte analyzed for but not detected.
B = Value is less than the practical quantitation limit but greater than or equal to the instrument detection limit.
U = Result less than sample MDC (Minimum Detectable Concentration). MDC varies by matrix, instrument, and count rates.
LT = Result is less than the requested minimum detectable concentration but greater than the sample-specific detectable concentration.

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Appendix C
Detailed Lithologic Log for Well ER-16-1

Table C-1
Detailed Lithologic Log for Well ER-16-1
Logged by Lance Prothro, Bechtel Nevada
August 2006

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type** [b]	**Depth of Analytical Samples** [c] meters (feet)	**Lithologic Description** [d]	**Stratigraphic Unit**
0 - ~15.2 (0 - ~50)	~15.2 (~50)	None	None	**Densely Welded Ash-Flow Tuff:** Lithology based on surface exposure.	Tiva Canyon Tuff
~15.2 - 47.5 (~50 - 156)	32.3 (~106)	DB1	None	**Bedded Tuff:** Grayish-orange (10YR 7/4); vitric. Drill cuttings samples are enriched with pumice fragments and lesser amounts of volcanic lithic fragments. Biotite and feldspar observed in some pumice fragments; no quartz observed.	
47.5 - 102.4 (156 - 336)	54.9 (180)	DA	None	**Densely Welded Ash-Flow Tuff:** Grayish-brown (5YR 3/2) in upper part becoming grayish-red (5R 4/2) lower; devitrified; rare flattened pumice; rare feldspar phenocrysts; rare biotite; trace lithic fragments. Upper 3.0 m (10 ft) is partially welded with vapor-phase mineralization.	Topopah Spring Tuff
102.4 - 108.5 (336 - 356)	6.1 (20)	DB4	None	**Nonwelded Ash-Flow Tuff:** Moderate-brown (5YR 4/4); vitric with very abundant glass shards; rare feldspar phenocrysts; rare biotite; trace lithic fragments.	
108.5 - 161.5 (356 - 530)	53.0 (174)	DB1, DB4	None	**Bedded Tuff:** Drill cuttings samples are very poor quality consisting of abundant welded and nonwelded tuff fragments from the overlying intervals, and vitric pumice fragments. Composition of drill cuttings samples is consistent with drilling of poorly indurated to friable, vitric bedded tuff. Geophysical log signatures through interval are also consistent with vitric bedded tuff. Lithology and alteration are consistent with correlative interval in nearby core hole UE-16a #1. Correlative interval in UE-16a #1 includes quartz-poor and mafic-rich beds characteristic of the Wahmonie Formation. Gamma ray signature from 118.9 to 134.1 m (390 to 440 ft) in Well ER-16-1 is characteristic of the Wahmonie Formation in Yucca Flat.	Calico Hills Formation and Wahmonie Formation

Table C-1
Detailed Lithologic Log for Well ER-16-1 (continued)

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type** [b]	**Depth of Analytical Samples** [c] meters (feet)	**Lithologic Description** [d]	**Stratigraphic Unit**
161.5 - 213.4 (530 - 700)	51.8 (170)	DB1, SWC	None	**Nonwelded Ash-Flow Tuff:** Drill cuttings samples are poor quality, consisting mostly of vitric pumice fragments and lesser amounts of volcanic lithic fragments. Pumice fragments are generally pale-brown (5YR 5/2) above approximately 198.1 m (650 ft) and generally white (N9) below. Geophysical logs indicate interval is vitric nonwelded tuff, which is consistent with correlative interval in core hole UE-16a #1. Sidewall core from 189.0 m (620 ft) in ER-16-1 is dark-yellowish-brown (10YR 4/2), vitric nonwelded tuff consisting of minor pumice, common feldspar, rare quartz, and biotite. Sidewall samples at 208.8 and 209.4 m (685 and 687 ft) are very-light-gray (N8), vitric, with minor to common felsic phenocrysts of feldspar and rare quartz, and common mafic minerals of hornblende and lesser biotite. These samples are consistent with the mineralogy of the correlative interval in UE-16a #1.	Bullfrog Tuff
213.4 - 249.3 (700 - 818)	36.0 (118)	DB1, SWC	None	**Bedded Tuff:** Cuttings are a mixture of volcanic lithic fragments, vitric pumice fragments, and loose feldspar and quartz phenocrysts. Loose crystals of hornblende are conspicuous near bottom of interval. Character of the drill cuttings samples indicate interval is vitric bedded tuff. Resistivity log suggests interval becomes zeolitic below 236.5 m (776 ft). Sidewall sample at 231.0 m (758 ft) is yellowish-gray (5Y 8/1) vitric nonwelded tuff with common quartz and feldspar and minor biotite. Lithology correlates well with nearby core hole UE-16a #1. Mineralogy of correlative interval in UE-16a #1 suggests interval is probably Crater Flat Group, but mafic-rich beds in UE-16a #1 indicate Wahmonie Formation may be intercalated within interval.	Crater Flat Group

Table C-1
Detailed Lithologic Log for Well ER-16-1 (continued)

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type** [b]	**Depth of Analytical Samples** [c] meters (feet)	**Lithologic Description** [d]	**Stratigraphic Unit**
249.3 - 330.7 (818 - 1,085)	81.4 (267)	DB4, SWC	None	**Nonwelded to Partially Welded Ash-Flow Tuff:** Very-pale-orange (10YR 8/2) to approximately 289.6 m (950 ft), grayish-orange (10YR 7/4) below; zeolitic; minor pumice; rare felsic phenocrysts of feldspar and quartz; minor mafic minerals of biotite and less partially altered hornblende; sphene is present; rare lithic fragments.	Lithic Ridge Tuff
330.7 - 385.9 (1,085 - 1,266)	55.2 (181)	DA, SWC	None	**Bedded-Tuff:** Light-brown (5YR 5/6), moderate-reddish-brown (10R 4/6), and very-pale-orange (10YR 8/2); zeolitic; conspicuous common white (N9) pumice; minor to common felsic phenocrysts of feldspar and lesser quartz; common to abundant mafic minerals of biotite and much less hornblende; minor lithic fragments.	Tunnel Formation
385.9 - 420.6 (1,266 - 1,380)	34.7 (114)	DA, SWC	405.4 (1,330)	**Nonwelded to Partially Welded Ash-Flow Tuff:** Light-olive-brown (5Y 5/6); zeolitic; common pumice; minor felsic phenocrysts of feldspar and quartz; rare biotite; minor lithic fragments.	
420.6 - 455.1 (1,380 - 1,493)	34.4 (113)	DA	None	**Bedded Tuff:** Moderate-orange-pink (10R 7/4), moderate-reddish-orange (10R 6/6), and moderate-reddish-brown (10R 4/6); zeolitic; common to abundant pumice; rare felsic phenocrysts of feldspar and quartz; rare biotite; rare to minor lithic fragments.	
455.1 - 488.3 (1,493 - 1,602)	33.2 (109)	DA, SWC	475.5 (1,560)	**Nonwelded to Partially Welded Ash-Flow Tuff:** Dusky-yellow (5Y 6/4); zeolitic; minor pumice; rare feldspar phenocrysts; very rare biotite; rare lithic fragments. Lower portion of interval below 480.4 m (1,576 ft) may be bedded tuff.	
488.3 - 533.4 (1,602 - 1,750)	45.1 (148)	DA, SWC	512.1 (1,680)	**Nonwelded to Partially Welded Ash-Flow Tuff:** Pale-yellowish-brown (10YR 6/2); mostly zeolitic, partially devitrified; minor to common pumice; common felsic phenocrysts of feldspar and much less quartz; very abundant biotite; sphene is present; rare lithic fragments.	Yucca Flat Tuff

Table C-1
Detailed Lithologic Log for Well ER-16-1 (continued)

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type** [b]	**Depth of Analytical Samples** [c] meters (feet)	**Lithologic Description** [d]	**Stratigraphic Unit**
533.4 - 579.1 (1,750 - 1,900)	45.7 (150)	DA, DB4, SWC	557.8 (1,830)	**Bedded Tuff:** Moderate-reddish-brown (10R 4/6); zeolitic to 552.9 m (1,814 ft), becoming argillic in part below; minor pumice; common to abundant felsic phenocrysts of feldspar and quartz; common to abundant biotite; rare lithic fragments. Bedding within interval dips approximately 10^{o} to the southwest.	tunnel bed 1
579.1 - 602.6 (1,900 - 1,977)	23.5 (77)	DA, SWC	603.5 (1,980)	**Partially Welded Ash-Flow Tuff:** Pale-red (5R 6/2) to moderate-red (5R 4/6); devitrified; rare pumice; common felsic phenocrysts of feldspar, many altered to a soft white (N 9) chalky mineral, and much less quartz; common biotite; rare lithic fragments. Interval shows a conspicuous increase in potassium content on spectral gamma ray log.	Redrock Valley Tuff
602.6 - 611.4 (1,977 - 2,006)	8.8 (29)	DB1, DB4	None	**Bedded Tuff:** Not represented in drill cuttings or sidewall core samples. Interval corresponds to large borehole washout typical of highly argillized, nonwelded tuffs near base of the volcanic section.	pre-Redrock Valley Tuff
611.4 - 646.8 (2,006 - 2,122)	35.4 (116)	DA, DB4	None	**Tuffaceous Paleocolluvium:** Moderate-reddish-brown (10R 4/6) to dark-reddish-brown (10R 3/4); argillic; tuffaceous matrix includes minor to common felsic phenocrysts of partially altered feldspar and lesser quartz, rare to minor biotite, and common to very abundant moderate-yellowish-brown (10YR 5/4) and dark-yellowish-brown (10YR 4/2) lithic fragments of subangular to subrounded sedimentary rock fragments including quartzite, siltstone, and argillite from the Eleana Formation and/or Chainman Shale.	Paleocolluvium

Table C-1
Detailed Lithologic Log for Well ER-16-1 (continued)

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type** [b]	**Depth of Analytical Samples** [c] meters (feet)	**Lithologic Description** [d]	**Stratigraphic Unit**
646.8 - 1,071.7 (2,122 - 3,516)	424.9 (1,394)	DA, SWC	None	**Shale, with minor Siltstone and Sandstone:** Shale is black (N1), well indurated, and weakly to moderately fissile. Siltstone and sandstone occur mainly above 838.2 m (2,750 ft) but are generally subordinate to shale except from approximately 731.5 to 762.0 m (2,400 to 2,500 ft) depth, where shale is a minor constituent. Sandstone dominates from approximately 746.8 to 762.0 m (2,450 to 2,500 ft). Sandstones are typically medium-dark-gray (N 4) to dark-gray (N 3), very-fine- to fine-grained, moderately-sorted, and subrounded. Clasts include chert and quartz grains. Cement is mainly silica. Some coarser-grained sandstones, including conglomerates, are also present. Some conglomerates show poor-sorting with angular chert grains. A monotonous section of shale with only very minor siltstone and almost no sandstone occurs from 838.2 m (2,750 ft) to the base of the interval. Pyrite is uncommon but ubiquitous above approximately 1,021.1 m (3,350 ft). Below 1,021.1 m (3,350 ft) pyrite becomes more common along with breccia fragments, coarsely-crystalline calcite fracture-filling, and coatings of very soft light-olive (10Y 5/4) secondary mineral. Conspicuous reddish iron-oxide staining is common below 1,066.8 m (3,500 ft). Caliper log shows borehole enlargement below 1,021.1 m (3,350 ft). Prominent uranium increase from 1,068.6 to 1,071.7 m (3,506 to 3,516 ft) suggests large fracture(s). Bedding at top of interval from 646.8 to 675.1 m (2,122 to 2,215 ft) dips 43^{o} to the northwest	Chainman Shale
1,071.7 - 1,086.9 (3,516 - 3,566)	15.2 (50)	DA, DB4	None	**Quartzite:** Pale-red (10R 6/2), grayish-orange (10YR 7/4), and medium-light-gray (N6); very well indurated; mostly fine-grained and very clean, consisting almost exclusively of quartz. Light-blue-green (5BG 6/6) silver chloride(?) mineralization was observed on one quartzite fragment.	Guilmette Formation

Table C-1
Detailed Lithologic Log for Well ER-16-1 (continued)

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type [b]**	**Depth of Analytical Samples [c]** meters (feet)	**Lithologic Description [d]**	**Stratigraphic Unit**
1,086.9 - 1,132.6 (3,566 - 3,716)	45.7 (150)	DA, DB4	**1,112.5 (3,650)**	**Dolomite:** Light-brownish-gray (5YR 6/1) to brownish-gray (5YR 4/1); well indurated; medium to coarsely crystalline. Spectral density/epithermal neutron log indicates quartzite may be present below 1,126.5 m (3,696 ft) although this could not be confirmed in the drill cuttings. High uranium values on the spectral gamma ray logs below 1,122.9 m (3,684 ft) may indicate possible intense fracturing.	Guilmette Formation
1,132.6 - 1,157.6 (3,716 - 3,798)	25.0 (82)	DA, DB4, SWC	**1,143.0 (3,750)**	**Limestone:** Brownish-gray (5YR 4/1); well indurated; very finely crystalline; dolomitic below 1,143.0 m (3,750 ft). Prominent increase in uranium on spectral gamma ray log suggests interval may be intensely fractured throughout. Bedding within interval dips 60^{o} to the north-northwest.	
1,157.6 - 1,188.7 (3,798 - 3,900)	31.1 (102)	DA, DB4	**1,173.5 (3,850)**	**Dolomite:** Dark-yellowish-brown (10YR 2/2); well indurated; coarsely crystalline. Bedding within interval dips 53^{o} to the northwest.	
1,188.7 - 1,243.6 (3,900 - 4,080)	54.9 (180)	DA, DB4	**1,204.0 (3,950)**	**Dolomite:** Brownish-black (5YR 2/1); well indurated; medium crystalline.	
1,243.6 - 1,310.6 (4,080 - 4,300)	67.0 (220)	DA	None	**Dolomite:** Light-brownish-gray (5YR 6/1) to brownish-gray (5YR 4/1); well indurated; medium crystalline. Moderate-red (5R 5/4) coloration from 1,295.4 to 1,304.5 m (4,250 to 4,280 ft).	
1,310.6 - 1,338.1 (4,300 - 4,390)	27.5 (90)	DA	None	**Dolomite:** Grayish-black (N2); well indurated; coarsely crystalline.	
1,338.1 - 1,365.5 (4,390 - 4,480)	27.4 (90)	DA	None	**Dolomite:** Medium-light-gray (N6); well indurated; coarsely crystalline.	

Table C-1
Detailed Lithologic Log for Well ER-16-1 (continued)

Depth Interval [a] meters (feet)	**Thickness** meters (feet)	**Sample Type** [b]	**Depth of Analytical Samples** [c] meters (feet)	**Lithologic Description** [d]	**Stratigraphic Unit**
1,365.5 - 1,374.6 (4,480 - 4,510)	9.1 (30)	DA	None	**Dolomite:** Dark-gray (N3); well indurated; medium crystalline.	Guilmette Formation
1,374.6 - 1,391.7 (4,510 - 4,566) Total Depth	17.1 (56)	DA	None	**Dolomite:** Light-olive-gray (5Y 6/1); well indurated; coarsely crystalline.	

a All depths are drilled depth, not corrected for borehole angle.

b **DA** = drill cuttings that represent lithologic character of interval; **DB1** = drill cuttings enriched in hard components; **DB4** = cuttings that are intimate mixtures of units, generally less than 50 percent of drill cuttings represent lithologic character of interval; **SWC** = sidewall core.

c Depth of lithologic samples selected for laboratory analyses. Laboratory analyses include biostratigraphy (depths in **bold**), petrography, mineralogy (x-ray diffraction), and chemistry (x-ray fluorescence). See Table 3-2 of this report for additional information on laboratory analyses.

d Descriptions are based mainly on visual examination of lithologic samples using a 10x- to 40x-zoom binocular microscope, and incorporating observations from geophysical logs and results of laboratory analyses. See Sections 3.4 and 4.1 of this report for information on laboratory analyses. Colors describe wet sample color (with numerical codes for hue, value, and chroma in parentheses), using the *Rock Color Chart*, Copyright 1991, The Geological Society of America, Boulder, CO.

Abundances for felsic phenocrysts, pumice fragments, and lithic fragments: **trace** = only one or two individuals observed; **rare** = $\leq$ 1%; **minor** = 5%; **common** = 10%; **abundant** = 15%; **very abundant** $\geq$ 20%.
Abundances for mafic minerals: **trace** = only one or two individuals observed; **rare** = $\leq$ 0.05%; **minor** = 0.2%; **common** = 0.5%; **abundant** = 1%; **very abundant** = $\geq$ 2%.

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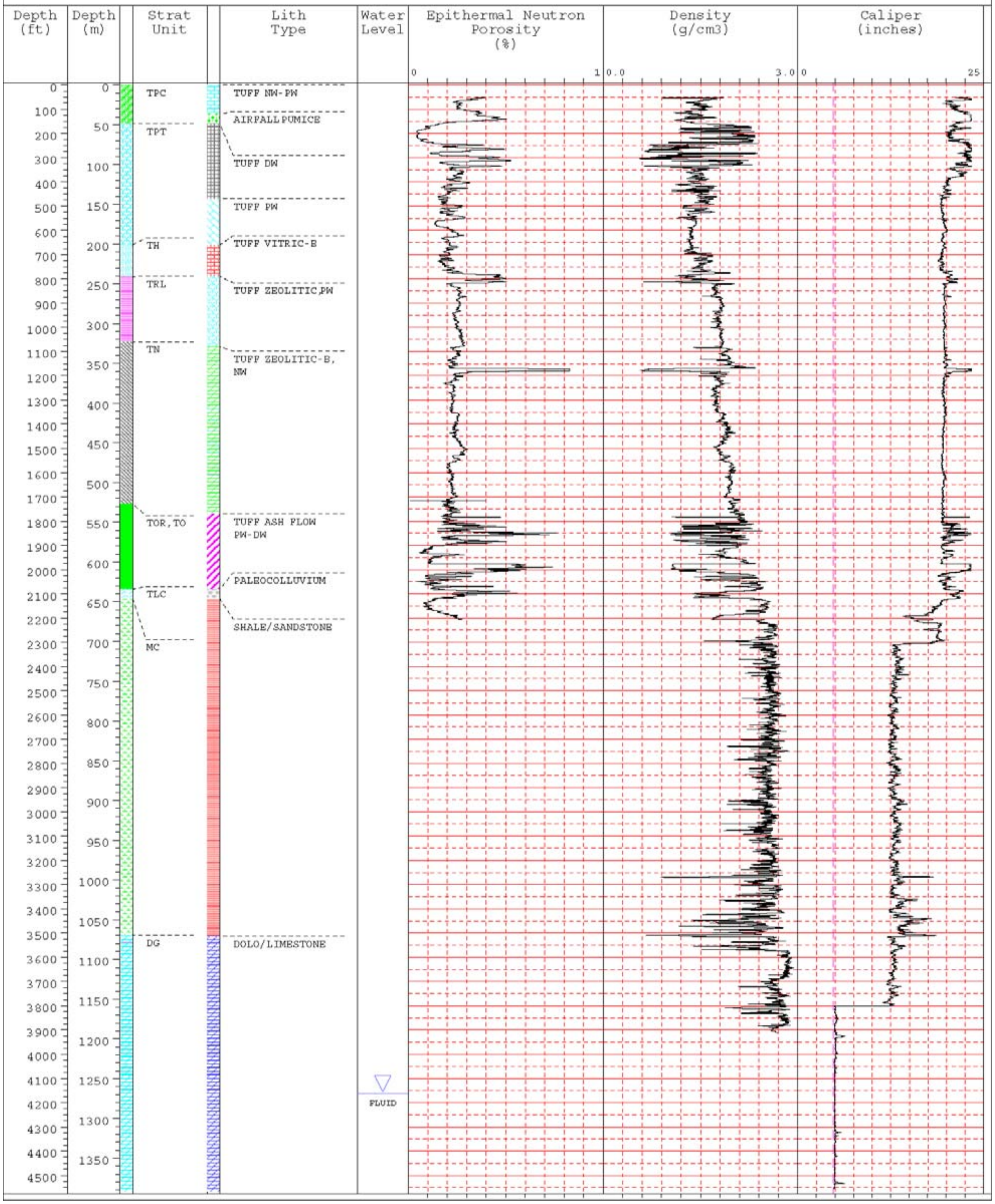
Appendix D
Geophysical Logs Run in Well ER-16-1

Appendix D contains unprocessed data presentations of selected geophysical logs run in Well ER-16-1. Table D-1 summarizes the logs presented. See Table 3-3 for more information.

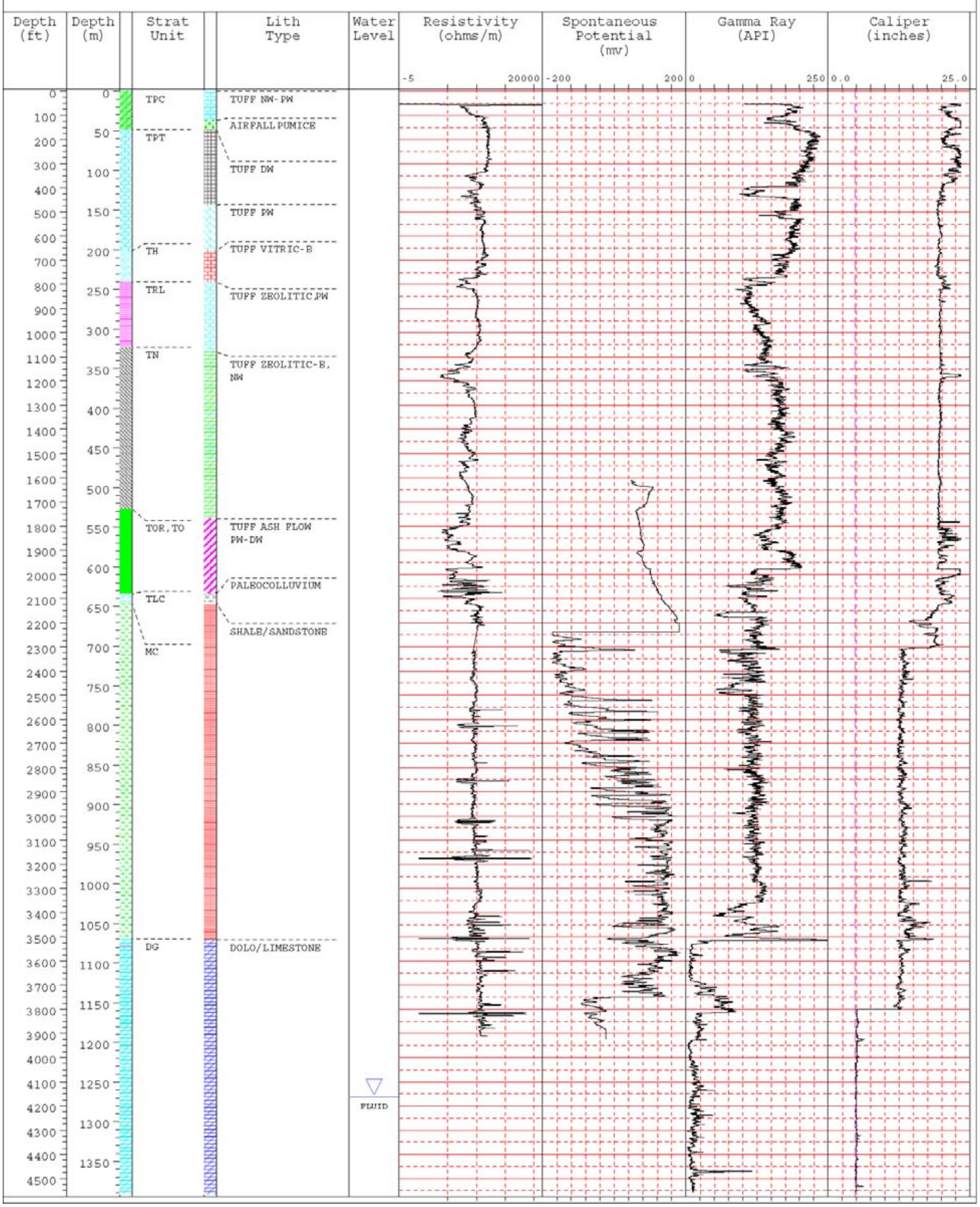
Table D-1
Well ER-16-1 Geophysical Logs Presented

Log Type	Run Number	Date	Log Interval meters	Log Interval feet
Caliper	CA6-2 CA6-3 CA6-4 CA4-1	06/19/2005 06/21/2005 06/28/2005 08/01/2006	15.9 - 665.4 459.6 - 678.8 663.6 - 1,185.4 1,143.0 - 1,388.4	52 - 2,055 1,626 - 2,214 2,177 - 3,889 3,750 - 4,555
Epithermal Neutron (porosity)	DSEN-1	06/21/2005	15.9 - 672.7	52 - 2,207
Density	SDL-1 SDL-3	06/21/2005 06/29/2005	15.9 - 672.7 487.7 - 1,187.2	52 - 2,207 1,600 - 3,895
Induction (resistivity)	HRI-1 HRI-2 HRI-3	06/19/2005 06/21/2005 06/28/2005	15.9 - 616.9 495.6 - 674.5 663.6 - 1,186.3	52 - 2,024 1,626 - 2,213 2,177 - 3,892
Spontaneous Potential	SP-1 SP-2	06/21/2005 06/28/2005	15.9 - 664.5 663.6 - 1,186.3	52 - 2,180 2,177 - 3,892
Gamma Ray	GR-2 GR-4 GR-8 GR-11	06/19/2005 06/21/2005 06/28/2005 08/01/2006	15.9 - 665.4. 459.6 - 678.8 663.6 - 1,185.4 1,127.8 - 1,388.4	52 - 2,183 1,626 - 2,214 2,177 - 3,889 3,700 - 4,555
Spectral Gamma Ray (potassium, thorium, uranium)	SGR-1 SGR-2 SGR-3	06/19/2005 06/21/2005 06/28/2005	15.9 - 585.8 495.6 - 665.1 663.6 - 1,176.8	52 - 1,922 1,626 - 2,182 2,177 - 3,861

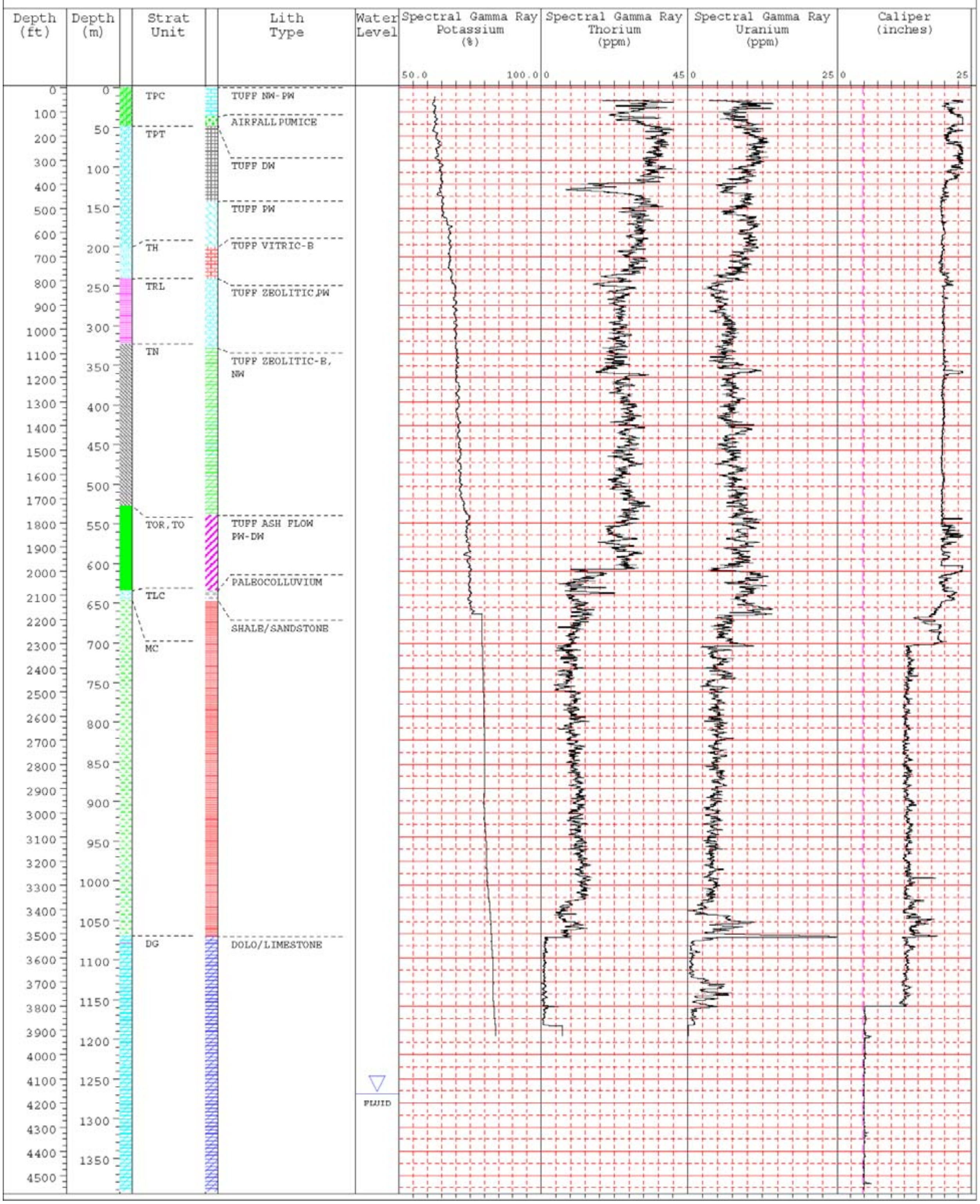
Well Name: ER-16-1	Rainier Mesa/Shoshone Mtn Drilling Program		Northing:4096113.4 m
Date: 09/20/06	Start Date: 06/12/05	Stop Date: 08/04/06	Easting:570820.7 m
Environmental Contractor: UGTA/SNJV		Proj No. UG06-850	Surface Elevation:6591.5 ft
Drilling Contractor: UDI/NSTec		Drilling Method: Air Foam	Depth: 4566 ft



Well Name: ER-16-1	Rainier Mesa/Shoshone Mtn Drilling Program		Northing:4096113.4 m
Date: 09/20/06	Start Date: 06/12/05	Stop Date: 08/04/06	Easting:570820.7 m
Environmental Contractor: UGTA/SNJV		Proj. No. UG06-850	Surface Elevation:6591.5 ft
Drilling Contractor: UDI/NSTec		Drilling Method: Air Foam	Depth: 4566 ft



Well Name: ER-16-1	Rainier Mesa/Shoshone Mtn Drilling Program		Northing: 4096113.4 m
Date: 09/20/06	Start Date: 06/12/05	Stop Date: 08/04/06	Easting: 570820.7 m
Environmental Contractor: UGTA/SNJV		Proj. No. UG06-850	Surface Elevation:6591.5 ft
Drilling Contractor: UDI/NSTec		Drilling Method: Air Foam	Depth: 4566 ft



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